



(51) International Patent Classification:

F04B 49/00 (2006.01)

(21) International Application Number:

PCT/US2013/036527

(22) International Filing Date:

15 April 2013 (15.04.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/636,192 20 April 2012 (20.04.2012) US

13/857,334 5 April 2013 (05.04.2013) US

(71) Applicant: GENERAL ELECTRIC COMPANY
[US/US]; 1 River Road, Schenectady, NY 12345 (US).

(72) Inventors: WORDEN, Bret, Dwayne; 2901 East Lake Road, Lawrence Park, PA 16531 (US). PEOPLES, Richard, C.; 600 Barkleyville Road, Grove City, PA 16127 (US). SABARAD, Jayaprakash, Shreeshailappa; Whitefield Road, Hoodi Village, Bangalore, Karnataka 560066 (IN). STRODE, Jason, M.; 2901 East Lake Road, Lawrence Park, PA 16531 (US).

(74) Agents: KRAMER, John A. et al.; GENERAL ELECTRIC COMPANY, Global Patent Operation, 2 Corporate Drive, Suite 648, Shelton, CT 06484 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

— as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: METHOD AND SYSTEM FOR RECIPROCATING COMPRESSOR STARTING

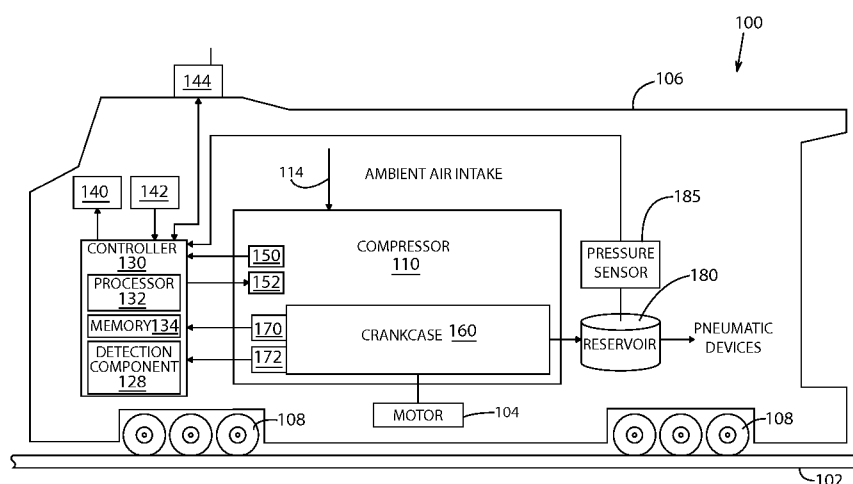


FIG. 1

(57) Abstract: Systems and methods of the invention may overcome a higher than normal starting torque for in a reciprocating, electric motor driven air compressor for a vehicle. A detection component can be configured to detect a stall condition for a reciprocating compressor based on a force from compressed air being compressed into a reservoir of the reciprocating compressor. Based upon the detected stall condition, a controller can reverse direction or increase torque to alleviate the stall condition. In the reverse direction mode, the controller component can change a direction of a piston rotation. In the torque increase mode, the controller increases a number of poles for the motor, a line voltage, or a volt/hertz.

METHOD AND SYSTEM FOR RECIPROCATING COMPRESSOR STARTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 61/636,192, filed April 20, 2012, and entitled "SYSTEM AND METHOD FOR A COMPRESSOR." The entirety of the aforementioned application is incorporated herein by reference.

BACKGROUND

TECHNICAL FIELD

[0002] Embodiments of the subject matter disclosed herein relate to facilitating starting a reciprocating compressor having a loaded start condition.

DISCUSSION OF ART

[0003] Compressors compress gas, such as air. An air compressor can include three cylinders with two stages and can be air cooled and driven by an electric motor. The compressor can have two low pressure cylinders which deliver an intermediate pressure air supply to a single high pressure cylinder for further compression for final delivery to an air reservoir. Compressors may sometimes have difficulty in starting.

[0004] It may be desirable to have a system and method that differs from those systems and methods that are currently available.

BRIEF DESCRIPTION

[0005] In an embodiment, a method is provided that includes detecting a compressor start failure (e.g., stall) condition for a reciprocating compressor based on a force from compressed air being compressed into a reservoir of the reciprocating compressor. Power may be removed from or reduced to a motor of the reciprocating compressor. A phase sequence of the motor (e.g., a three (3) phase AC motor) may be reversed to force a recompression of air against a piston in the reciprocating compressor. A reverse stall or a start of the reciprocating compressor may be detected while in a reverse direction as the piston moves toward a Top-Dead-Center (TDC)

position. In another embodiment, a compressor can be started by employing a high starting torque due to, for instance, wear or a failure.

[0006] In an embodiment, a vehicle is provided that includes an engine, a compressor operatively connected to the engine, wherein the compressor includes a reservoir configured to store compressed air, a detector component that is configured to detect a stall condition of the compressor, and a controller. The controller can be configured to control at least one of removal power from the motor of the compressor, reversal a phase sequence of the motor to force a recompression of a piston of the compressor, and detection of at least one of a reverse stall or a start of the compressor while in a reverse direction as the piston moves to a Top-Dead-Center (TDC) position.

[0007] In an embodiment, a system can be provided that includes means for detecting a stall-when-starting condition for a reciprocating bidirectional based on a speed signal, a measured current signal, or a measured pressure signal. The system further includes means for removing power from a motor of the reciprocating bidirectional compressor and means for reversing a phase sequence to the motor to force a recompression of a piston of the reciprocating bidirectional compressor. The system includes means for detecting at least one of a reverse stall or a start of the reciprocating bidirectional compressor while in a reverse direction as the piston moves toward a Top-Dead-Center (TDC) position.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Reference is made to the accompanying drawings in which particular embodiments and further benefits of the invention are illustrated as described in more detail in the description below, in which:

[0009] FIG. 1 is an illustration of an embodiment of a vehicle system with a compressor;

[0010] FIG. 2 is an illustration of an embodiment of system that includes a compressor;

[0011] FIG. 3 is an illustration of an embodiment of a system that controls a motor based upon a detection component for a compressor;

[0012] FIG. 4 is an illustration of an embodiment of a system that includes a compressor;

[0013] FIG. 5 is an illustration of an embodiment of a system that includes a compressor;

[0014] FIG. 6 is an illustration of an embodiment of a system that includes a compressor;

[0015] FIG. 7 is an illustration of an embodiment of a valve that has a leak to cause a loading sat for a compressor;

[0016] FIG. 8 is an illustration of an embodiment of a system for a system that includes a compressor;

[0017] FIG. 9 is an illustration of a reverse direction mode in response to a stall when starting condition of a compressor;

[0018] FIG. 10 illustrates a flow chart of an embodiment of a method for detecting a stall

[0019] FIG. 11 illustrates a flow chart of an embodiment of a method for increasing torque for a compressor motor in response to a detected stall condition and

[0020] FIG. 12 illustrates a flow chart of an embodiment of a method for increasing torque for a compressor motor and reversing a phase sequence of the motor in response to a detected stall-when starting

DETAILED DESCRIPTION

[0021] Embodiments of the subject matter disclosed herein relate to systems and methods that overcome a higher than normal starting torque for in a reciprocating, electric motor driven air compressor for a vehicle. A detection component can be configured to detect a stall condition for a reciprocating compressor based on a force from compressed air being compressed into a reservoir of the reciprocating compressor. Based upon the detected stall condition, a controller can be configured to control at least one of a reverse direction mode (also referred to as reverse phase mode) or a torque increase mode in order to alleviate the stall condition. In the reverse direction mode, the controller component can be configured to change a direction of a crankshaft rotation in order to allow a gain in momentum during a subsequent start attempt to overcome a high starting torque requirement. In the torque

increase mode, the controller can be configured to increase at least one of a number of poles for the motor, a line voltage, or a volt/hertz (e.g., motor flux). In another embodiment, the controller component can utilize the reverse direction mode alone, or in combination with the torque increase mode. In still another embodiment, the controller component can utilize the torque increase mode alone, or in combination with the reverse direction mode.

[0022] With reference to the drawings, like reference numerals designate identical or corresponding parts throughout the several views. However, the inclusion of like elements in different views does not mean a given embodiment necessarily includes such elements or that all embodiments of the invention include such elements.

[0023] The term “component” as used herein can be defined as a portion of hardware, a portion of software, or a combination thereof. A portion of hardware can include at least a processor and a portion of memory, wherein the memory includes an instruction to execute. The term “vehicle” as used herein can be defined as an asset that is a mobile machine or a moveable transportation asset that transports at least one of a person, people, or a cargo. For instance, a vehicle can be, but is not limited to being, a rail car, an intermodal container, a locomotive, a marine vessel, mining equipment, a stationary power generation equipment, industrial equipment, construction equipment, and the like. The term “loaded” as used herein can be defined as a compressor system mode where air is being compressed into the reservoir. The term “loaded start” as used herein can be defined as a compressor system mode in a loaded condition during a starting phase of the compressor.

[0024] A compressor compresses gas, such as air. In some embodiments, the compressed gas is supplied to operate pneumatic or other equipment powered by compressed gas. A compressor may be used for mobile applications, such as vehicles. By way of example, vehicles utilizing compressors include locomotives, on-highway vehicles, off-highway vehicles, mining equipment, and marine vessels. In other embodiments, a compressor may be used for stationary applications, such as in manufacturing or industrial applications requiring compressed air for pneumatic equipment among other uses. The compressor depicted in the below figures is one which utilizes spring return inlet and discharge valves for each cylinder, wherein the movement of these valves is caused by the differential pressure across each cylinder

as opposed to a mechanical coupling to the compressor crank shaft. The subject invention can be applicable to machines with either type of valve (e.g., spring return valves, mechanical coupled valves, among others) and the spring return valve is depicted solely for example and not to be limiting on the subject innovation.

[0025] FIG. 1 illustrates a block diagram of an embodiment of a vehicle system 100 (e.g., a locomotive system, a system, among others). The vehicle system 100 is depicted as a rail vehicle 106 configured to run on a rail 102 via a plurality of wheels 108. The rail vehicle includes a compressor system with a compressor 110. In an embodiment, the compressor is a reciprocating compressor that delivers air at high pressure. In another embodiment, the compressor is a reciprocating compressor with a bi-directional drive system that drives a piston in a forward direction and the reverse direction. In an embodiment, the compressor receives air from an ambient air intake 114. The air is then compressed to a pressure greater than the ambient pressure and the compressed air is stored in reservoir 180, which is monitored by a reservoir pressure sensor 185. In one embodiment, the compressor is a two-stage compressor (such as illustrated in FIG. 2) in which ambient air is compressed in a first stage to a first pressure level and delivered to a second stage, which further compresses the air to a second pressure level that is higher than the first pressure level. The compressed air at the second pressure level is stored in a reservoir. The compressed air may then be provided to one or more pneumatic devices as needed. In other embodiments, the compressor 110 may be a single stage or multi-stage compressor.

[0026] The compressor includes a crankcase 160. The crankcase is an enclosure for a crankshaft (not shown in FIG. 1) connected to cylinders (not shown in FIG. 1) of the compressor. A motor 104 is employed to rotate the crankshaft to drive the pistons within the cylinders. In embodiments, the motor 104 may be an electric or non-electric motor. In another embodiment, the crankshaft may be coupled to a drive shaft of an engine or other power source configured to rotate the crankshaft of the compressor. In each embodiment, the crankshaft may be lubricated with compressor oil that is pumped by an oil pump (not shown) and sprayed onto the crankshaft. The crankshaft is mechanically coupled to a plurality of pistons via respective connecting rods. The pistons are drawn and pushed within their respective cylinders as the crankshaft is rotated to compress a gas in one or more stages.

