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(54) **Compressor digital control failure shutdown algorithm**

(57) A method of controlling the loading and unloading of a scroll compressor includes selectively loading and unloading a scroll compressor by engaging and disengaging, respectively, compressor members with the controller in response to system load data, monitoring at least one of the discharge pressure and the suction pressure at a predetermined time interval for a continuous time period, storing values based on the at least one of the discharge pressure and the suction pressure during the continuous time period, and determining a predetermined value indicative of compressor operation in which the compressor members are engaged. The method further includes comparing at least one of the stored values with the predetermined value and providing a signal to cease operation of the compressor when the comparison fails to indicate compressor operation in which the compressor members are engaged.

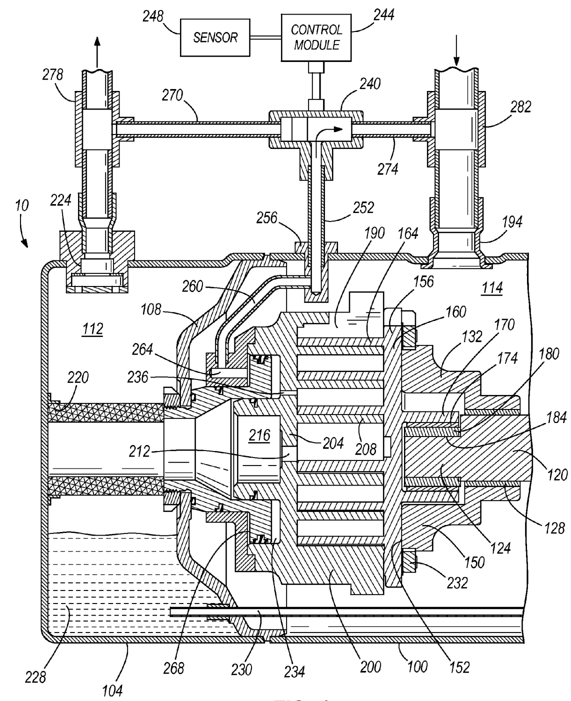

FIG. 1

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Description

RELATED APPLICATION DATA

[0001] The present application claims priority under 35 U.S.C. § 119 to Provisional Patent Application No. 61/558,750, filed November 11, 2011, the disclosure of which is hereby incorporated by reference.

BACKGROUND

[0002] The present invention relates to an algorithm for a compressor controller that initiates a shutdown of the compressor in the event of a digital control valve or other failure.

[0003] In a conventional digital scroll compressor, a solenoid valve in communication with both the compressor discharge line and the compressor suction line is energized to modulate the compressor capacity for load control. The solenoid directs compressed discharge gas to separate the orbiting scroll from the fixed scroll while the compressor prime mover remains energized. In some applications, the bearings and other components are lubricated by virtue of the pressure differential between the low and high sides of the compressor in lieu of an oil pump. During separation of the scroll set this pressure differential will typically be insufficient to provide adequate oil to the bearings and other components, thus limiting the duration that the compressor can safely operate with the scrolls separated.

SUMMARY

[0004] A compressor controller, among other things, monitors and records suction and discharge pressure data of a digital scroll compressor over time, and specifically over a series of duty cycles. Based on this data, an algorithm determines if the digital solenoid valve is stuck or if the scroll set otherwise remains disengaged. If so, the controller initiates a shutdown of the prime mover of the compressor.

[0005] In one embodiment of a method of controlling the loading and unloading of a compressor, the method includes selectively loading and unloading a compressor by engaging and disengaging, respectively, compressor members with the controller in response to system load data, loading the compressor to increase a fluid pressure from a suction pressure to a discharge pressure when the compressor members are engaged, and unloading the compressor when the compressor members are disengaged. The method also includes monitoring at least one of the discharge pressure and the suction pressure at a predetermined time interval for a continuous time period, storing values based on the at least one of the discharge pressure and the suction pressure during the continuous time period, and determining a predetermined value indicative of compressor operation in which the compressor members are engaged. The method further includes comparing at least one of the stored values with the predetermined value and providing a signal to cease operation of the compressor when the comparison fails to indicate compressor operation in which the compressor members are engaged.
According to an aspect of the invention there is provided a method of controlling the loading and unloading of a compressor, the method comprising: selectively loading and unloading a compressor by engaging and disengaging, respectively, compressor members with the controller in response to system load data: loading the compressor to increase a fluid pressure from a suction pressure to a discharge pressure when the compressor members are engaged; unloading the compressor when the compressor members are disengaged; monitoring at least one of the discharge pressure and the suction pressure at a predetermined time interval for a continuous time period; storing values based on the at least one of the discharge pressure and the suction pressure during the continuous time period; determining a predetermined value indicative of compressor operation in which the compressor members are engaged; comparing at least one of the stored values with the predetermined value; providing a signal to cease operation of the compressor when the comparison fails to indicate compressor operation in which the compressor members are engaged.

[0006] The method may further include the step of providing a signal to restart the compressor after waiting for a second predetermined time interval and if fewer than a predetermined number of signals to cease operation of the compressor have occurred during the second predetermined time interval.

[0007] Storing values based on the at least one of the discharge pressure and the suction pressure during the continuous time period may mean storing the maximum and minimum values of one of the discharge pressure and the suction pressure during the continuous time period, the method further including calculating a difference between a stored maximum value of the one of the discharge pressure and the suction pressure and a stored minimum value of the one of the discharge pressure and the suction pressure, and wherein comparing at least one of the stored values with the predetermined value means comparing the difference with the predetermined value.

[0008] Optionally, the comparison fails to indicate compressor operation in which the compressor members are engaged when the difference is not equal to or greater than the predetermined value at any time during the continuous time period.

[0009] The difference may represent an increase in discharge pressure.

[0010] The difference may represent a decrease in suction pressure.

[0011] The method may further include calculating a direction of the slope of the at least one of the discharge pressure and the suction pressure for the continuous time period, and comparing at least one of the stored values with the predetermined value means comparing the direction with the predetermined value.

[0012] Optionally, the comparison fails to indicate compressor operation in which the compressor members are engaged when the direction of the slope does not change during the continuous time period.

[0013] Optionally, the comparison fails to indicate compressor operation in which the compressor members are engaged if the direction of the slope of the discharge pressure does not change from negative to positive during the continuous period.

[0014] Optionally, the comparison fails to indicate compressor operation in which the compressor members are engaged if the direction of the slope of the suction pressure does not change from positive to negative during the continuous period.

[0015] The method may further include determining a maximum pressure differential between the discharge pressure and the suction pressure at each time interval and determining a minimum pressure differential between the discharge pressure and the suction pressure at each time interval, and further include calculating a difference between the determined maximum pressure differential and the determined minimum pressure differential, and comparing at least one of the stored values with the predetermined value means comparing the difference with the predetermined value.

