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(54) **METHOD FOR SOFT EXPULSION OF A FLUID FROM A COMPRESSOR AT START-UP**

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See application file for complete search history.

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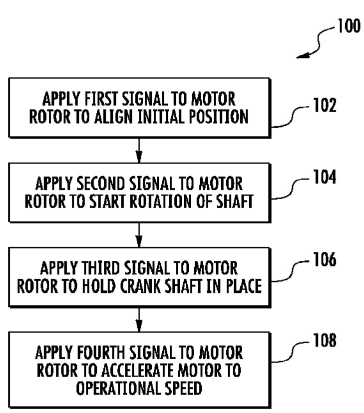
(57) **ABSTRACT**

A method for expulsion of a fluid inside a compressor at start-up including the steps: applying a first signal to the motor windings for a first duration of time to align the motor rotor to the initial position; applying a second signal to the motor windings to start rotation of the compressor shaft; applying a third signal to the motor windings for a second duration of time to hold the compressor shaft in place; and applying a fourth signal to the motor windings to accelerate the motor to an operational speed.

12 Claims, 3 Drawing Sheets



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F04B 49/06	(2006.01)
F04B 49/10	(2006.01)
F04C 18/02	(2006.01)
F04C 28/08	(2006.01)

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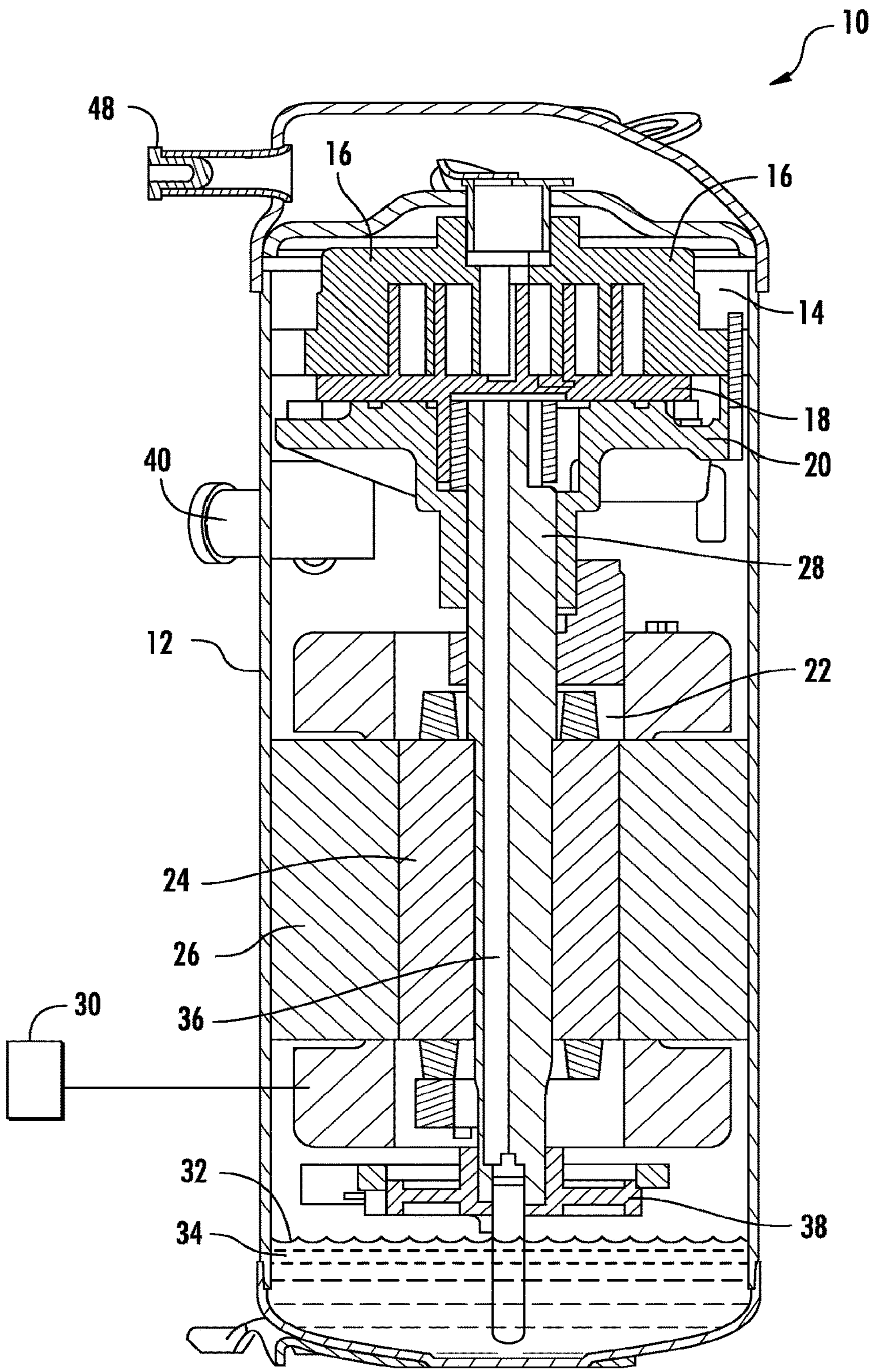