[0027] The rail vehicle further includes a controller 130 for controlling various components related to the vehicle system. In an embodiment, the controller is a computerized control system with a processor 132 and a memory 134. The memory may be computer readable storage media, and may include volatile and/or non-volatile memory storage. In an embodiment, the controller includes multiple control units and the control system may be distributed among each of the control units. In yet another embodiment, a plurality of controllers may cooperate as a single controller interfacing with multiple compressors distributed across a plurality of vehicles. Among other features, the controller may include instructions for enabling on-board monitoring and control of vehicle operation. Stationary applications may also include a controller for managing the operation of one or more compressors and related equipment or machinery.

[0028] In an embodiment, the controller receives signals from one or more sensors 150 to monitor operating parameters and operating conditions, and correspondingly adjust actuators 152 to control operation of the rail vehicle and the compressor. In various embodiments, the controller receives signals from one or more sensors corresponding to compressor speed, compressor load, boost pressure, exhaust pressure, ambient pressure, exhaust temperature, or other parameters relating to the operation of the compressor or surrounding system. In another embodiment, the controller receives a signal from a crankcase pressure sensor 170 that corresponds to the pressure within the crankcase. In yet another embodiment, the controller receives a signal from a crankshaft position sensor 172 that indicates a position of the crankshaft. The position of the crankshaft may be identified by the angular displacement of the crankshaft relative to a known location such that the controller is able to determine the position of each piston within its respective cylinder based upon the position of the crankshaft. In some embodiments, the controller controls the vehicle system by sending commands to various components. On a locomotive, for example, such components may include traction motors, alternators, cylinder valves, and throttle controls among others. The controller may be connected to the sensors and actuators through wires that may be bundled together into one or more wiring harnesses to reduce space in vehicle system devoted to wiring and to protect the signal wires from abrasion and vibration. In other embodiments, the controller

communicates over a wired or wireless network that may allow for the addition of components without dedicated wiring.

[0029] The controller may include onboard electronic diagnostics for recording operational characteristics of the compressor. Operational characteristics may include measurements from sensors associated with the compressor or other components of the system. These measurements may include motor currents, compressor rotational speed, air pressure and/or temperature at various locations. Such operational characteristics may be stored in a database in memory. In one embodiment, current operational characteristics may be compared to past operational characteristics to determine trends of compressor performance.

[0030] The controller may include onboard electronic diagnostics for identifying and recording potential degradation and failures of components of vehicle system. For example, when a potentially degraded component is identified, a diagnostic code may be stored in memory. In one embodiment, a unique diagnostic code may correspond to each type of degradation that may be identified by the controller. For example, a first diagnostic code may indicate a malfunctioning exhaust valve of a cylinder, a second diagnostic code may indicate a malfunctioning intake valve of a cylinder, a third diagnostic code may indicate deterioration of a piston or cylinder resulting in a blow-by condition. Additional diagnostic codes may be defined to indicate other deteriorations or failure modes. In yet other embodiments, diagnostic codes may be generated dynamically to provide information about a detected problem that does not correspond to a predetermined diagnostic code. In some embodiments, the controller modifies the output of charged air from the compressor, such as by reducing the duty cycle of the compressor, based on parameters such as the condition or availability of other compressor systems (such as on adjacent locomotive engines), environmental conditions, and overall pneumatic supply demand.

[0031] The controller may be further linked to display 140, such as a diagnostic interface display, providing a user interface to the operating crew and/or a maintenance crew. The controller may control the compressor, in response to operator input via user input controls 142, by sending a command to correspondingly adjust various compressor actuators. Non-limiting examples of user input controls may include a throttle control, a braking control, a keyboard, and a power switch.

Further, operational characteristics of the compressor, such as diagnostic codes corresponding to degraded components, may be reported via display to the operator and/or the maintenance crew.

[0032] The vehicle system may include a communications system 144 linked to the controller. In one embodiment, communications system may include a radio and an antenna for transmitting and receiving voice and data messages. For example, data communications may be between vehicle system and a control center of a railroad, another locomotive, a satellite, and/or a wayside device, such as a railroad switch. For example, the controller may estimate geographic coordinates of a vehicle system using signals from a GPS receiver. As another example, the controller may transmit operational characteristics of the compressor to the control center via a message transmitted from communications system. In one embodiment, a message may be transmitted to the command center by communications system when a degraded component of the compressor is detected and the vehicle system may be scheduled for maintenance.

[0033] The system can include a detection component 128 that is configured to detect a stall condition for the compressor. The detection component can ascertain whether a failure detected corresponds to a loaded start condition. Based on the stall condition detected by the detection component, the controller can be configured to employ at least one of a reverse direction mode or a torque increase mode. The controller can employ the reverse direction mode in order to reverse a direction of the compressor crankshaft temporarily, to be followed by another start attempt in the forward direction in order to overcome a high starting torque required to start the compressor. Additionally or alternatively, the controller can employ the torque increase mode that increases at least one of a number of poles for the motor, a line voltage, or a volt/hertz (e.g., motor flux). In an embodiment, the controller utilizes the reverse direction mode alone, or in combination with the torque increase mode. In another embodiment, the controller utilize one of the reverse direction mode or the torque increase mode for a duration of time and then utilize the both the reverse direction mode or the torque increase mode in combination. Yet, a suitable combination of the modes can be employed by the controller and either mode alone or in combination can be selected with sound engineering judgment.

[0034] During the reverse direction mode, the controller communicates to the motor to remove power therefrom. The controller can communicate with the motor to reverse the phase sequence to the motor, wherein the reversed direction sequence forces a recompression. During this reversed direction sequence, the compressor can either stall again or run in the reverse direction. If the compressor runs in the reverse direction, the controller can be configured to run in a reverse direction (if the compressor can function in such reverse direction). If the compressor is not capable of reverse direction running, the compressor can change to the forward directions after a duration of time after a rotation is detected. A stuck loaded Control Mag Valve (CMV) (not shown but discussed below) or unloader valves can return to a normal operation (e.g., not stuck, not loaded condition, and the like) when the reservoir pressure elevates or the compressor is able to run again (e.g., in a reverse direction for a duration of time, in a forward direction after the reverse direction, among others).

[0035] If during the reversed direction sequence, a stall is detected (e.g., a stall during the reverse direction), the controller can reverse the motor to the forward direction to accelerate the compressor. For instance, the stall in the reverse direction can be detected as pistons move to a Top-Dead-Center (TDC) and the motor can be reversed to accelerate pistons past Bottom-Dead-Center (BDC) with a combination of motor torque and pneumatic force on the piston(s). For instance, the motor torque and pneumatic forces build enough momentum to overcome the compressed air forces.

[0036] The recovery of the compressor after rotation at a running speed is based upon at the following: unloader valve differential pressure reduces or even changes direction to the unload direction during high speed piston down-strokes which allows opening of an unloader valve when the CMV provides compressed control air to drive the unload mode; or CMV valves transition to an unloaded state as control air pressure is elevated by the loaded compressor cycle.

[0037] As discussed above, the term “loaded” refers a compressor mode where air is being compressed into the reservoir. The compressor depicted is one which utilizes spring return inlet and discharge valves for each cylinder in which the movement of these valves is caused by the differential pressure across them as opposed to a mechanical coupling to the compressor crank shaft. The subject disclosure may be

applicable to machines with either type of valve, but the spring return type will be illustrated here for the sake of brevity. For instance, an unloaded condition or unloaded compressor mode is illustrated in FIG. 4.

[0038] The detection component can be a stand-alone component (as depicted), incorporated into the controller component, or a combination thereof. The controller component can be a stand-alone component (as depicted), incorporated into the repair component, or a combination thereof.

[0039] FIG. 2 illustrates a detailed view of the compressor set forth in FIG. 1 above. The compressor includes three cylinders 210, 220, 230. Each cylinder contains a piston 218, 228, 238 that is coupled to a crankshaft 250 via connecting rods 240, 242, 244. The crankshaft is driven by the motor to cyclically pull the respective pistons to a Bottom-Dead-Center (BDC) and push the pistons to a Top-Dead-Center (TDC) to output charged air, which is delivered to the reservoir via air lines 280, 282, 284, 286. In this embodiment, the compressor is divided into two stages: a low pressure stage and a high pressure stage to produce charged air in a stepwise approach. The low pressure stage compresses air to a first pressure level which is further compressed by the high pressure stage to a second pressure level. In this example, the low pressure stage includes cylinders 220, 230 and the high pressure stage includes cylinder 210.

[0040] In operation, air from the ambient air intake is first drawn into the low pressure cylinders via intake valves 222, 232, which open and close within intake ports 223, 233. The ambient air is drawn in as the low pressure cylinders are pulled towards BDC and the intake valves 222, 232 separate from intake ports 223, 233 to allow air to enter each cylinder 220, 230. Once the pistons reach BDC, the intake valves 222, 232 close the intake ports 223, 233 to contain air within each cylinder. Subsequently, pistons 228, 238 are pushed toward TDC, thereby compressing the ambient air initially drawn into the cylinders. Once the cylinders have compressed the ambient air to a first pressure level, exhaust valves 224, 234 within exhaust ports 225, 235 are opened to release the low pressure air into low pressure lines 280, 282.

[0041] The air compressed to a first pressure level is routed to an intermediate stage reservoir 260. The intermediate stage reservoir 260 received air from one stage of a multistage compressor and provides the compressed air to a subsequent stage of a

multistage compressor. In an embodiment, the intermediate stage reservoir 260 is a tank or other volume connected between successive stages by air lines. In other embodiments, the air lines, such as low pressure lines 280, 282 provide sufficient volume to function as an intermediate stage reservoir without the need for a tank or other structure.

[0042] In an embodiment, the compressor system also includes an intercooler 264 that removes the heat of compression through a substantially constant pressure cooling process. One or more intercoolers may be provided along with one or more intercooler controllers 262. In some embodiments, the intercooler 264 is integrated with the intermediate stage reservoir 260. A decrease in the temperature of the compressed air increases the air density allowing a greater mass to be drawn into the high pressure stage increasing the efficiency of the compressor. The operation of the intercooler is controlled by the intercooler controller 262 to manage the cooling operation. In an embodiment, the intercooler controller 262 employs a thermostatic control through mechanical means such as via thermal expansion of metal. In a multistage compressor system having more than two stages, an intercooler may be provided at each intermediate stage.

[0043] The air at a first pressure level (e.g., low pressure air) is exhausted from the intercooler into low pressure air line 284 and subsequently drawn into the high pressure cylinder 210. More particularly, as piston 218 is pulled toward BDC, the intake valve 212 opens, thereby allowing the low pressure air to be drawn into the cylinder 210 via intake port 213. Once the piston 218 reaches BDC, the intake valve 212 closes to seal the low pressure air within the cylinder 210. The piston is then pushed upward thereby compressing the low pressure air into high pressure air. High pressure air is air at a second pressure level greater than the first pressure level, however the amount of compression will vary based upon the requirements of the application. As compression increases, the exhaust valve 214 is opened to allow the high pressure air to exhaust into high pressure line 286 via exhaust port 215. An aftercooler 270 cools the high pressure air to facilitate a greater density to be delivered to the reservoir via high pressure air line 288.

[0044] The above process is repeated cyclically as the crankshaft 250 rotates to provide high pressure air to the reservoir 180, which is monitored by the reservoir

pressure sensor 185. Once the reservoir reaches a particular pressure level (e.g., 140 psi), the compressor operation is discontinued.