[0016] Optionally, the comparison fails to indicate compressor operation in which the compressor members are engaged when the difference did not rise by the predetermined value during the continuous time period.

[0017] The method may further include calculating the ratio of the discharge pressure to the suction pressure over the continuous time period, and comparing at least one of the stored values with the predetermined value means comparing the calculated ratio with the predetermined value.

[0018] Optionally, the comparison fails to indicate compressor operation in which the compressor members are engaged when the calculated ratio drops below the predetermined value.

[0019] The predetermined value may be approximately 1.4.

[0020] The compressor may be a scroll compressor.

[0021] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Fig. 1 is a sectional view of a scroll compressor with the scrolls engaged and having a controller for use with an embodiment of the invention.

[0023] Fig. 2 is another sectional view of the scroll compressor of Fig. 1, with the scrolls disengaged.

[0024] Fig. 3 is a plot of the discharge and suction pressures of the scroll compressor of Figs. 1 and 2, and of the control valve applied voltage, vs. time.

[0025] Fig. 4 is a flow chart of a control algorithm embodying the invention.

[0026] Fig. 5 is a flow chart of another control algorithm embodying the invention.

[0027] Fig. 6 is a flow chart of another control algorithm embodying the invention.

[0028] Fig. 7 is a flow chart of another control algorithm embodying the invention.

DETAILED DESCRIPTION

[0029] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. As used herein and in the appended claims, the terms "upper", "lower", "top", "bottom", "front", "back", and other directional terms are not intended to require any particular orientation, but are instead used for purposes of description only.

[0030] Referring to Fig. 1, a portion of a compressor 10 is shown and comprises a generally cylindrical shell 100 having secured at one end thereof a cap 104. A transverse partition 108 extends to the periphery of the shell 100 and separates the compressor into a high pressure side 112 and a low pressure side 114.

[0031] A drive shaft or crankshaft 120 having an eccentric crank pin 124 is rotatably journaled in a bearing 128 in a main bearing housing 132. The crankshaft 120 is driven by a prime mover (not shown) external to the shell 100. The prime mover may be, for example, a diesel engine, an electric motor, or any other machine capable of driving the crankshaft 120. The main bearing housing 132 includes a generally cylindrical portion 150 that defines a flat thrust bearing surface 152 on which is supported an orbiting scroll member 156. The orbiting scroll member 156 includes an end plate 160 and a spiral vane or wrap 164 extending therefrom. Projecting from the opposing face of the end plate 160 is a cylindrical hub 170 having a journal bearing 174 therein and in which is rotatively disposed a drive bushing 180 having an inner bore 184 in which the crank pin 124 is drivingly disposed. The crank pin 124 has a flat on one surface which drivingly engages a flat surface (not shown) formed in a portion of the bore 184 to provide a radially compliant driving arrangement therebetween such that the crank pin 124 and the drive bushing 180 do not substantially rotate relative to one another. The orbiting scroll member 156 further includes an inlet 190 in fluid communication with a suction port 194 adjoining the shell 100 at the low pressure side 114.

[0032] A non-orbiting scroll member 200 includes an end plate 204 and a wrap 208 projecting therefrom which is positioned in meshing engagement with the wrap 164 of the orbiting scroll member 156. The non-orbiting scroll member 200 has a centrally disposed discharge passage

212 that communicates with a recess 216, which in turn is in fluid communication with an oil separator 220 positioned in the high pressure side 112. The oil separator 220 is in fluid communication with a discharge port 224 adjoining the shell 100. Due to the orientation of the compressor 10, an oil sump 228 is located at a lower portion of the high pressure side 112 and receives oil separated by the oil separator 220. An oil tube 230 extends through the partition 108 and provides oil to the bearings and other components (not shown) via the pressure difference between the high pressure side 112 and the low pressure side 114. The non-orbiting scroll member 200 is secured to the main bearing housing 132 through a plurality of circumferentially spaced bolts (not shown) extending through associated sleeve members and configured to allow limited axial movement of the non-orbiting scroll member 200 with respect to the orbiting scroll member 156.

[0033] In order to allow orbiting motion of the orbiting scroll member 156 and prevent relative rotation between the orbiting scroll member 156 and the non-orbiting scroll member 200, an Oldham coupling 232 is disposed between the cylindrical portion 150 of the main bearing housing 132 and the end plate 160 of the orbiting scroll member 156.

[0034] A solenoid valve 240 is connected by a control line 252 to a fitting 256 extending through the shell 100. The solenoid valve 240 is configured to receive a pulse width modulation signal from a control module or controller 244 based in part on data supplied from a load sensor 248, such as a temperature or pressure sensor. An internal fluid line 260 connects the fitting 256 to a passage 264 in communication with a chamber 268. The solenoid valve 240 includes a discharge connecting tube 270 and a suction connecting tube 274 affixed to the discharge tee 278 and suction tee 282, respectively.

[0035] A recess 234 is formed in the non-orbiting scroll member 200 in communication with a compression pocket at an intermediate pressure through a bleed hole 236. The intermediate pressure within recess 234, along with the discharge pressure within recess 216, will exert an axial biasing force on the non-orbiting scroll member 200 to thereby urge the tips of the respective wraps 164, 208 into sealing engagement with the opposed end plates 160, 204. The solenoid valve 240 is closed such that the chamber 268 is in fluid communication with the suction tee 282.

[0036] Although the compressor illustrated and described with regard to Figs. 1 and 2 is a scroll compressor, the compressor can be any type of compressor (using refrigerant or another fluid, such as air) with a digital or other unloading device. In particular, the compressor can be of the type in which the bearings and other components are lubricated by a high/low pressure differential rather than by an oil pump.

[0037] In operation, the orbiting scroll 156 orbits relative to the non-orbiting scroll 200, drawing system refrigerant through the suction tee 282 and the suction port 194 and into the inlet 190. The intermeshing wraps 164, 208, as known by those of ordinary skill in the art, progressively decrease the size of a refrigerant containing pocket formed therein as the refrigerant is moved radially inward. This action compresses the refrigerant, which is discharged sequentially through the centrally disposed passage 212, the recess 216, the oil separator 220, the discharge port 224, and the discharge tee 278 for use in the refrigerant system.