FIG. 1

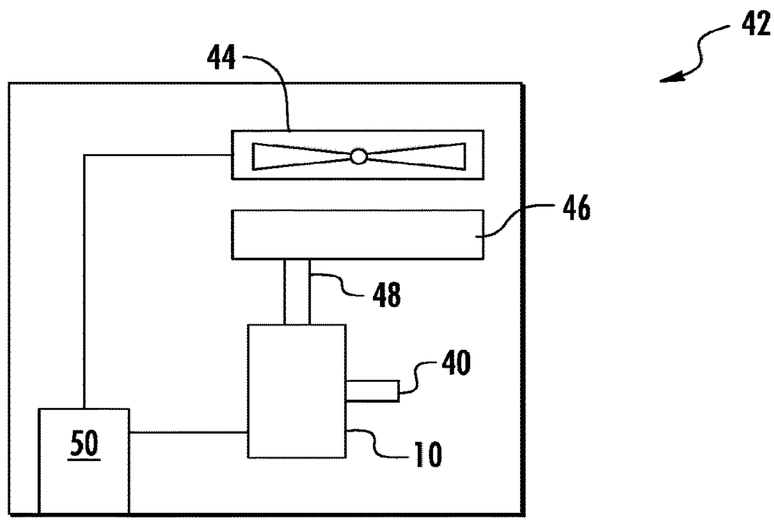
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FIG. 2

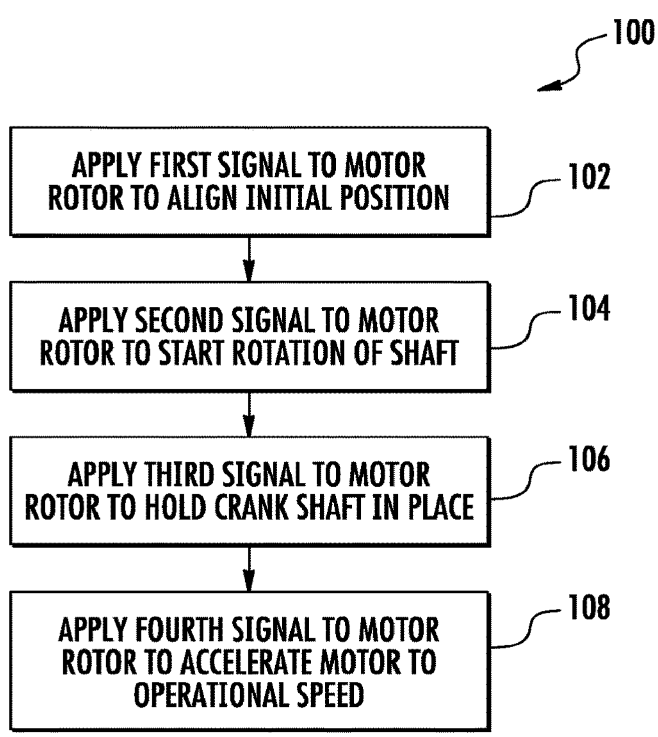

100
APPLY FIRST SIGNAL TO MOTOR ROTOR TO ALIGN INITIAL POSITION
102
APPLY SECOND SIGNAL TO MOTOR ROTOR TO START ROTATION OF SHAFT
104
APPLY THIRD SIGNAL TO MOTOR ROTOR TO HOLD CRANK SHAFT IN PLACE
106
APPLY FOURTH SIGNAL TO MOTOR ROTOR TO ACCELERATE MOTOR TO OPERATIONAL SPEED
108