[0045] In some embodiments, the compressor includes one or more valves configured to vent compressed air from intermediate stages of the compressor system. The unloader valves and/or relief valves may be operated after compressor operations are discontinued, or may be operated during compressor operations to relieve pressure in the compressor system. In an embodiment, an unloader valve 268 is provided in the intermediate stage reservoir 260 and configured to vent the low pressure compressed air from the intermediate stage reservoir, low pressure air lines 280, 282 and intercooler 264. Venting compressed air reduces stress on system components during periods when the compressor is not in use and may extend the life of the system. In another embodiment, the unloader valve 268 operates as a relief valve to limit the buildup of pressure in the intermediate stage reservoir 260. In yet another embodiment, intake valves 222, 232 operate as unloader valves for the cylinders 220, 230 allowing compressed air in the cylinders to vent back to the ambient air intake 114. In another embodiment, the system 200 can include relief valves such as breather valve 174, a relieve valve on the intercooler 264 (shown in FIG. 4), a relieve valve for air line 286, a rapid unloader valve on the intercooler 264 (shown in FIG. 4)

[0046] A compressor, such as the compressor illustrated in FIG. 2, operates to charge the reservoir 180 with compressed air or other gas. Once the compressor charges the reservoir to a determined pressure value the compressor operation is discontinued. In some embodiments, when compressor operations are discontinued, one or more unloader valves are opened to vent intermediate stages of the compressor to the atmosphere. The intake valves of the cylinders as well as unloader valves of the intermediate stage reservoirs may all operate as unloader valves to vent the cylinders of the compressor to the atmosphere. Once the unloader valves are actuated and the cylinders and intermediate stages of the compressor have been vented to the atmosphere the pressure within the reservoir is expected to remain constant as previously discussed.

[0047] As discussed above, the controller can be configured to employ at least one of a torque increase mode or a phase reverse mode or a combination thereof. This mode implementation by the controller can be based upon, but not limited to, the

detection component identifying at least one of a failure mode, a stall condition, a loaded start condition, a combination thereof, among others.

[0048] FIG. 3 illustrates a system 300 that controls a motor based upon a detection component for a compressor, wherein the control relates to the increase torque mode. The system 300 can include the detection component (e.g., detection can be embedded within the controller) that is configured to identify a stall condition for a reciprocating compressor based at least one of compressor speed, compressor motor current, compressor output, and/or reservoir pressure. The controller can be configured to manage an increase in torque (e.g., torque increase mode) based upon such detection. For instance, the increase in torque can be an increase in a pole mode for the motor, a line voltage increase, or a volt/hertz increase. The motor can include a number of poles 310 such as pole₁ to pole_N, where N is a positive integer. For instance, N can be an even positive integer. The motor can further include a pole mode that includes use of a set number of poles. In an embodiment, the motor can include a suitable number of pole modes in which each pole mode includes a specific amount of poles. For instance, a pole mode can include a first number of poles and a second pole mode can include a second number of poles. In such instance, the first number of poles can be less than the second number of poles. Based on the detection component, the motor can increase a number of poles such that the motor updates from the first pole mode to a second pole mode (e.g., where the second pole mode includes more poles than the first pole mode). For example, a motor can include a six (6) pole mode and a twelve (12) pole mode. Based upon detecting a stall condition, the controller can increase the pole mode from six (6) to twelve (12) for the motor to increase torque. This can allow for a degree of freedom for speed which proves useful in non-inverter applications where auxiliary AC voltage frequency is supplied by an auxiliary alternator driven by a variable speed engine. It is to be appreciated that the controller can utilize a combination of an increase of a number of poles, an increase in line voltage, and an increase of volt/hertz to increase starting torque FIG. 4 illustrates a system 400 that depicts a compressor in an unloaded condition. The system illustrates additional features and/or components that can be included in FIGS. 1, 2, and 3. The system includes a Control Mag Valve (CMV) 402, a Thermostatically Controlled Intercooler System (TCIS) bypass 404, a rapid unloader

valve 406, an unloader valve 408 for cylinder 230, an unloader valve 410 for cylinder 220, a relief valve 420, a relief valve 430, and relief valve 440 (e.g., substantially similar to breather valve 174 in FIG. 2).

[0049] Crankshaft can include a first end opposite a second end in which the first end is coupled to one or more connecting rods for each respective cylinder. The crankshaft, cylinders, and pistons are illustrated in BDC position based upon the location of the first end. BDC position is a location of the first end at approximately negative ninety degrees (-90 degrees) or 270 degrees. A TDC position is a location of the first end at approximately ninety degrees (90 degrees) or -270 degrees.

[0050] As discussed, the controller implements one or more modes based upon the detection component identifying a stall condition. For instance, failure modes for the compressor can result in a fully or partially loaded start condition. In an embodiment, the detection component can utilize suitable sensor(s) within the system to identify a loaded start condition. In FIGS. 5-8, examples of failures for stall conditions are described in which such stall conditions can be detected by the detection component and, in turn, utilized by the controller to employ at least one of the torque increase mode or the reverse direction mode. The below is solely for exemplary purposes and not to be limiting on the subject innovation.

[0051] A CMV stuck loaded (e.g., CMV 402 in FIG. 4) failure can relate to a CMV being stuck in the “loaded” position which closes all un-loader valves. The effect of the CMV stuck loaded failure is to trap air within each cylinder which will need to be compressed on the subsequent “start.” This amount of air mass and the pressure of the trapped air depend on the final position of the pistons and the reservoir pressure both when the compressor was stopped and after. The trapped air in the high pressure cylinder results in increased starting torque and may stall. This is illustrated in FIG. 5, wherein FIG. 5 illustrates a system 500 that depicts a compressor in a CMV stuck loaded failure.

[0052] A CMV stuck loaded failure and leakage on a high pressure cylinder discharge valve can be a failure. For instance, the high pressure cylinder discharge valve can be exhaust valve 214. This failure can be related to the CMV stuck in the loaded position which closes all unloader valves except the main reservoir air leaks back into the high pressure cylinder via a faulty exhaust valve. The effect of this

failure (e.g., leaking valve) can result in increased air mass and pressure in the High Pressure Cylinder. Larger leaks may cause the high pressure piston to move BDC. The trapped air in the High Pressure Cylinder results in increased starting torque and may stall. This is illustrated in FIG. 6, wherein FIG. 6 illustrates a system 600 that depicts a compressor in a CMV stuck loaded failure and leakage on a high pressure cylinder discharge valve. Turning to FIG. 7, a valve 700 that is a high pressure cylinder discharge valve is depicted. The valve 700 can be from a compressor and include a leak source 702 which relates to the a compressor for a CMV stuck loaded failure and leakage on a high pressure cylinder discharge valve failure.

[0053] A high pressure cylinder unloader valve stuck loaded failure can relate to the high pressure cylinder being not able to release to atmosphere. The effect of this failure is that trapped air in the high pressure cylinder results in increased starting torque and may stall. This is illustrated in FIG. 8, wherein FIG. 8 illustrates a system 800 that depicts a compressor in a high pressure cylinder unloader valve stuck failure in which unloader valve 268 is unable to release to atmosphere.

[0054] A high pressure cylinder unloader valve stuck loaded and leakage on the high pressure cylinder discharge valve can be a failure related to the high pressure cylinder not being able to release to atmosphere except the main reservoir leaks back into the main pressure cylinder. The effect of this failure is the discharge valve leak can result in increased air mass and pressure in the high pressure cylinder. Larger leaks may cause the high pressure piston to move to BDC. The trapped air in the high pressure cylinder results in increased starting torque and may stall.

[0055] A low pressure cylinder unloader valve stuck loaded can be a failure. This failure relates to a low pressure cylinder not being able to release to atmosphere. The effect of this failure is the trapped air in the low pressure cylinder results in increased starting torque and may stall.

[0056] Another failure can be leakage on the high pressure cylinder discharge valve. This failure can lead to starting issues if the CMV is at a point in time put in the loaded state even transiently. This can be caused by the fact that when the high pressure cylinder contains pressurized air, the unloader valve actuator may not have enough force capability to overcome the differential pressure across the inlet valve. This can lead to a latched unloader state of closed.

[0057] The controller and the detection component facilitate overcoming the above stall conditions and/or failures. Moreover, the above referenced failures are not to be limiting on the subject disclosure and a suitable combination or amount of failures related to a stall condition for a loaded start condition can be mitigated by the controller and the detection component.

[0058] FIG. 9 illustrates a reverse direction mode 900 in response to a stall condition of a compressor. As discussed above, the controller can employ a reverse direction mode based upon an identified stall condition from the detection component. The reverse direction mode 900 is illustrated in a series of images for a cylinder of a reciprocating compressor as described above. The reverse direction mode 900 depicts cylinder 210 but is to be appreciated that the depiction can apply to each cylinder of the compressor and the subject innovation is not limited to a single cylinder. The cylinder 210 includes the unloader valve 268 and is coupled to the crankshaft via the connecting rod. Once a stall condition is detected by the detection component, power can be removed and the cylinder can settle at Bottom-Dead-Center. Once detection of the cylinder being at BDC, power can be reversed (e.g., reverse direction of the motor) and compressed air can enter the cylinder.

[0059] Next, a reverse stall can be detected. As discussed, a reverse stall can be detected or the compressor can run in reverse. In FIG. 9, a reverse stall is detected. Upon detection of the reverse stall, the power is applied in the forward direction (e.g., forward power, not reversed power) and forward momentum is built (e.g., motor torque and/or pneumatic force). In an embodiment, the torque increase mode can be employed as well to increase torque and momentum. This forward momentum built and applied increased torque (e.g., if the increase torque mode is employed) can result in a start of the compressor.

[0060] The aforementioned systems, components, (e.g., detection component, controller, among others), and the like have been described with respect to interaction between several components and/or elements. It should be appreciated that such devices and elements can include those elements or sub-elements specified therein, some of the specified elements or sub-elements, and/or additional elements. Further yet, one or more elements and/or sub-elements may be combined into a single component to provide aggregate functionality. The elements may also interact with

one or more other elements not specifically described herein. These components or elements may be software, hardware, or a combination.

[0061] In view of the exemplary devices and elements described supra, methodologies that may be implemented in accordance with the disclosed subject matter will be better appreciated with reference to the flow charts of FIGS. 10-12. The methodologies are shown and described as a series of blocks, the claimed subject matter is not limited by the order of the blocks, as some blocks may occur in different orders and/or concurrently with other blocks from what is depicted and described herein. Moreover, not all illustrated blocks may be required to implement the methods described hereinafter. The methodologies can be implemented by a component or a portion of a component that includes at least a processor, a memory, and an instruction stored on the memory for the processor to execute.

[0062] FIG. 10 illustrates a flow chart of a method 1000 for detecting a stall condition related to a force from compressed air being compressed into a reservoir of the reciprocating compressor. At reference numeral 1010, a stall condition can be detected for a reciprocating compressor based on measured speed, motor current, or air pressure.. For instance, the stall condition can be detected based on a a force from compressed air being compressed into a reservoir of the reciprocating compressor, wherein a detection component can be used to detect such force. At reference numeral 1020, a portion of power from a motor of the reciprocating compressor can be removed. At reference numeral 1030, a phase sequence of the motor can be reversed to force a recompression of a piston of the reciprocating compressor. At reference numeral 1040, at least one of a reverse stall or a start of the reciprocating compressor can be detected while in a reverse direction as the piston moves to a Top-Dead-Center (TDC) position.