[0038] To unload the compressor, the solenoid valve 240 energizes in response to a signal from the controller 244. Referring to Fig. 2, this signal opens the solenoid valve 240, allowing high pressure refrigerant discharge to flow through the control line 252, the internal fluid line 260, the passage 264, and into the chamber 268. The pressure within the chamber 268 is increased such that the resultant applied force from the gas will overcome the previously described axial biasing force on the non-orbiting scroll member 200. The non-orbiting scroll member 200 will therefore move axially, disengaging the non-orbiting scroll 200 from the orbiting scroll 156. The leakage path formed between the two scrolls 156, 200 effectively eliminates compression of the refrigerant.

[0039] To load the compressor, the controller 244 deenergizes the solenoid valve 240. Referring to Fig. 1, this closes the solenoid valve 240, which discharges the gas within the chamber 268 back through the passage 264, the internal fluid line 260, the control line 252, and to the suction tee 282, which moves the orbiting and non-orbiting scrolls 156, 200 back into engagement.

[0040] The control module 244 switches the solenoid valve 240, and thus the compressor 10, between engaged and disengaged states while the prime mover remains energized. One or more load sensors 248, such as temperature or pressure sensors, alone or in combination, provide system load data to the control module 244. The control module 244 adjusts the pulse width of the control signal to modulate the compressor 10 between its full load and no-load states to meet the system demand for refrigerant. Rather than being directly responsive to the difference between set point and real time parameters (e.g., of temperature or pressure), the modulation frequency is a function of the duty cycle calculated by the controller to meet the system demand.

[0041] When the scroll set is disengaged, the pressure differential required to lubricate the bearings and other components (in the absence of an oil pump) is insufficient for continuous operation. As a result, the duration of time that the compressor 10 can be safely operated in the disengaged mode is limited. If the solenoid valve 240 remains in the open position for an extended period of time, damage may occur to the compressor 10 requiring replacement of multiple components, or, for non-serviceable compressors, total compressor replacement.

[0042] The controller is configured to chart the compressor discharge pressure and suction pressure over time. Referring to Fig. 3, plots 300, 304 show pressure vs. time and solenoid valve voltage vs. time for corresponding time periods and for a given ambient and conditioned space temperature. As an example, the plots 300, 304 are based on an operating condition of 15° F ambient and 15° F box conditions, with a 50% duty cycle (e.g., 5 seconds on, 5 seconds off).

[0043] Referring to plot 304, during the loading phase of a cycle 308, the valve 240 is deenergized (V_{closed}) and the scroll set (scroll members 156, 200) is biased together or engaged (see, e.g., Fig. 1). During an unloading phase of the cycle 308, a voltage (V_{open}) is applied to the solenoid valve 240 and the scroll set disengaged (see, e.g., Fig. 2). In normal operation, the discharge pressure trace 310 and the suction pressure trace 314 are out of phase, as shown in plot 300 of Fig. 3. For example, as the discharge pressure 310 decreases over the cycle 308, the suction pressure 314 increases. Specifically, when the solenoid valve 240 closes and the scroll set moves to the engaged position, the refrigerant discharge pressure 310 increases while the suction pressure 314 decreases over the same time period. When the solenoid valve 240 opens and the scroll set moves to the disengaged position, the discharge pressure 310 decreases while the suction pressure 314 increases. Similar plots can be derived for additional operating conditions.

[0044] Referring to Figs. 3 and 4, in one embodiment of a control algorithm, the routine begins at step 400, in which the discharge pressure is monitored at a predetermined time interval, for example, every 0.5 seconds, over the course of a continuous time period, for example, one minute (or any time period sufficient to include a number of duty cycles). During this continuous time period the maximum and minimum values of discharge pressure monitored are stored in the controller 244. At the end of the continuous time period (step 404), the controller 244 calculates the difference between the stored maximum value and the stored minimum value (step 408) and determines whether the discharge pressure increased a certain amount, for example, 5 psi, at any time during the continuous time period (step 412). If the discharge pressure did not increase by at least 5 psi within the continuous time period, then a shutdown signal is sent from the controller 244 (step 416) to shut down the compressor 10 (i.e., deenergize the prime mover). The shutdown signal indicates that the solenoid valve 240 may be stuck in the open position or that the scroll set remains otherwise disengaged.

[0045] To avoid nuisance shutdown cycles, the controller 244, after waiting a certain time interval, for example, 15 minutes (step 420), and if fewer than three shutdowns have occurred (step 424) sends a signal to restart the compressor 10 and the control algorithm is reinitiated (step 428). If the controller 244, after once more completing steps 400-412, determines that the discharge pressure has not increased by 5 psi within the continuous time period, the controller again shuts down the compressor 10 in accordance with step 416. As previously noted, the controller 244 is programmed to allow a certain number, for example, three, such shutdowns and restarts during a continuous one hour period, at which point an error code will be displayed on the controller 244 (step 432) and the compressor 10 will not restart without service.

[0046] Referring to Figs. 3 and 5, in another embodiment of a control algorithm, the routine begins at step 500, in which the suction pressure is monitored at a predetermined time interval, for example, every 0.5 seconds, over the course of a continuous time period, for example, one minute. During this continuous time period the maximum and minimum values of suction pressure are stored in the controller 244. At the end of the continuous time period (step 504), the controller calculates the difference between the stored maximum value and the stored minimum value (step 508) and determines whether the suction pressure decreased a certain amount, for example, 2 psi, at any time during the continuous time period (step 512). If the suction pressure did not decrease by at least 2 psi, the shutdown signal is sent from the controller 244 (step 516) to deenergize the prime mover. The absence of a pressure decrease of at least 2 psi signals that the scroll set remains in a disengaged state. The controller will energize the prime mover as previously described, steps 520-528 and, after three such shutdowns, generate the error code (step 532).

[0047] Referring to Figs. 3 and 6, in another embodiment of the control algorithm, the slope of the discharge pressure trace 310 and the slope of the suction pressure trace 314 are monitored and stored by the controller over the course of a continuous time period (step 600). At the end of the continuous time period (step 604), the controller 244 analyzes the discharge pressure slope and/or the suction pressure slope profiles and determines the change in slope(s) over the time period (step 608). As previously described, the discharge pressure of the refrigerant increases when the solenoid valve 240 is deenergized, i.e., the slope of the discharge pressure changes from negative to positive upon closing the solenoid valve. The suction pressure of the refrigerant decreases when the solenoid valve 240 is deenergized, i.e., the slope of the suction pressure changes from positive to negative upon closing the solenoid valve. If the discharge pressure slope does not change from negative to positive, or if the suction pressure slope does not change from positive to negative during the time period (step 612) the controller 244 initiates the shutdown sequence previously described (steps 616-632), indicating that the system remains disengaged. In this algorithm, the discharge and suction pressures can be analyzed alone or in combination, and the controller-initiated signal can be triggered by either condition or by a combination of conditions.