FIG. 3

FIG. 4A

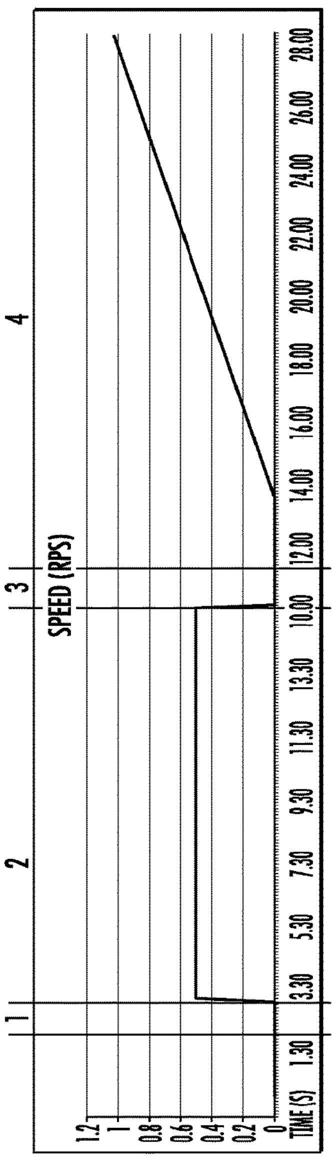


FIG. 4B

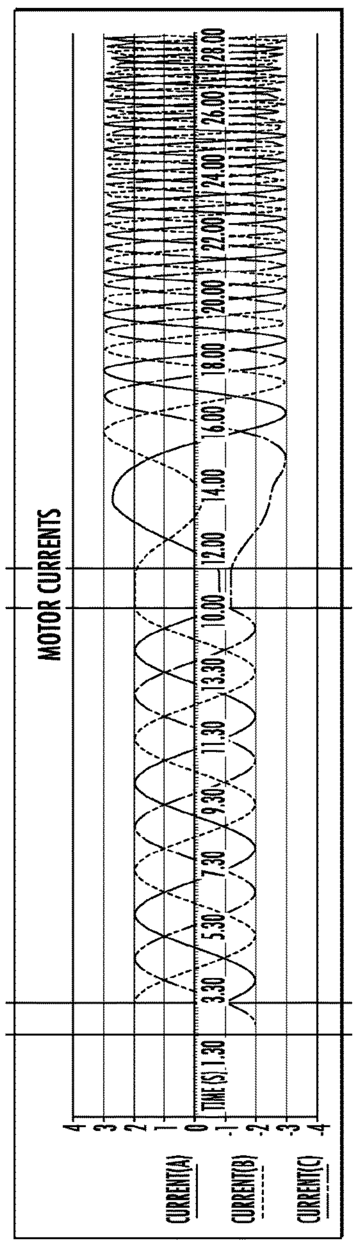
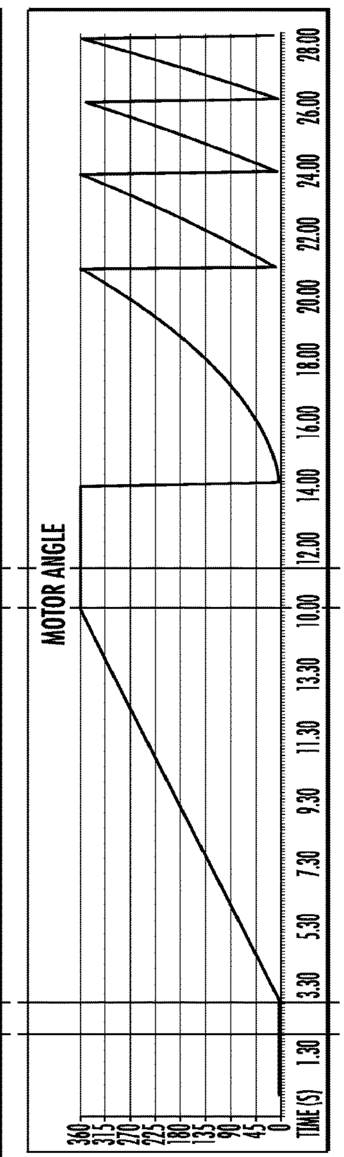


FIG. 4C



METHOD FOR SOFT EXPULSION OF A FLUID FROM A COMPRESSOR AT START-UP

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of and incorporates by reference herein the disclosure of U.S. Ser. No. 61/822,076, filed May 10, 2013. The present application is also a U.S. nationalization of PCT Application No. PCT/US2014/036938, filed May 6, 2014, the text and drawings of which are hereby incorporated by reference in their entireties.