[0063] FIG. 11 illustrates a flow chart of a method 1100 for increasing torque for a compressor motor in response to a detected stall condition related to a force from compressed air being compressed into a reservoir of the reciprocating compressor. At reference numeral 1110, a stall condition can be detected for a reciprocating compressor based on a force from compressed air being compressed into a reservoir of the reciprocating compressor. At reference numeral 1120, a torque to start the motor of the compressor can be increased with at least one of a pole switching, a line

voltage increase, or a voltz/hertz increase. At reference numeral 1130, the torque can be increased with a selection from a first pole mode to a second pole mode, wherein the first pole mode includes a first number of poles that is less than a second number of poles for a second pole mode.

[0064] FIG. 12 illustrates a flow chart of a method 1200 for increasing torque for a compressor motor and reversing a phase sequence of the motor in response to a detected stall condition related to a force from compressed air being compressed into a reservoir of the reciprocating compressor. At reference numeral 1210, a stall condition for a reciprocating compressor can be detected based on a force from compressed air being compressed into a reservoir of the reciprocating compressor. At reference numeral 1220, a portion of power can be removed from a motor of the reciprocating compressor. At reference numeral 1230, a phase sequence to the motor can be reversed which forces a recompression of a piston of the reciprocating compressor. At reference numeral 1240, at least one of a reverse stall or a start of the reciprocating compressor can be detected while in a reverse direction as the piston moves to a Top-Dead-Center (TDC) position. At reference numeral 1250, a torque to start the engine of the reciprocating bidirectional compressor can be increased by selecting a number of poles used by the motor from a first number to a second number, wherein the second number is greater than the first number.

[0065] In an embodiment, the method includes reversing a phase direction of the motor to accelerate the piston past a Bottom-Dead-Center (BDC) position based on the detected reverse stall. In such embodiment, the method further includes accelerating the compressor past the BDC with at least one of a torque of the motor or a pneumatic force on the piston to overcome the force. In an embodiment, the method can include driving the compressor in the reverse direction for a duration of time based on the detection of the start of the compressor. In another embodiment, the method can include reversing a phase direction of the motor after the start of the compressor for a duration of time.

[0066] In still another embodiment, the method includes returning a stuck loaded control magnet valve (CMV) or an un-loader valve based on the start of the compressor. In still another embodiment, the method includes returning a stuck

loaded control magnet valve (CMV) or an un-loader valve based on elevation of a pressure of the reservoir due to the start of the compressor.

[0067] In an embodiment of the method, the stall condition can be based on at least one of a control magnet valve stuck failure, a leakage on a high pressure cylinder discharge valve of the compressor, a high pressure cylinder un-loader valve stuck failure, or a low pressure cylinder un-loader valve stuck failure. In still another embodiment, the method includes increasing a torque to start the motor of the compressor with at least one of a pole switching, a line voltage increase, or a volt/hertz increase.

[0068] In the embodiment of the method, the torque used to start the motor can be increased in a forward direction of the piston or the reverse direction of the piston. In the embodiment of the method, the torque is increased with a selection of a first pole mode to a second pole mode, wherein the first pole mode includes a first number of poles and the second pole mode includes a second number of poles in which the second number of poles is greater than the first number of poles.

[0069] In an embodiment, a vehicle can be provided with a detector component and a controller as discussed above. Also, the detector may be embedded within the controller component. The vehicle can include an engine in which a compressor can be operatively connected to the engine, wherein the compressor includes a reservoir configured to store compressed air. The controller can provide at least one of a removal power from the motor of the compressor, a reversal a phase sequence of the motor to force a recompression of a piston of the compressor, and a detection of at least one of a reverse stall or a start of the compressor while in a reverse direction as the piston moves to a Top-Dead-Center (TDC) position. In the embodiment, the compressor is a reciprocating compressor with a bi-directional drive system that drives a piston in a forward direction and the reverse direction.

[0070] In an embodiment, the controller is configured to reverse a phase direction of the motor to accelerate the piston past a Bottom-Dead-Center (BDC) position based on the detected reverse stall and accelerate the compressor past the BDC position with at least one of a torque of the motor or a pneumatic force on the piston to overcome the force.

[0071] In an embodiment of the subject disclosure, the controller can be further configured to control at least one of the following: a drive of the compressor in the reverse direction for a duration of time based on the detection of the start of the compressor; or a reversal of a phase direction of the motor after the start of the compressor for a duration of time. In an embodiment, the controller can be further configured to increase a torque to start the engine of the compressor by selecting a number of poles used by the motor from a first number to a second number, wherein the second number is greater than the first number. In the embodiment, the controller can be configured to control an increase to at least one of a line voltage or a volt/hertz to change a torque for an engine start of the compressor.

[0072] In an embodiment, a system can be provided that includes means for increasing a torque to start the engine of the reciprocating bidirectional compressor by selecting a number of poles used by the motor from a first number to a second number, wherein the second number is greater than the first number.

[0073] In an embodiment, a method is provided to accommodate a failure to start a reciprocating air compressor due to a high starting torque associated with wear or failure of a component or system that includes the steps of: detecting a stall condition for a reciprocating compressor based on at least one of a compressor speed, a motor current, or a measured pressure signal; and increasing a torque to start the motor of the compressor with at least one of a pole switching, a line voltage increase, or a volt/hertz increase. In the embodiment, the torque to start the motor is increased in at least one of a forward direction of a piston of the motor or a reverse direction of the piston of the motor. In the embodiment, the torque is increased with a selection of a first pole mode to a second pole mode.

[0074] In the embodiment, the first pole mode includes a first number of poles and the second pole mode includes a second number of poles in which the second number of poles is greater than the first number of poles. In the embodiment, the method can respond to a stall during a compressor start sequence by increasing the line voltage to above-normal levels to facilitate extra starting torque for the compressor. In the embodiment, the method can respond to a stall during a compressor start sequence by increasing the motor flux to above-normal levels to facilitate providing extra starting torque for the compressor. In the embodiment, after

a successful re-start at increase torque level, the motor control is returned to normal except the compressor motor run duration is extended in order to avoid troubled re-starts. In the embodiment, the method can include regulating reservoir air pressure using a controllable loading valve to load and unloading the compressor while it maintains rotation. In the embodiment, the method can include regulating reservoir air pressure using a hardware relief valve.

[0075] In an embodiment, a method can be provided to accommodate a failure to start a reciprocating air compressor due to a high starting torque associated with wear or failure of a component or system that includes the steps of: detecting a stall condition for a compressor based on at least one of a compressor speed, a motor current, or a measured pressure signal; and reversing the compressor rotation transiently to accommodate the failure. In the embodiment, a reverse rotation is driven by reversing a phase sequence to a three (3) phase induction motor driving the compressor. In the embodiment, an induction motor is powered by a variable frequency inverter drive. In the embodiment, a reverse rotation is limited to a position from which momentum is obtained on a subsequent forward restart. In the embodiment, if during reverse rotation, the compressor successfully starts in a reverse direction, this rotation is maintained if the compressor can pump air in either direction. In the embodiment, if during reverse rotation, the compressor successfully starts in a reverse direction, this rotation is maintained only for a short period of time after which the compressor is stopped and restarted in a forward direction.

[0076] In an embodiment, a system can be provided that includes means for detecting a stall condition for a reciprocating bidirectional compressor based on a force from compressed air being compressed into a reservoir of the reciprocating bidirectional compressor, wherein the means for detecting can be the detection component, the controller component, a sensor, a component, or a combination thereof. The system can include means for removing power from a motor of the reciprocating bidirectional compressor, wherein the means for removing can be the controller, the motor, the compressor, a component, among others. The system can include means for reversing a phase sequence to the motor to force a recompression of a piston of the reciprocating bidirectional compressor, wherein the means for reversing can be the controller component, the compressor, the motor, a

component, among others. The system can include means for detecting at least one of a reverse stall or a start of the reciprocating bidirectional compressor while in a reverse direction as the piston moves to a Top-Dead-Center (TDC) position, wherein the means for detecting is the detector component, a sensor, a compressor, a controller component, a component, among others.

[0077] In the specification and claims, reference will be made to a number of terms that have the following meanings. The singular forms “a”, “an” and “the” include plural referents unless the context clearly dictates otherwise. Approximating language, as used herein throughout the specification and claims, may be applied to modify a quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term such as “about” is not to be limited to the precise value specified. In some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Moreover, unless specifically stated otherwise, a use of the terms “first,” “second,” etc., do not denote an order or importance, but rather the terms “first,” “second,” etc., are used to distinguish one element from another.

[0078] As used herein, the terms “may” and “may be” indicate a possibility of an occurrence within a set of circumstances; a possession of a specified property, characteristic or function; and/or qualify another verb by expressing one or more of an ability, capability, or possibility associated with the qualified verb. Accordingly, usage of “may” and “may be” indicates that a modified term is apparently appropriate, capable, or suitable for an indicated capacity, function, or usage, while taking into account that in some circumstances the modified term may sometimes not be appropriate, capable, or suitable. For example, in some circumstances an event or capacity can be expected, while in other circumstances the event or capacity cannot occur – this distinction is captured by the terms “may” and “may be.”

[0079] This written description uses examples to disclose the invention, including the best mode, and also to enable one of ordinary skill in the art to practice the invention, including making and using a devices or systems and performing incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to one of ordinary skill in the art. Such

other examples are intended to be within the scope of the claims if they have structural elements that do not differentiate from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A method, comprising:
removing power from or reducing power to a motor coupled to a reciprocating compressor;
reversing a phase sequence of the motor to force a recompression of a piston of the reciprocating compressor; and
detecting at least one of a reverse stall or a start of the reciprocating compressor while in a reverse direction.
2. The method of claim 1, further comprising reversing a torque direction of the motor to accelerate the piston past a Bottom-Dead-Center (BDC) position based on the detected reverse stall.
3. The method of claim 2, further comprising accelerating the compressor past the BDC position with at least one of a torque of the motor or a pneumatic force on the piston to overcome a force from compressed air being compressed into a reservoir of the reciprocating compressor.
4. The method of claim 1, further comprising driving the compressor in the reverse direction for a duration of time based on the detection of the start of the compressor.
5. The method of claim 1, further comprising reversing a phase direction of the motor after the start of the compressor for a duration of time.
6. The method of claim 5, further comprising returning a stuck loaded control magnet valve (CMV) or an un-loader valve based on the start of the compressor.
7. The method of claim 5, further comprising returning a stuck loaded control magnet valve (CMV) or an un-loader valve based on elevation of a pressure of a reservoir due to the start of the compressor.

8. The method of claim 1, further comprising detecting a stall condition to initiate the reversing of the phase sequence, wherein the stall condition is based on at least one of a control magnet valve stuck failure, a leakage on a high pressure cylinder discharge valve of the compressor, a high pressure cylinder un-loader valve stuck failure, or a low pressure cylinder un-loader valve stuck failure.

9. The method of claim 1, further comprising increasing a torque to start the motor of the compressor with at least one of a pole switching, a line voltage increase, or a volt/hertz increase.

10. The method of claim 9, further comprising increasing the torque to start the motor in at least one of a forward direction of the piston or the reverse direction of the piston.

11. The method of claim 9, further comprising increasing the torque with a selection of a first pole mode to a second pole mode.

12. The method of claim 11, wherein the first pole mode includes a first number of poles and the second pole mode includes a second number of poles in which the second number of poles is greater than the first number of poles, and further comprising detecting a stall condition based on at least one of a compressor speed, a motor current, or a measured pressure signal.