[0048] Referring to Figs. 3 and 7, in another embodiment of the control algorithm, the difference between the discharge pressure and the suction pressure is monitored at a predetermined time interval for a continuous time period (step 700), during which the maximum and minimum difference values are stored in the controller. At the end of the time period (step 704) the controller 244 calculates the difference between the stored maximum value of pressure differential and the stored minimum value of pressure differential (step 708) and determines whether the differential rose by at least a certain amount, for example, 10 psi, during the continuous time period (step 712). If not, the controller sends a shutdown signal (step 716) to deenergize the prime mover and continues with the shutdown sequence as necessary (steps 720-732).

[0049] In another embodiment of the control algorithm, the pressure ratio, which is the ratio of the discharge pressure to the suction pressure, can be monitored continuously by the controller 244. If this ratio drops below a predetermined ratio, for example, 1.4, at any time during compressor operation, the shutdown signal and sequence are initiated.

[0050] Any of the algorithms can be activated during digital operation of the compressor 10. In some compressor systems, the compressor is operable in both a digital and non-digital mode (e.g., to facilitate a change in a parameter setpoint or a change in system environment) and the controller 244 may direct the compressor 10 to switch from digital to non-digital mode during a period in which the scroll set is stuck in the disengaged position. The controller 244 is configured to continue to monitor the algorithm embodied in steps 700-732 and the pressure ratio of the compressor for an additional time period, for example, one minute, immediately after the compressor 10 is transitioned out of the digital mode, to ensure normal operation and, if necessary, initiate the shutdown signal and sequence as previously described.

[0051] The above-described embodiments can be used together to monitor the compressor system. Alternatively, one or more of the embodiments can be used as a backup to another of the embodiments. In some applications, one or more of the embodiments may be preferable. The numerical values provided for pressure, temperature, length of time, or any other parameter above are exemplary only and not limiting within the scope of the invention.

[0052] Various features and advantages of the invention are set forth in the following claims.

Claims

1. A method of controlling the loading and unloading of a compressor, the method comprising:

    selectively loading and unloading a compressor by engaging and disengaging, respectively, compressor members with the controller in response to system load data:

        loading the compressor to increase a fluid pressure from a suction pressure to a discharge pressure when the compressor members are engaged;
        unloading the compressor when the compressor members are disengaged;
        monitoring at least one of the discharge pressure and the suction pressure at a predetermined time interval for a continuous time period;
        storing values based on the at least one of the discharge pressure and the suction pressure during the continuous time period;
        determining a predetermined value indicative of compressor operation in which the compressor members are engaged;
        comparing at least one of the stored values with the predetermined value;
        providing a signal to cease operation of the compressor when the comparison fails to indicate compressor operation in which the compressor members are engaged.

2. The method of claim 1, further including the step of providing a signal to restart the compressor after waiting for a second predetermined time interval and if fewer than a predetermined number of signals to cease operation of the compressor have occurred during the second predetermined time interval.

3. The method of claim 1, wherein storing values based on the at least one of the discharge pressure and the suction pressure during the continuous time period means storing the maximum and minimum values of one of the discharge pressure and the suction pressure during the continuous time period, the method further including
    calculating a difference between a stored maximum value of the one of the discharge pressure and the suction pressure and a stored minimum value of the one of the discharge pressure and the suction pressure,
    and wherein comparing at least one of the stored values with the predetermined value means comparing the difference with the predetermined value.

4. The method of claim 3, wherein the comparison fails to indicate compressor operation in which the compressor members are engaged when the difference is not equal to or greater than the predetermined value at any time during the continuous time period.

5. The method of claim 3, wherein the difference represents an increase in discharge pressure.

6. The method of claim 3, wherein the difference represents a decrease in suction pressure.

7. The method of claim 1, further including calculating a direction of the slope of the at least one of the discharge pressure and the suction pressure for the continuous time period, and wherein comparing at

least one of the stored values with the predetermined value means comparing the direction with the predetermined value.

8. The method of claim 7, wherein the comparison fails to indicate compressor operation in which the compressor members are engaged when the direction of the slope does not change during the continuous time period.

9. The method of claim 7, wherein the comparison fails to indicate compressor operation in which the compressor members are engaged if the direction of the slope of the discharge pressure does not change from negative to positive during the continuous period; or
wherein the comparison fails to indicate compressor operation in which the compressor members are engaged if the direction of the slope of the suction pressure does not change from positive to negative during the continuous period.

10. The method of claim 1, further including determining a maximum pressure differential between the discharge pressure and the suction pressure at each time interval and determining a minimum pressure differential between the discharge pressure and the suction pressure at each time interval, and further including calculating a difference between the determined maximum pressure differential and the determined minimum pressure differential, and wherein comparing at least one of the stored values with the predetermined value means comparing the difference with the predetermined value.