TECHNICAL FIELD OF THE DISCLOSED EMBODIMENTS

The presently disclosed embodiments generally relate to positive displacement compressors, and more particularly, to a method for soft expulsion of a fluid from a compressor at start-up.

BACKGROUND OF THE DISCLOSED EMBODIMENTS

Positive displacement compressors are widely used in refrigerant compressor applications. One known type, a scroll compressor, includes compression elements and an electric motor disposed within a sealed compressor shell. A quantity of lubricant is also received in the compressor shell. In such compressors, the refrigerant passes over the motor on its way to the inlet of the compression elements, cooling the motor.

At start-up, the oil located in the compressor's sump may contain a quantity of fluid, such as a liquid refrigerant. At start-up, the sump and the motor are cool, and pre-heating does not occur. Therefore, idle compressors often accumulate liquid refrigerant and/or oil in the compression pocket and in the suction plenum. Because the fluids are incompressible, detrimental forces can result if the compressor is rapidly started.

Electric heaters are occasionally used to pre-heat the compressor and thus reduce the amount of accumulated fluid present at start-up. However, this approach has numerous issues. Use of electric heaters adds cost and complexity to the system, and it is ineffective on expelling oil, to name only two examples. Another approach used to prevent accumulation of fluid involves the addition of valves to isolate the compressor during off periods. This approach also adds cost, and adds detrimental stress cycles to the motor and valves. There is therefore a need for a method to remove accumulated fluids from a compressor's compression chamber before operational start-up.

SUMMARY OF THE DISCLOSED EMBODIMENTS

In one aspect, a method for soft expulsion of a fluid from a compressor at start-up is provided. The method includes the step of applying a first signal to windings of the motor for a first duration of time to align the motor rotor to an initial position. In one embodiment, the initial position of the motor rotor is set by a control determining the placement of a magnet within the motor rotor and holding that position for a period of time. In one embodiment, a DC current is applied to the windings of motor for a period of time to generate a DC flux, so that the motor rotor position is forced to align with the stationary magnet fixed at the initial position. In one embodiment, the DC currents are applied to the windings of motor for approximately 3.3 seconds. In other embodiments, the DC current is applied for a duration sufficient to ensure alignment of the motor rotor position with the stationary magnet flux.

The method also includes the step of applying a second signal to the windings of the motor to start rotation of the shaft. In one embodiment, a sinusoidal current of sufficient amplitude, is slowly applied to the windings of the motor using an open speed loop vector control. The frequency of the current waveforms are set to provide the correct speed of rotation for shaft. In one embodiment, the shaft rotates at a speed of approximately one revolution per second. As the shaft rotates slowly, fluid is discharged from the compression chamber into the discharge chamber.

The method also includes the step of applying a third signal to the windings of the motor for a second duration of time to hold the shaft in place. In one embodiment, once the shaft has been rotated the desired number of revolutions to clear the compression chamber of the excess fluid, the DC currents are again applied to the windings of the motor at amplitudes necessary to hold the shaft in place. In one embodiment, DC currents are applied for a second duration of time of approximately four seconds. In other embodiments, the DC currents are applied for a duration of time sufficient to align the motor rotor position with the stationary magnet flux.

The method also includes the step of applying a fourth signal to the windings of the motor to accelerate the motor to an operational speed. In one embodiment, a sinusoidal current is applied to the windings of motor using a speed ramp profile to bring the motor up to an operational speed.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments and other features, advantages and disclosures contained herein, and the manner of attaining them, will become apparent and the present disclosure will be better understood by reference to the following description of various exemplary embodiments of the present disclosure taken in conjunction with the accompanying drawings, wherein:

FIG. **1** is a cross-sectional view of a positive displacement compressor incorporated into the exemplary embodiment;

FIG. **2** illustrates a schematic view of an outdoor unit assembly incorporated into the exemplary embodiment.