13. A system, comprising:
- a compressor operatively connected to an electric motor, wherein the compressor includes a reservoir configured to store compressed air; and
 - a detector component that is configured to detect a stall condition of the compressor;
 - a controller that is configured to control the following based on the detected stall condition:
 - removal of power from the motor of the compressor;
 - reversal of a phase sequence of the motor to force a recompression of a piston of the compressor; and
 - detection of at least one of a reverse stall or a start of the compressor while in a reverse direction as the piston moves to a Top-Dead-Center (TDC) position.
14. The system of claim 13, wherein the compressor is a reciprocating compressor with a bi-directional drive system that drives the piston in a forward direction and the reverse direction.
15. The system of claim 13, wherein the controller is further configured to:
- control reversal of a phase direction of the motor to accelerate the piston past a Bottom-Dead-Center (BDC) position based on the detected reverse stall; and
 - control acceleration of the compressor past the BDC position with at least one of a torque of the motor or a pneumatic force on the piston to overcome a force from compressed air being compressed into a reservoir of the reciprocating compressor.
16. The system of claim 13, wherein the controller is further configured to control at least one of the following:
- a drive of the compressor in the reverse direction for a first duration of time based on the detection of the start of the compressor; or
 - a reversal of a phase direction of the motor after the start of the compressor for a second duration of time.

17. The system of claim 13, wherein the controller is further configured to increase a torque to start the motor of the compressor by selecting a number of poles used by the motor from a first number to a second number, wherein the second number is greater than the first number.

18. The system of claim 13, wherein the controller is further configured to control an increase to at least one of a line voltage or a volt/hertz to change a torque for an engine start of the compressor.

19. A system, comprising:

means for detecting a stall condition for a reciprocating bidirectional compressor based on a force from compressed air being compressed into a reservoir of the reciprocating bidirectional compressor;

means for removing power from a motor of the reciprocating bidirectional compressor;

means for reversing a phase sequence to the motor to force a recompression of a piston of the reciprocating bidirectional compressor; and

means for detecting at least one of a reverse stall or a start of the reciprocating bidirectional compressor while in a reverse direction as the piston moves to a Top-Dead-Center (TDC) position.

20. A method to accommodate a failure to start a reciprocating air compressor due to a high starting torque associated with wear or failure of a component or system, comprising:

detecting a stall condition for a reciprocating compressor based on at least one of a compressor speed, a motor current, or a measured pressure signal; and

increasing a torque to start the motor of the compressor with at least one of a pole switching, a line voltage increase, or a volt/hertz increase.