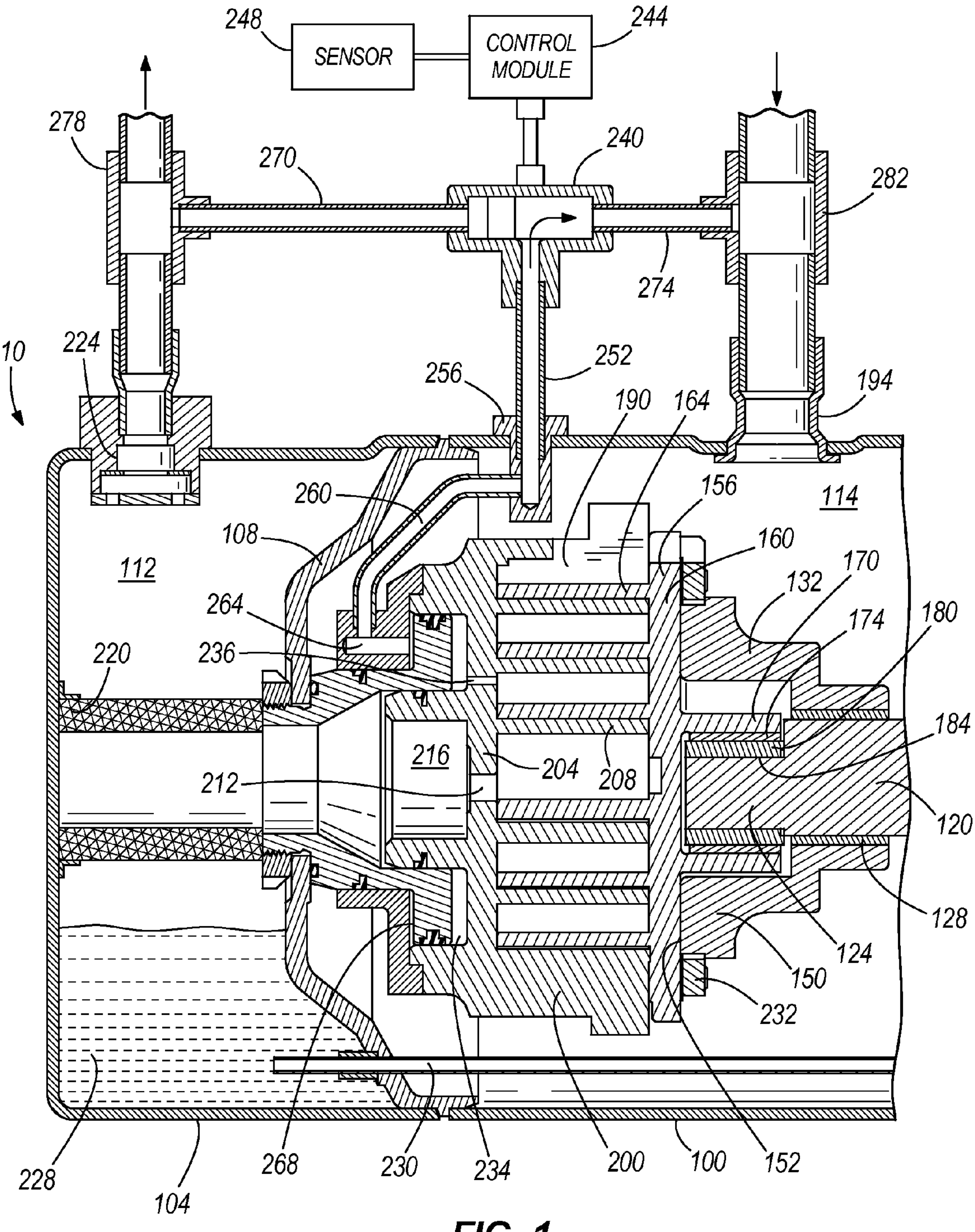
11. The method of claim 10, wherein the comparison fails to indicate compressor operation in which the compressor members are engaged when the difference did not rise by the predetermined value during the continuous time period.

12. The method of claim 1, further including calculating the ratio of the discharge pressure to the suction pressure over the continuous time period, and wherein comparing at least one of the stored values with the predetermined value means comparing the calculated ratio with the predetermined value.

13. The method of claim 12, wherein the comparison fails to indicate compressor operation in which the compressor members are engaged when the calculated ratio drops below the predetermined value.

14. The method of claim 13, wherein the predetermined value is approximately 1.4.

15. The method of claim 1, wherein the compressor is a scroll compressor.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160
112
170
132
264
174
180
236
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FIG. 1