FIG. **3** is an exemplary embodiment of a method to remove a liquid from a compressor at start-up;

FIG. **4**A illustrates the speed profile of a positive displacement compressor motor in revolutions per second;

FIG. **4**B illustrates sinusoidal current profile applied to a positive displacement compressor motor; and

FIG. **4**C illustrates the motor angle position of a positive displacement compressor motor.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of this disclosure is thereby intended.

FIG. **1** illustrates a positive displacement compressor, such as a scroll compressor to name one non-limiting example, incorporated into an exemplary embodiment of the present disclosure and indicated generally at **10**. Particularly, the compressor **10** includes a sealed compressor shell **12**. Disposed within the sealed compressor shell **12** is a compressor pump unit **14** including a fixed scroll **16**, an orbiting scroll **18**, and a crankcase **20**. Further disposed within the sealed compressor shell **12** is a motor **22** including a motor rotor **24** spaced from a stator **26**. A motor **22**, such as a permanent magnet motor to name one non-limiting example, drives a shaft **28** which in turn drives the orbiting scroll **18**. A variable speed drive **30** is schematically connected to drive the motor **22**.

A liquid **32**, for example oil, fills an oil sump **34** and the bottom of the motor rotor **24**, wherein shaft **28** rotates within the oil sump **34**. As is known in the art, oil travels up a passage **36** to lubricate bearings, fixed scroll **16** and orbiting scroll **18**. The fixed scroll **16** is supported by crankcase **20** and the shaft **28** is supported axially by lower bearing ring **38**.

During normal operation, a fluid, for example a refrigerant, enters the sealed compressor shell **12** through inlet **40** as a saturated vapor. The saturated vapor enters the compressor chamber (not shown) and as the motor rotor **24** rotates in a forward direction, orbiting scroll **18** rotates around the fixed scroll **16** to compress the saturated vapor into a high-pressure, high-temperature vapor. After motor rotor **24** stops, some uncompressed saturated vapor remains within the compressor chamber.

FIG. **2** illustrates a schematic view of an outdoor unit assembly **42** which may be used for residential heating and cooling. In one embodiment, the outdoor unit assembly **42** includes a fan **44**, compressor **10**, and condenser **46** connected to compressor discharge line **48**. A control **50** is in electrical communication with the fan **44** and the compressor **10** for control thereof.

FIG. **3** illustrates an exemplary method for soft expulsion of a fluid from a compressor at start up. As shown in FIG. **3**, an exemplary method **100** includes the step **102** of applying a first signal to windings of the motor **22** for a first duration of time to align the motor rotor **24** to an initial position. In one embodiment, the initial position of the motor rotor **24** is set by control **50** commanding the shaft **28** to rotate until sensing the placement of at least one magnet (not shown) disposed on the motor rotor **24**. In other embodiments, the initial position of the motor rotor **24** is set by the placement of a stationary magnet (not shown) adjacent to the motor rotor **24**. In one embodiment, as shown in FIG. **4**C, a DC current is applied to the windings of motor **22** for a period of time to generate a DC flux, so that the motor rotor **24** position is forced to align with the at least one magnet. In other embodiments, a DC current is applied to the windings of motor **22** for a period of time to generate a DC flux, so that the motor rotor **24** position is forced to align with the stationary magnet fixed at the initial position. In one embodiment, the DC currents are applied to the windings of motor **22** for approximately 3.3 seconds. In other embodiments, the DC currents are applied for a duration sufficient to ensure alignment of the motor rotor **24** position with the stationary magnet flux. It will be appreciated that the amplitude of the DC current must be sufficient to overcome the resistive torque on the shaft **28**. It will be appreciated that depending on the type of motor **22**, such as a permanent magnet motor to name one non-limiting example, step **102** may not be necessary.