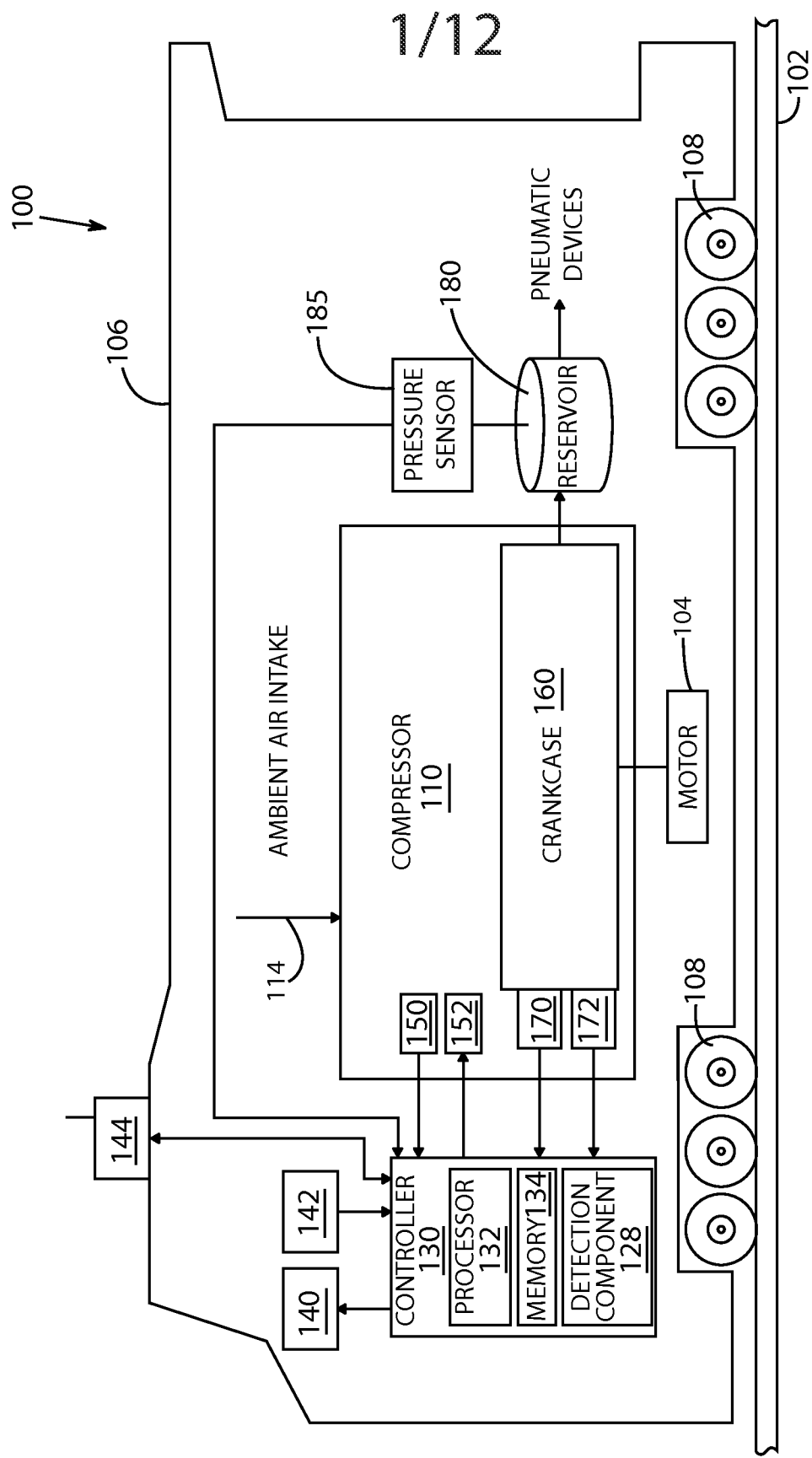


FIG.1

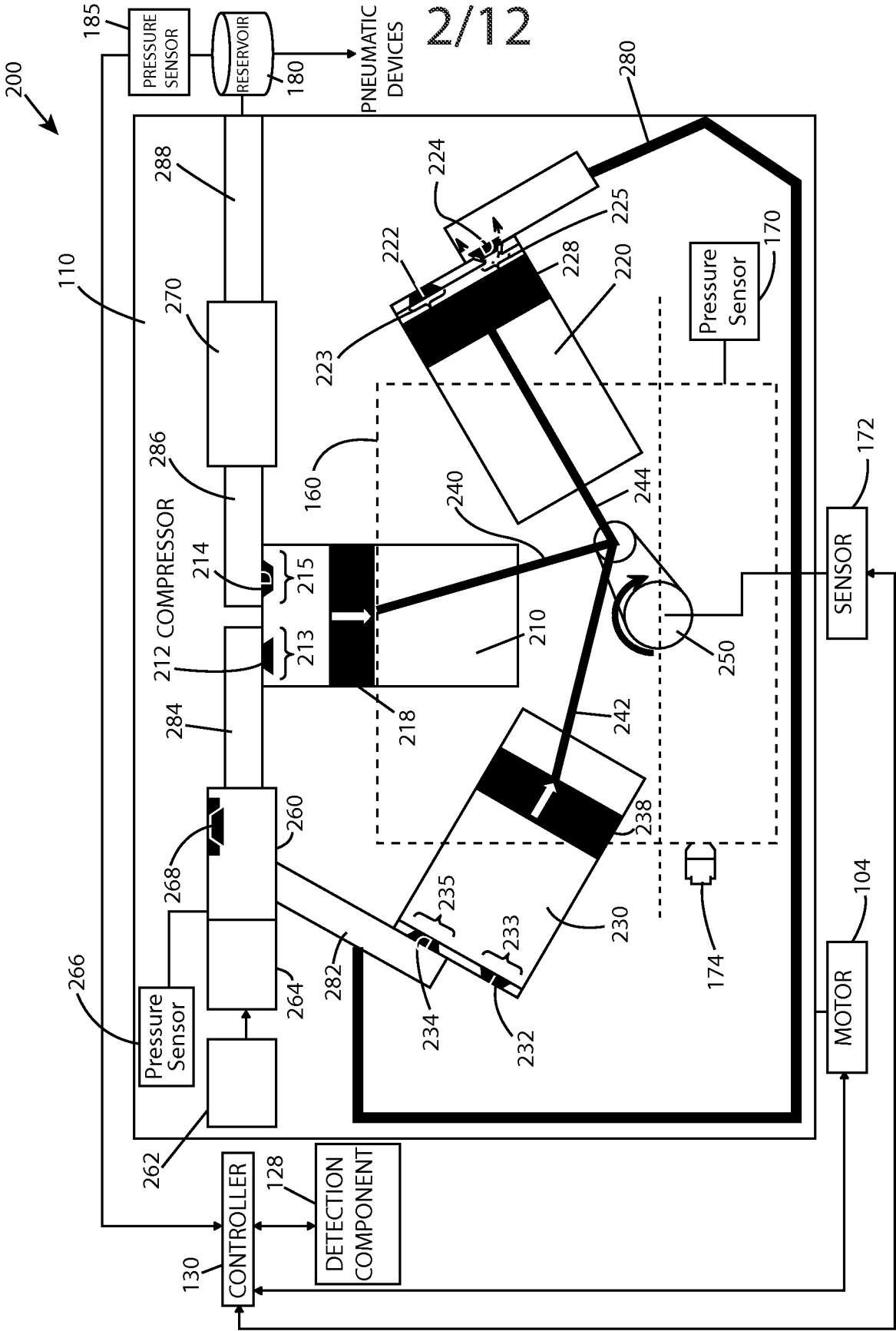


FIG.2

3/12

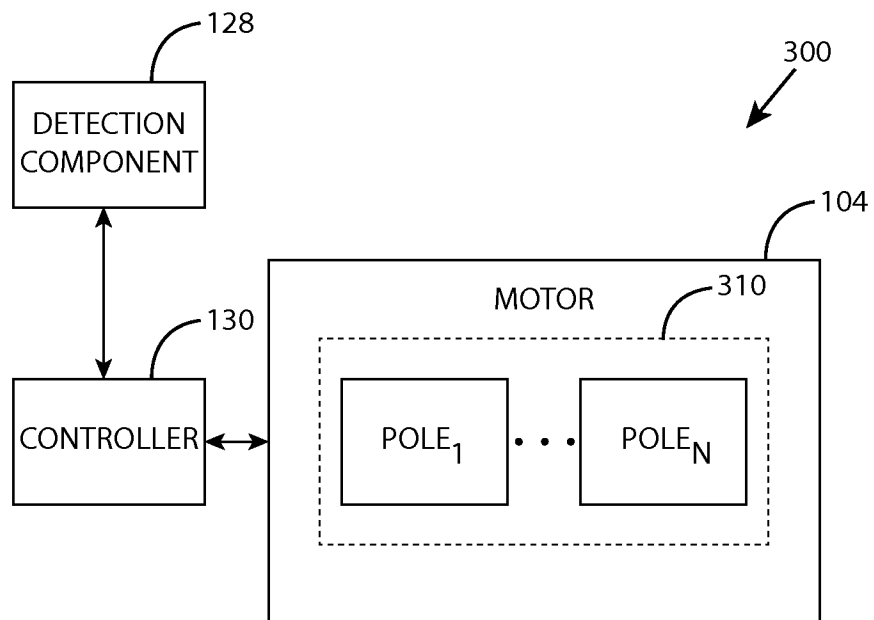


FIG. 3

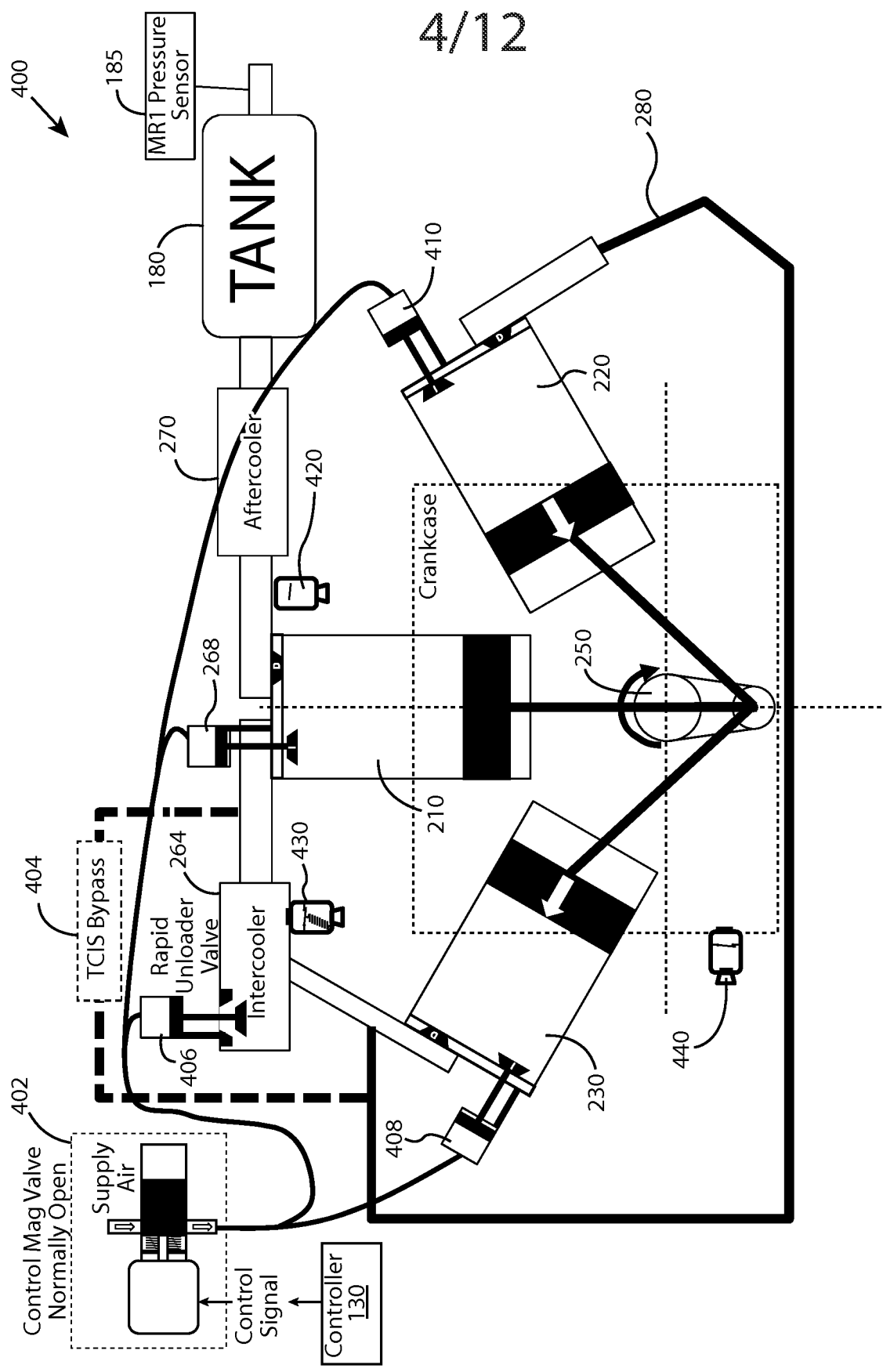


FIG.4