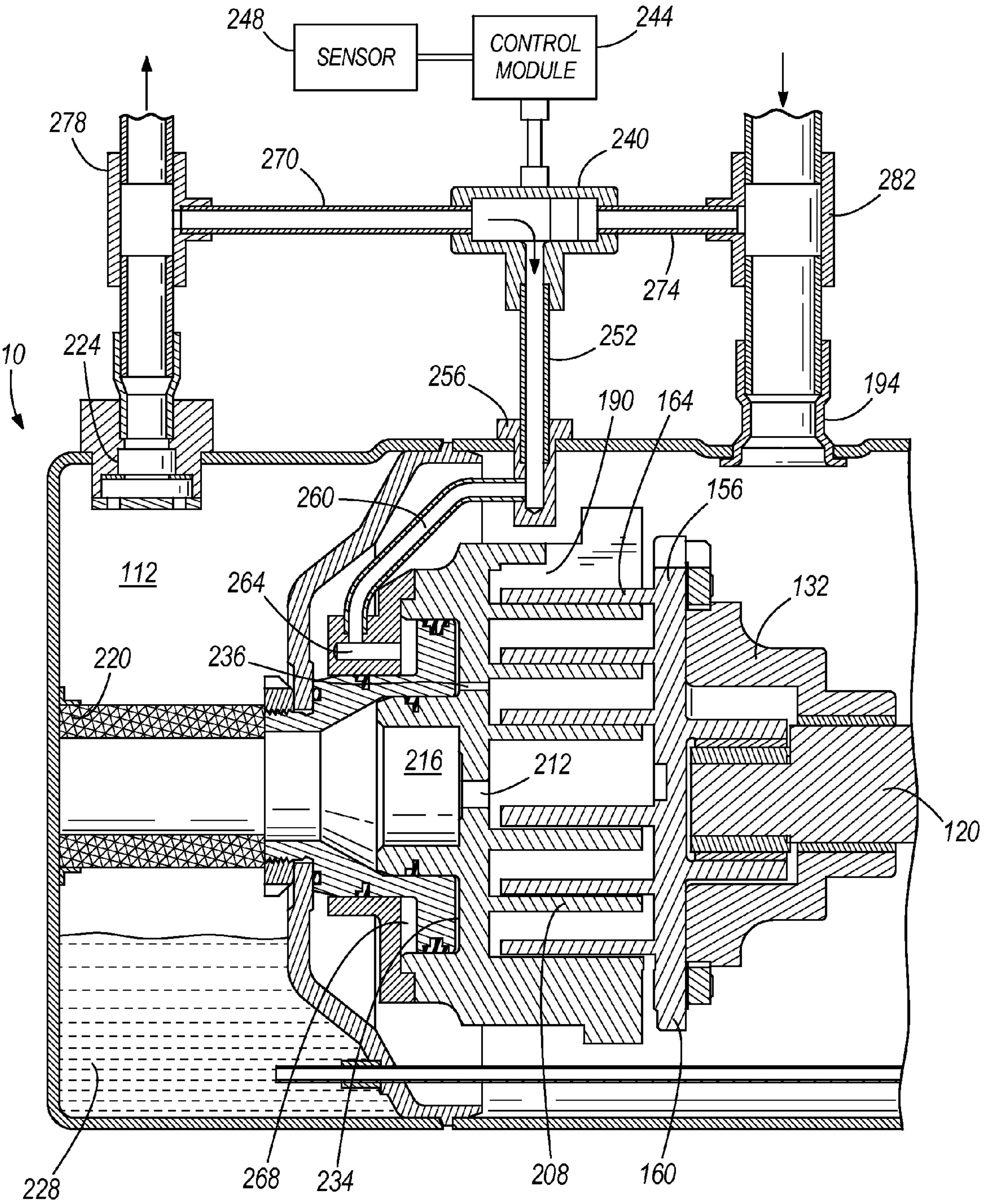
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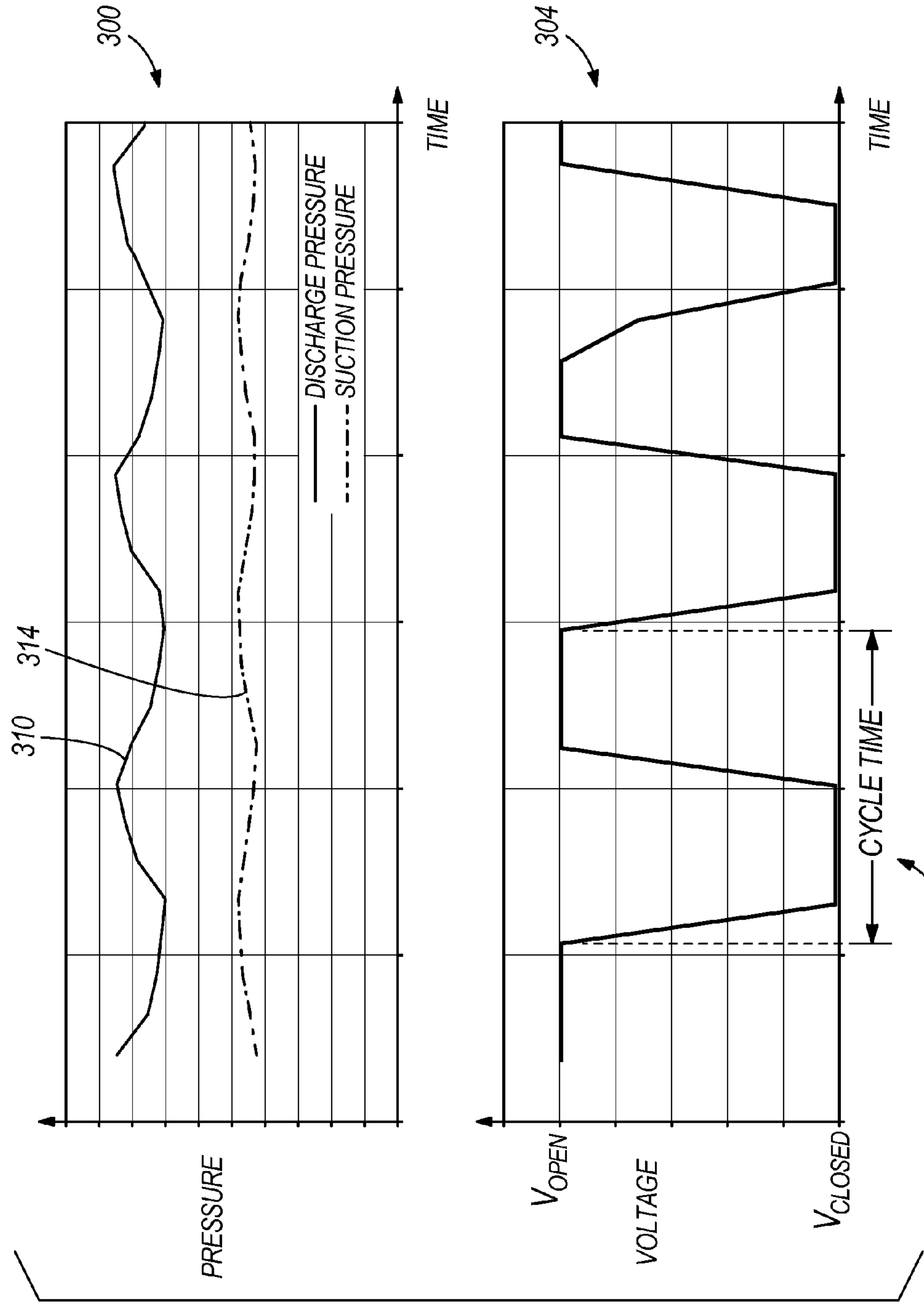
FIG. 2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TIME
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PRESSURE
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VOLTAGE
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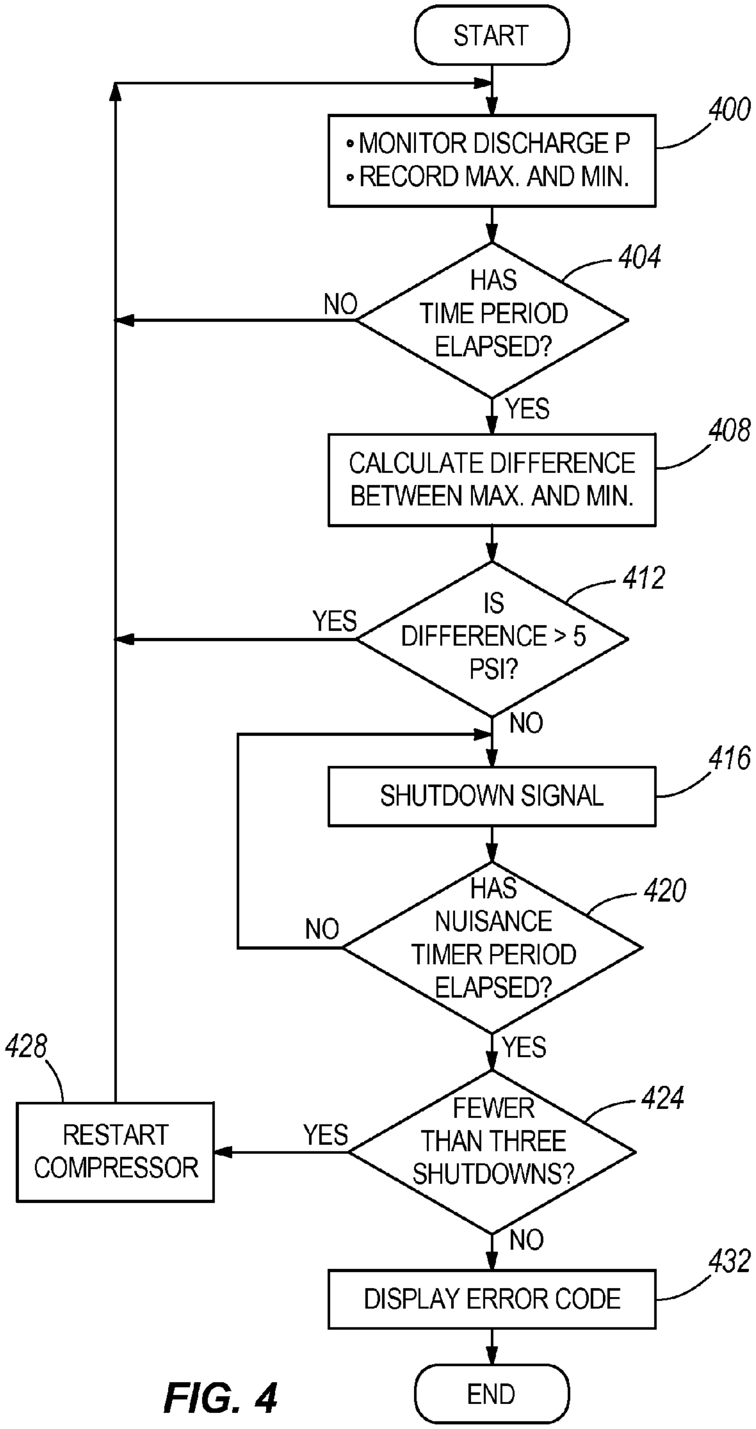
308