Step **104** includes applying a second signal to the windings of the motor **22** to start rotation of the shaft **28**. In one embodiment, as shown in FIG. **4**B, a sinusoidal current of sufficient amplitude, for example two amperes in one non-limiting embodiment, is applied to the windings of motor **22** using an open speed loop vector control. The variable speed drive **30** outputs a pulse-width modulation (PWM) pattern to the motor **22**. The PWM pattern is designed to generate a slow rotating flux pattern and induce the motor rotor **24** to rotate according to the rotating flux. The variable speed drive **30** may be used to vary the frequency of input voltage and current to the motor **22**, thereby controlling the motor speed. The frequency, for example 0.5 Hertz, of the current/voltage is set to provide the correct speed of rotation for shaft **28**. The maximum speed for a particular motor **22** may be determined by the viscosity of the liquid **32**. In one embodiment, the shaft rotates at a speed of approximately one revolution per second. As the shaft **28** rotates slowly (in one embodiment, the shaft **28** rotates for at least one revolution), a fluid is discharged from the compression chamber (not shown) into the discharge chamber (not shown). It will be appreciated that depending on the power rating of the motor **22** and the volume of the compressor pump unit **14**, the frequency may vary to slowly rotate the shaft **28**.

Step **106** includes applying a third signal to the windings of the motor **22** for a second duration of time to hold the shaft **28** in place. In one embodiment, once the shaft **28** has been rotated the desired number of revolutions to clear the compression chamber (not shown) of the excess fluid, a DC current is again applied to the windings of motor **22**, for a second duration of time, at amplitudes necessary to hold the shaft **28** in place. In one embodiment, the DC currents are applied for a second duration of time sufficient to ensure alignment of the motor rotor **24** position to the initial position. It will be appreciated that depending on the type of motor **22**, such as a permanent magnet motor to name one non-limiting example, step **106** may not be necessary.

Step **108** includes applying a fourth signal to the windings of the motor **22** to accelerate the motor **22** to an operational speed. In one embodiment, as shown in FIGS. **4**A and **4**B, a sinusoidal current is applied to the windings of motor **22** using a speed ramp profile to bring the motor **22** up to an operational speed.

It will be appreciated that, as the shaft **28** of compressor **10** is slowly rotated the desired number of revolutions, accumulated fluid in the compression chamber may be safely discharged into the discharge chamber prior to accelerating the compressor to an operational speed.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only certain embodiments have been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

What is claimed is:

1. A method of operating a positive displacement compressor, including a compressor shaft and a motor including a rotor coupled to the compressor shaft and further including motor windings, the method comprising the steps of:

(a) applying a first signal to the motor windings for a first duration of time to align the rotor to an initial position;

(b) applying a second signal to the motor windings to start rotation of the compressor shaft;

(c) applying a third signal to the motor windings for a second duration of time to hold the compressor shaft in place; and

(d) applying a fourth signal to the motor windings to accelerate the motor to an operational speed.

2. The method of claim **1**, wherein the initial position 1s aligned by a control commanding the shaft to rotate until sensing the placement of at least one magnet disposed on the rotor, and holding that position for a period of time.

3. The method of claim **1**, wherein the first signal comprises a direct current signal.

4. The method of claim **1**, wherein the second signal comprises a sinusoidal alternating current signal, wherein a frequency of the sinusoidal alternating current is approximately 0.5 Hz.

5. The method of claim **1**, wherein the compressor shaft rotates at a speed of approximately one revolution per second.

6. The method of claim **1**, wherein the third signal comprises a direct current signal.

7. The method of claim **1**, wherein the second duration of time comprises a sufficient time to align the rotor to the initial position.

8. The method of claim **1**, wherein the fourth signal comprises a sinusoidal alternating current signal, wherein the sinusoidal alternating current signal comprises a speed ramp profile.

9. A method of operating a positive displacement compressor, including a compressor shaft and a motor including a rotor coupled to the compressor shaft and further including motor windings, the method comprising the steps of:

(a) applying a first signal to only one of the motor windings for a first duration of time to align the rotor to an initial position, wherein the first signal comprises a direct current signal;

(b) applying a second signal to the motor windings to start rotation of the compressor shaft;

(c) applying a third signal to the motor windings to accelerate the motor to an operational speed.

10. The method of claim **9**, wherein the second signal comprises a sinusoidal alternating current signal, wherein a frequency of the sinusoidal alternating current is approximately 0.5 Hz.

11. The method of claim **9**, wherein the compressor shaft rotates at a speed of approximately one revolution per second.

12. The method of claim **9**, wherein the third signal comprises a sinusoidal alternating current signal, wherein the sinusoidal alternating current signal comprises a speed ramp profile.

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