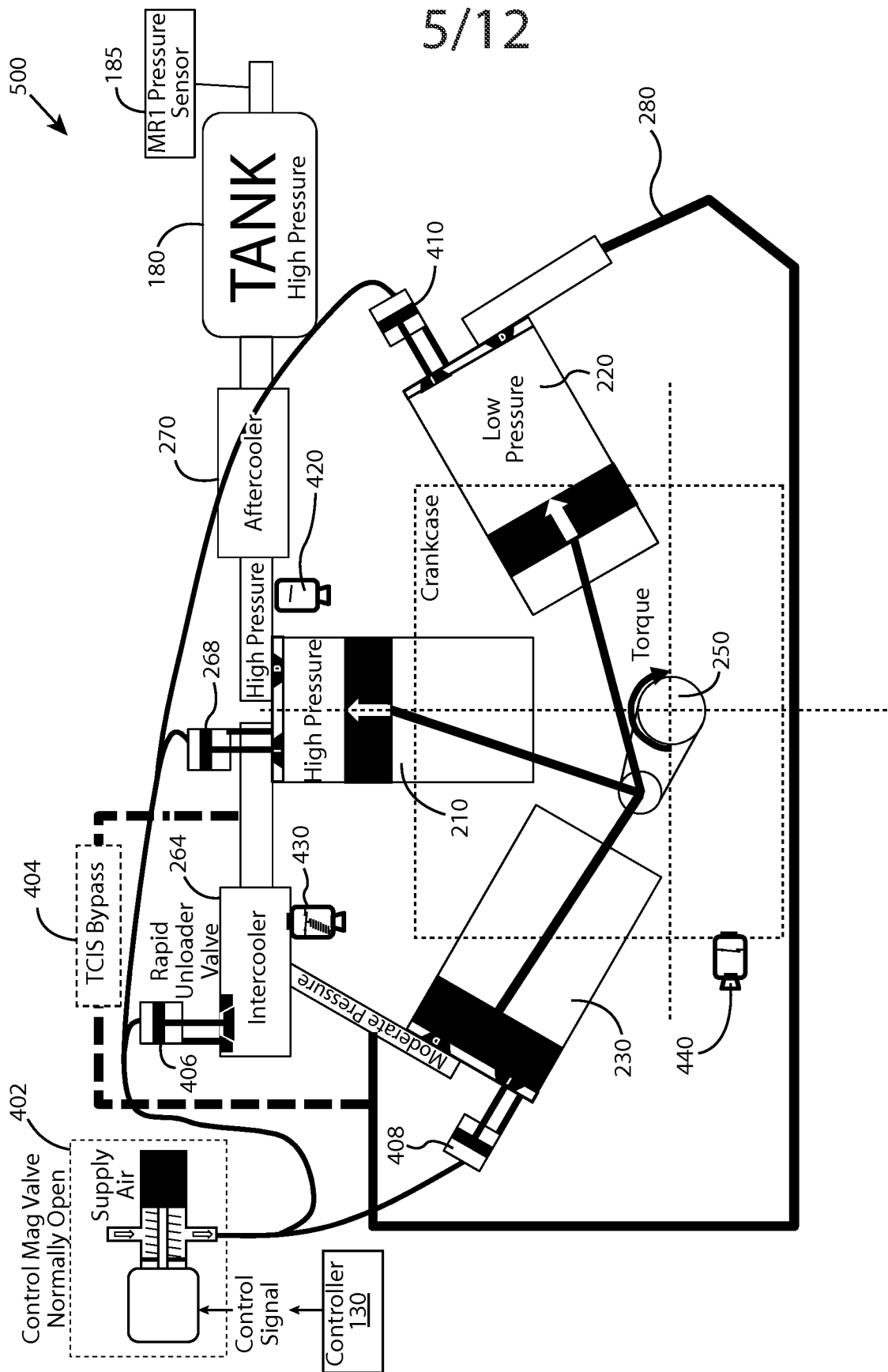


FIG. 5

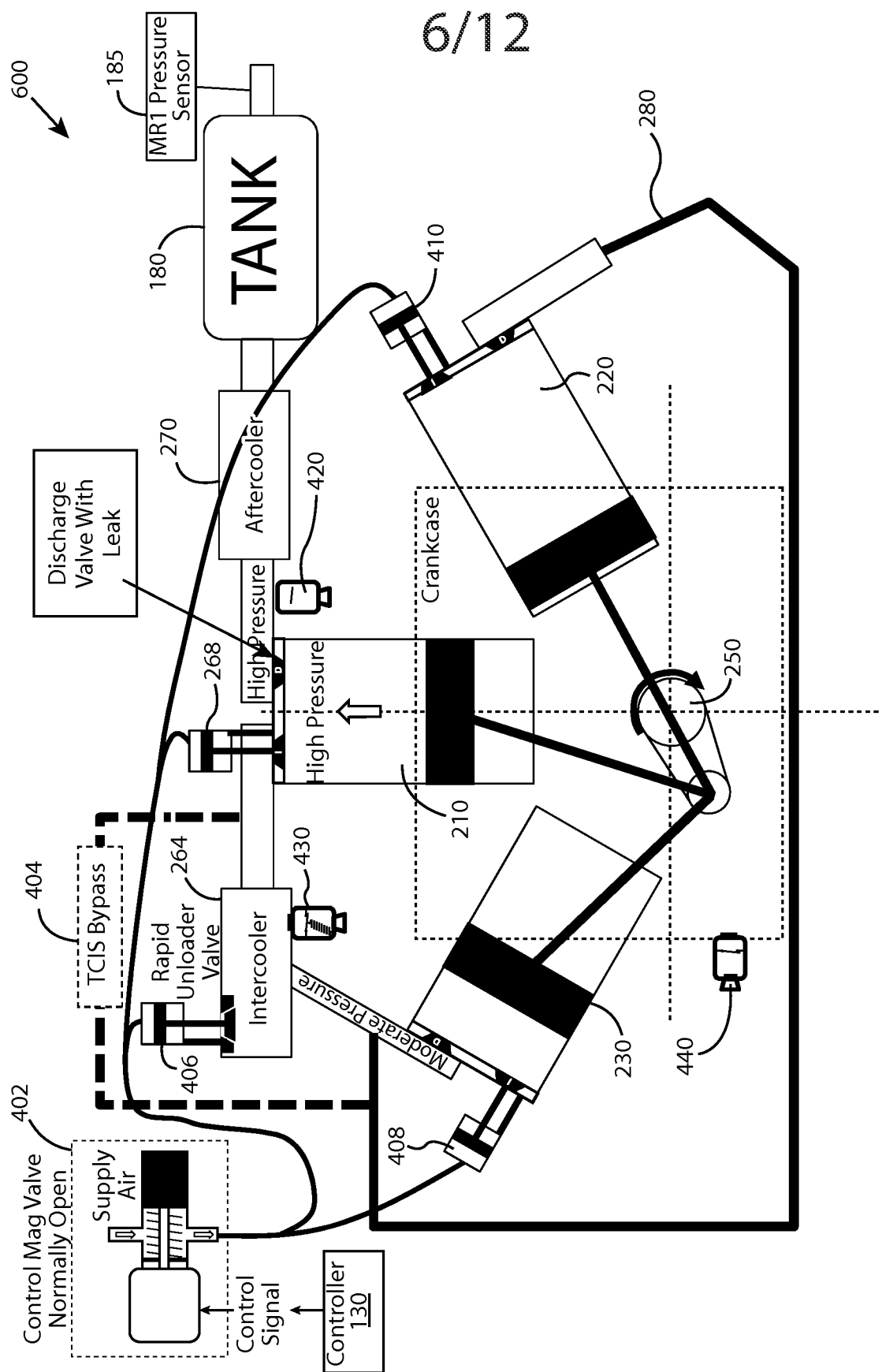


FIG.6

7/12

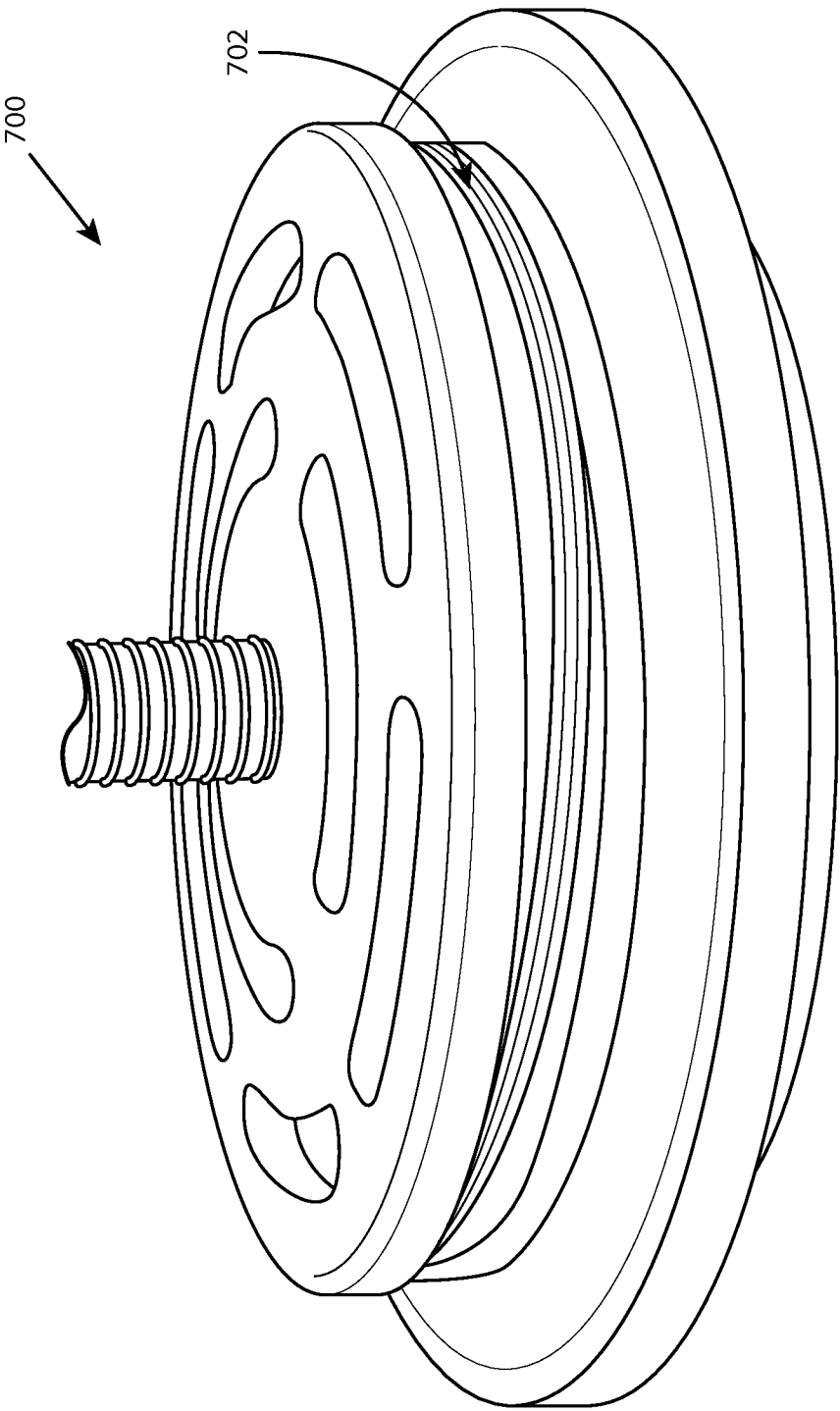


FIG. 7

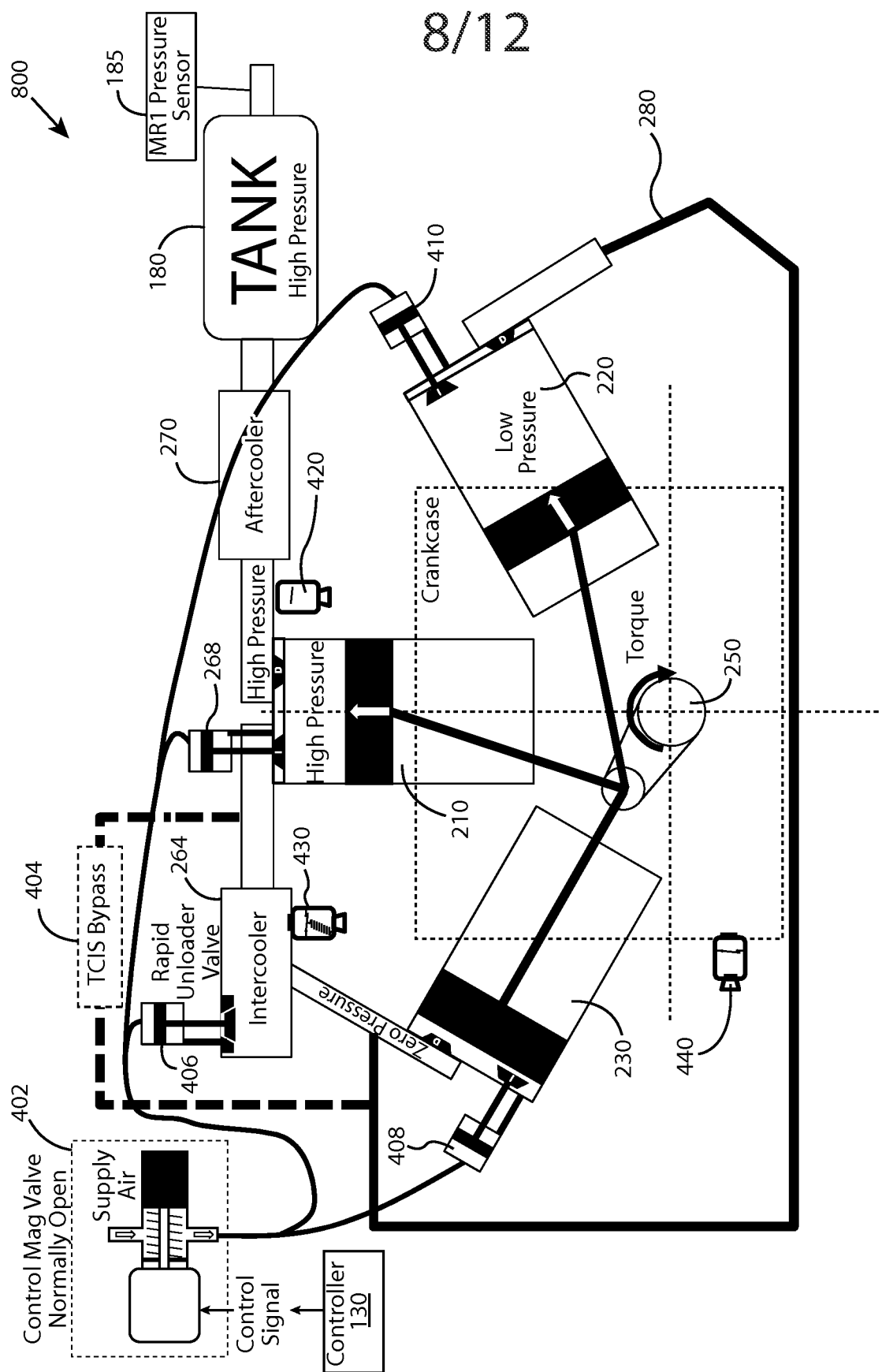


FIG.8

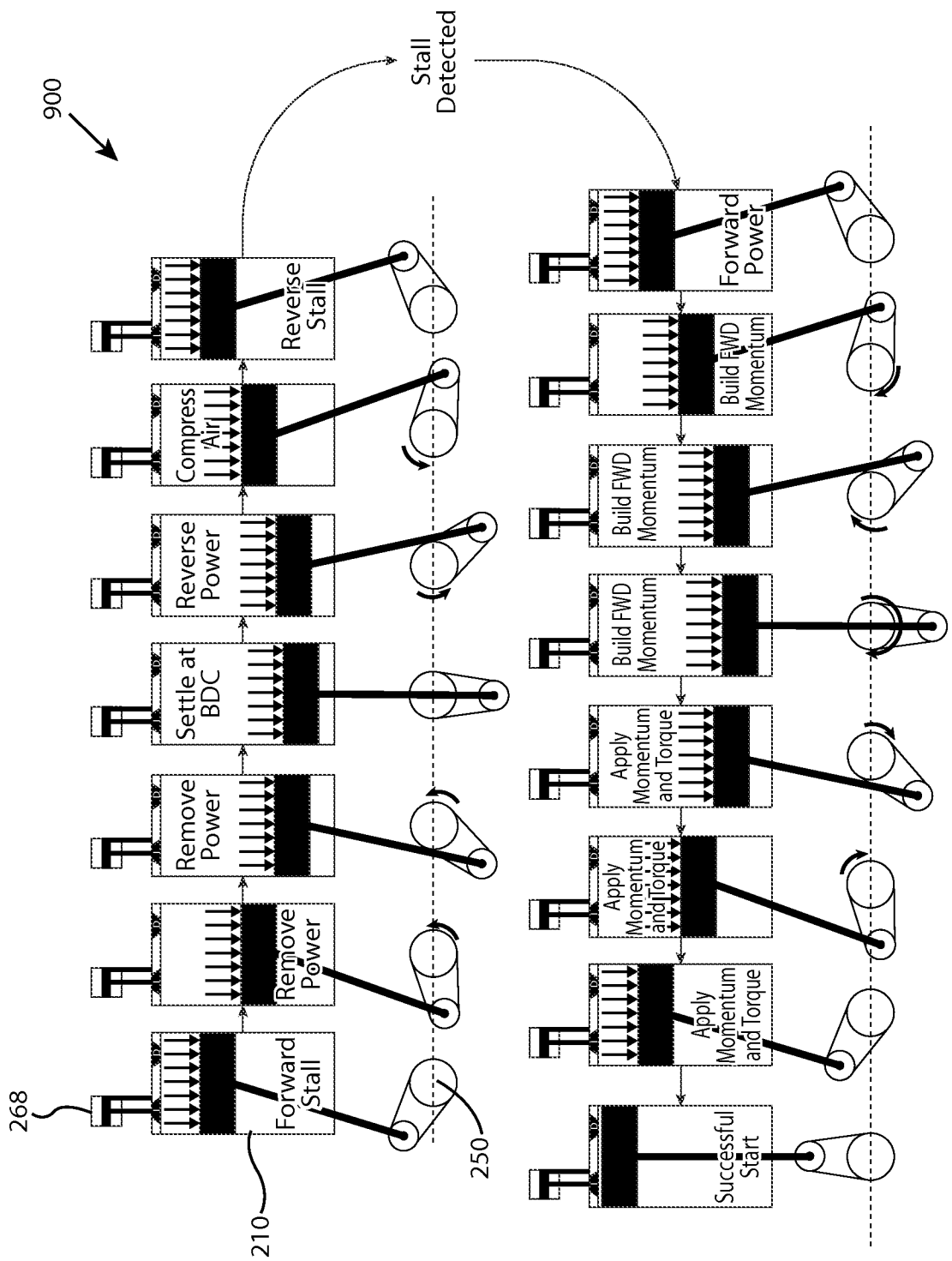