FIG. 3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YES
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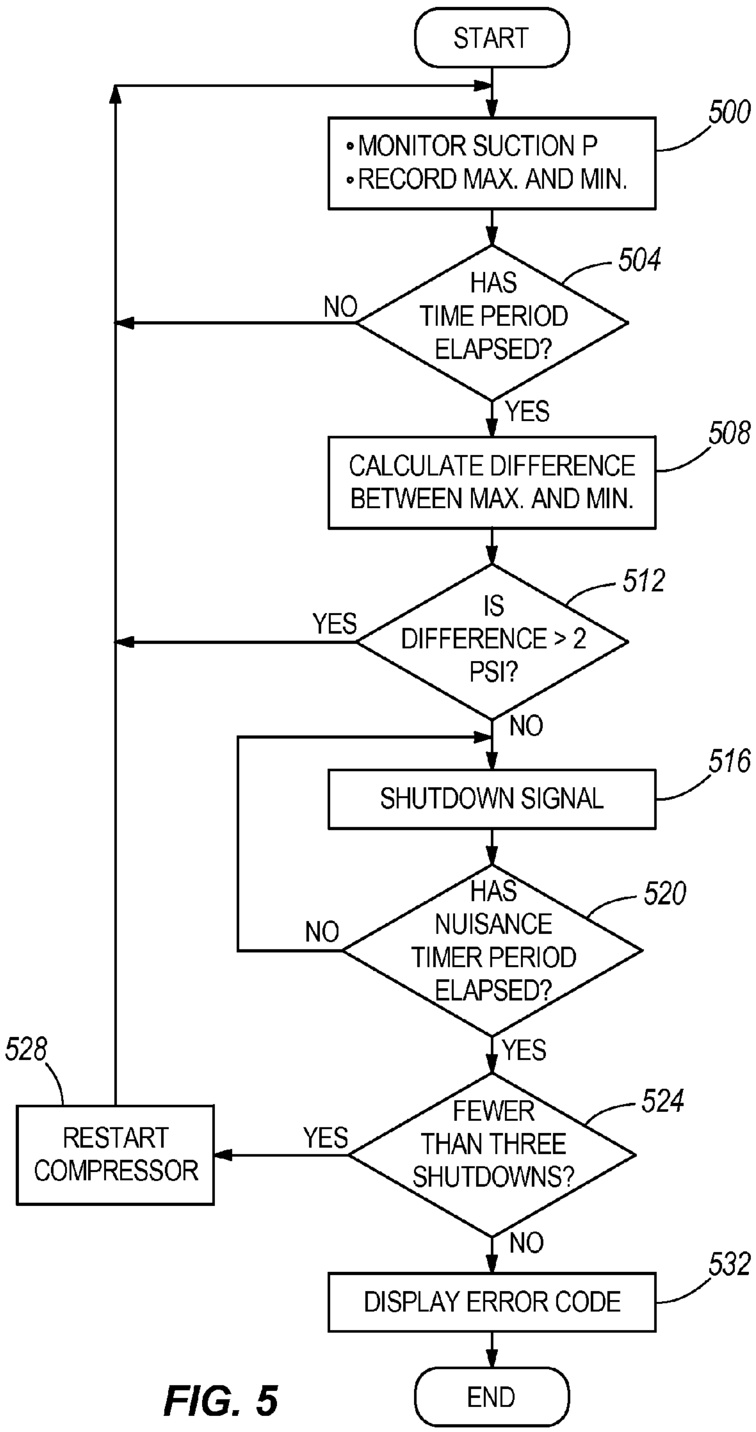
408
IS DIFFERENCE > 5 PSI?
412
YES
NO
SHUTDOWN SIGNAL
416
HAS NUISANCE TIMER PERIOD ELAPSED?
420
NO
YES
FEWER THAN THREE SHUTDOWNS?
424
YES
NO
RESTART COMPRESSOR
428
DISPLAY ERROR CODE
432
END

FIG. 4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HAS TIME PERIOD ELAPSED?
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YES
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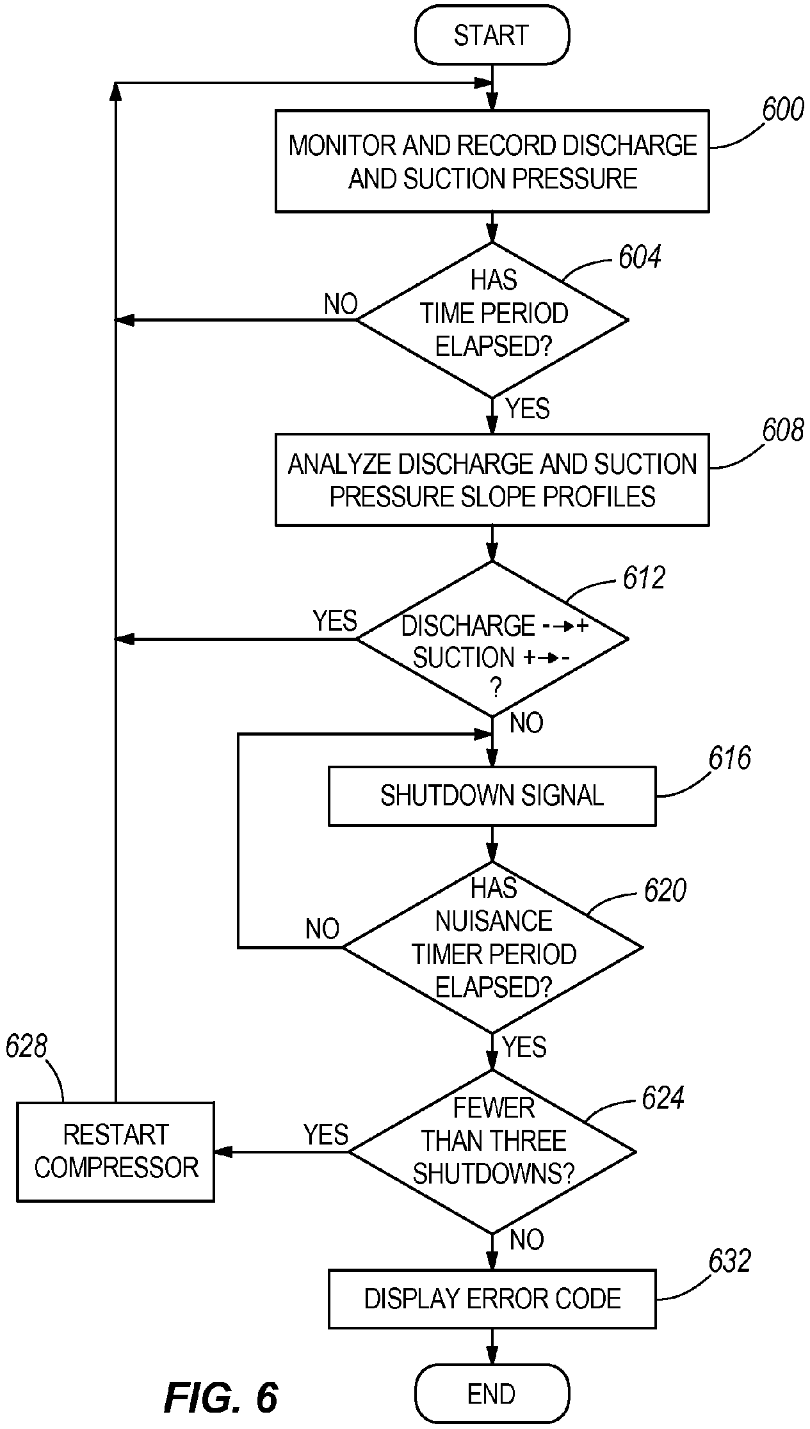
IS DIFFERENCE > 2 PSI?
512
YES
NO
SHUTDOWN SIGNAL
516
HAS NUISANCE TIMER PERIOD ELAPSED?
520
NO
YES
FEWER THAN THREE SHUTDOWNS?
524
YES
NO
RESTART COMPRESSOR
528
DISPLAY ERROR CODE
532
END

FIG. 5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DISCHARGE - → + SUCTION + → - ?
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NO
SHUTDOWN SIGNAL
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HAS NUISANCE TIMER PERIOD ELAPSED?
620
NO
YES
FEWER THAN THREE SHUTDOWNS?
624
YES
NO
RESTART COMPRESSOR
628
DISPLAY ERROR CODE
632
END

FIG. 6

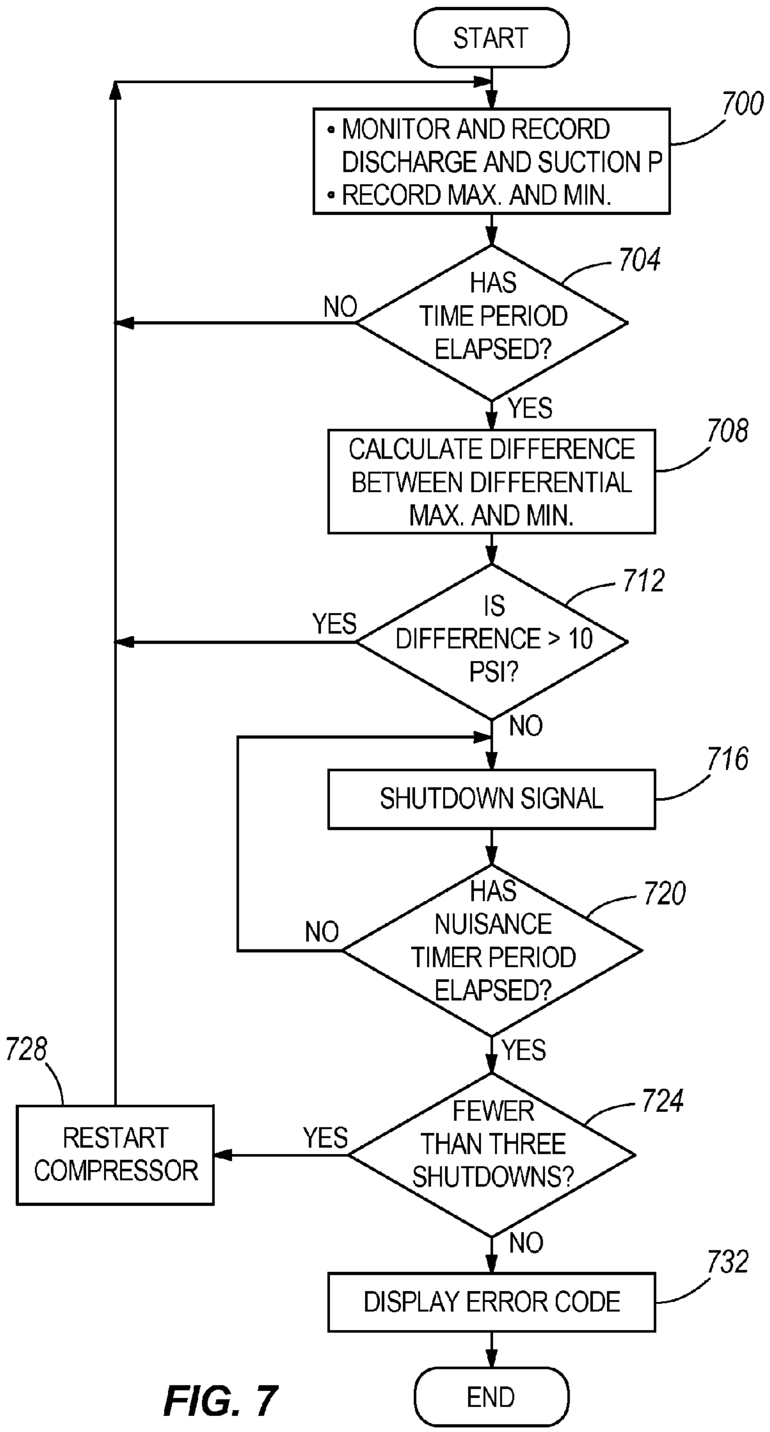
START
MONITOR AND RECORD DISCHARGE AND SUCTION P
RECORD MAX. AND MIN.
700
HAS TIME PERIOD ELAPSED?
704
NO
YES
CALCULATE DIFFERENCE BETWEEN DIFFERENTIAL MAX. AND MIN.
708
IS DIFFERENCE > 10 PSI?
712
YES
NO
SHUTDOWN SIGNAL
716
HAS NUISANCE TIMER PERIOD ELAPSED?
720
NO
YES
FEWER THAN THREE SHUTDOWNS?
724
YES
NO
RESTART COMPRESSOR
728
DISPLAY ERROR CODE
732
END

FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 61558750 B **[0001]**