FIG.9

10/12

1000

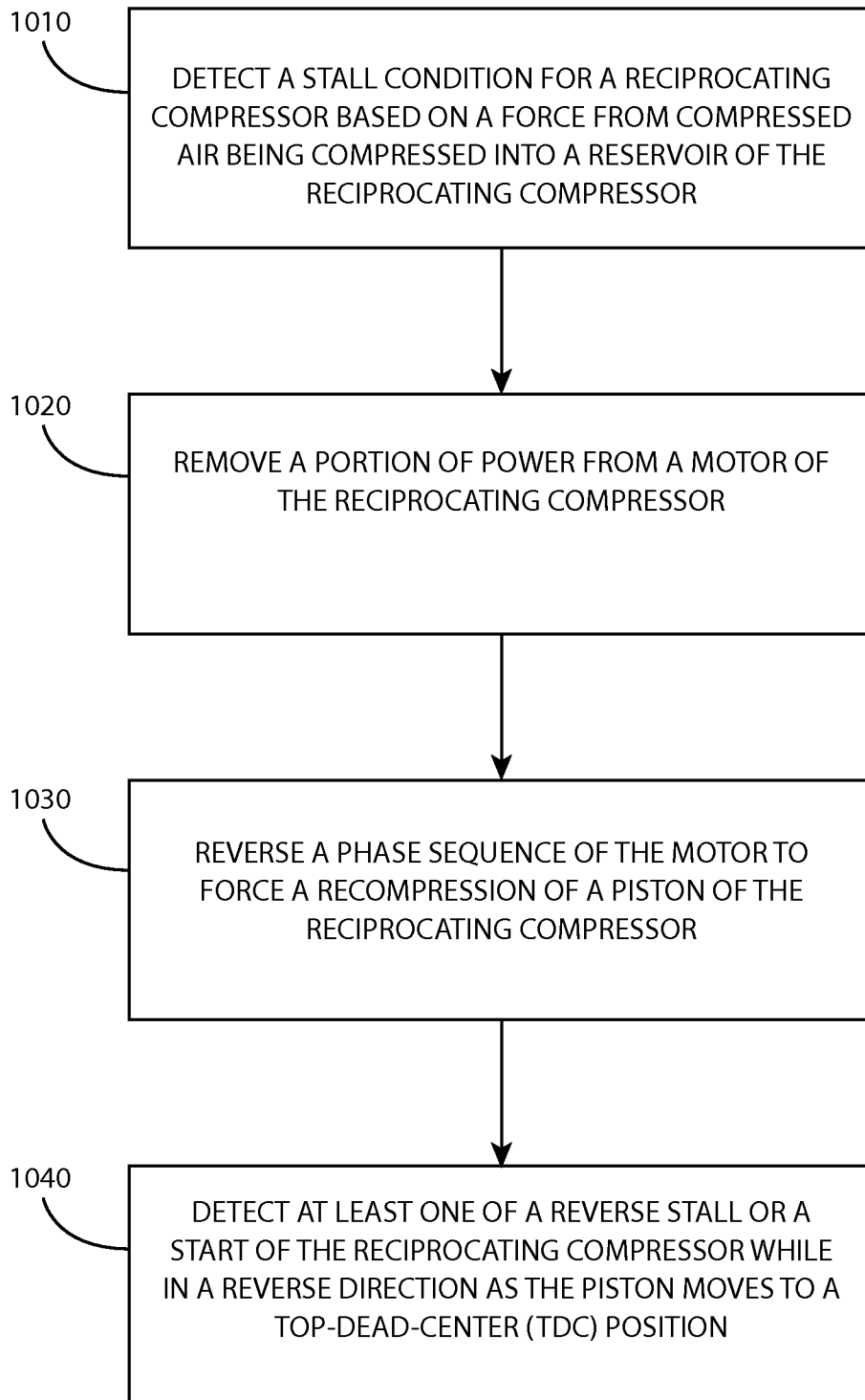


FIG. 10

11/12

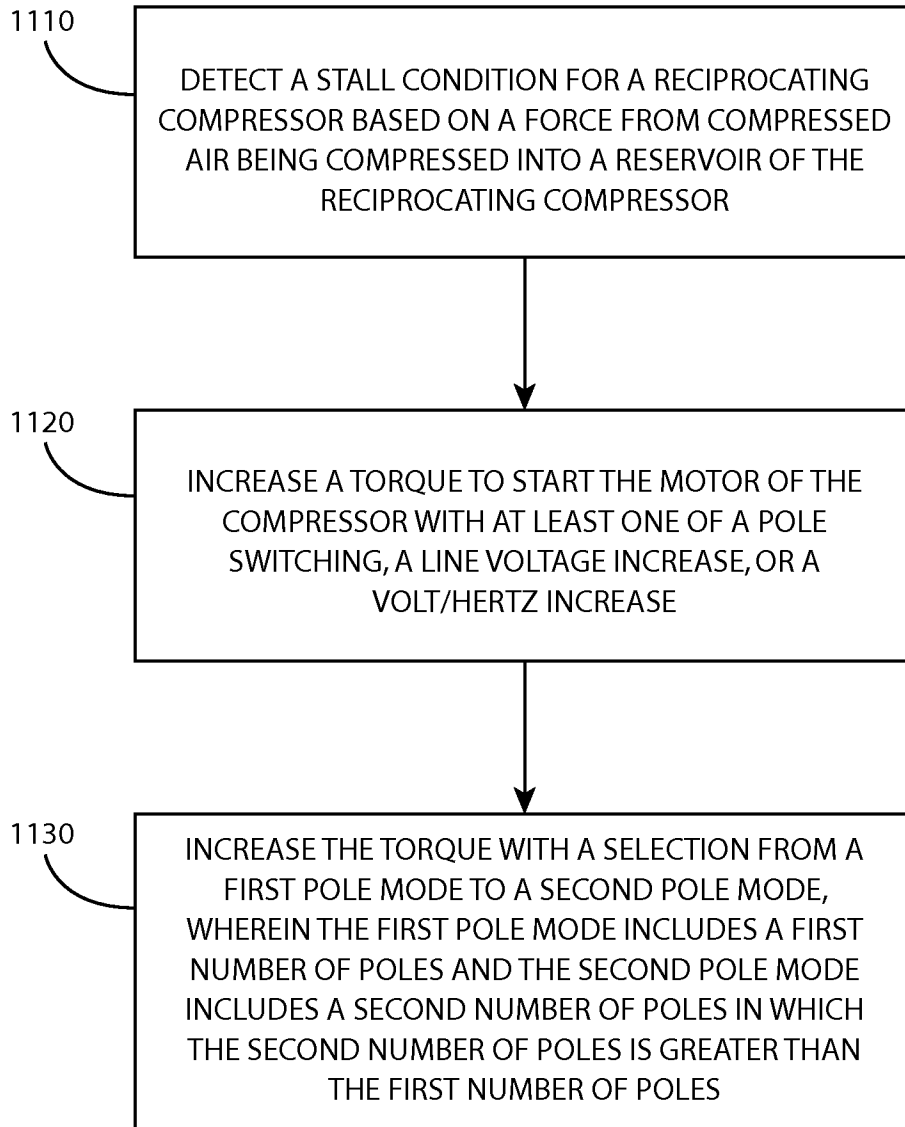
1100


FIG. 11

12/12

1200

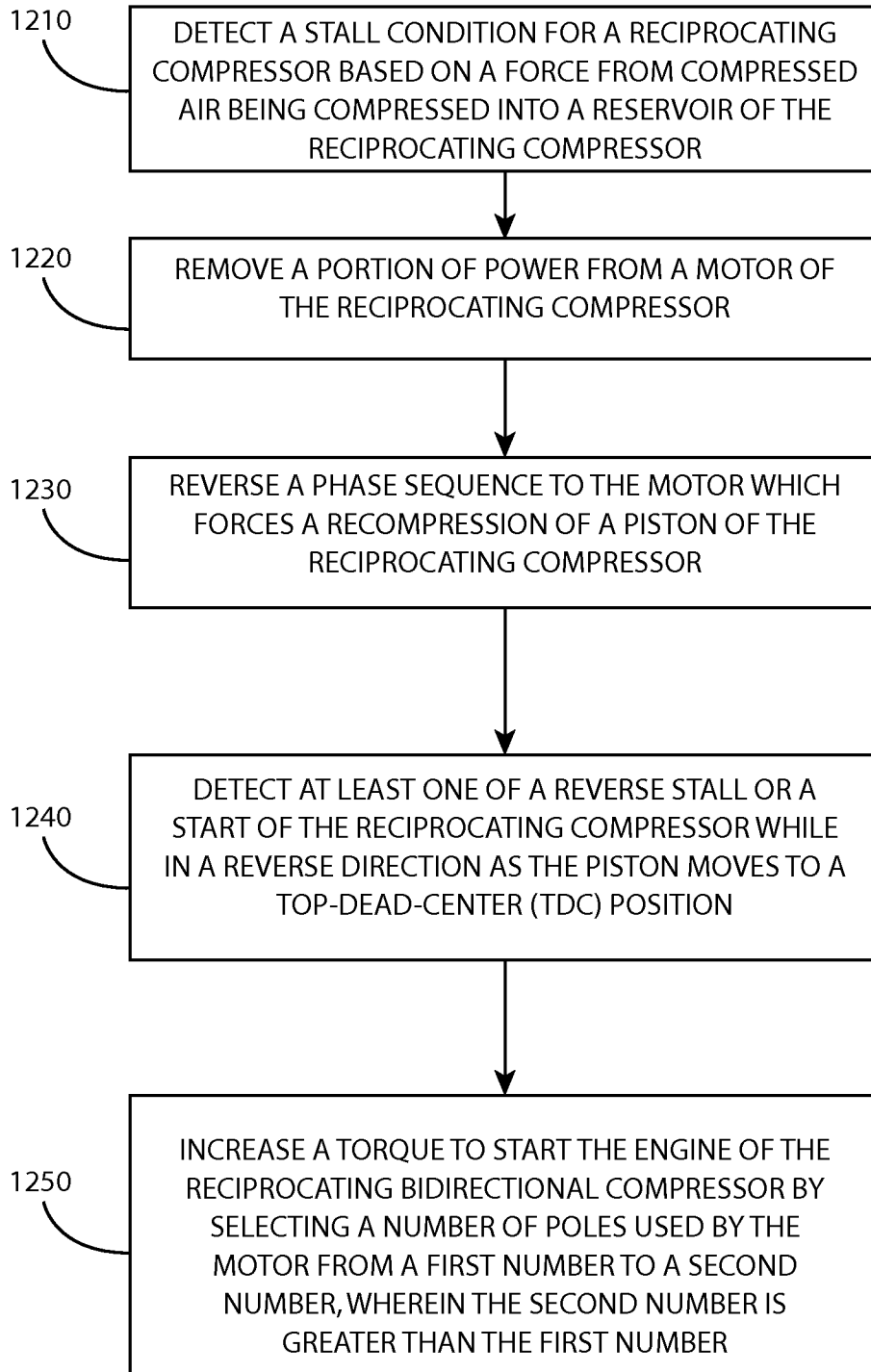


FIG. 12