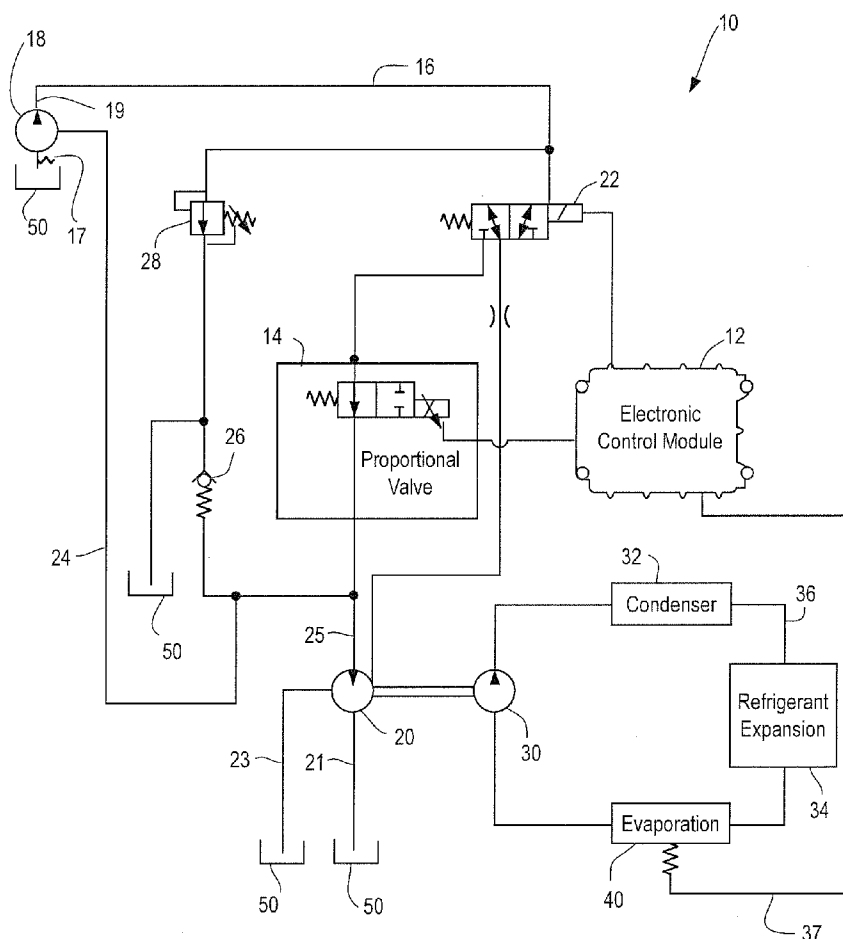




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A modular HVAC unit may incorporate a hydraulically powered refrigerant compressor to more efficiently provide air conditioning to an operator cab of a work machine. The refrigerant compressor may be fluidly powered by a hydraulic fluid motor fluidly coupled to and driven by a variable displacement pump. An electronic controller may be configured to vary hydraulic pump flow rates to the motor via use of a proportioning control valve to maintain a desired evaporator performance temperature. The control valve may be configured to stop the HVAC unit whenever a backup system may be used, when a discharge is to be prevented, and/or when operator air-conditioning is not desired. The controller may monitor evaporator performance via a fin temperature sensor, and may send appropriate signals to the control valve for modulating hydraulic flows through the motor. The arrangement may provide a significant increase in the life and performance of the compressor.



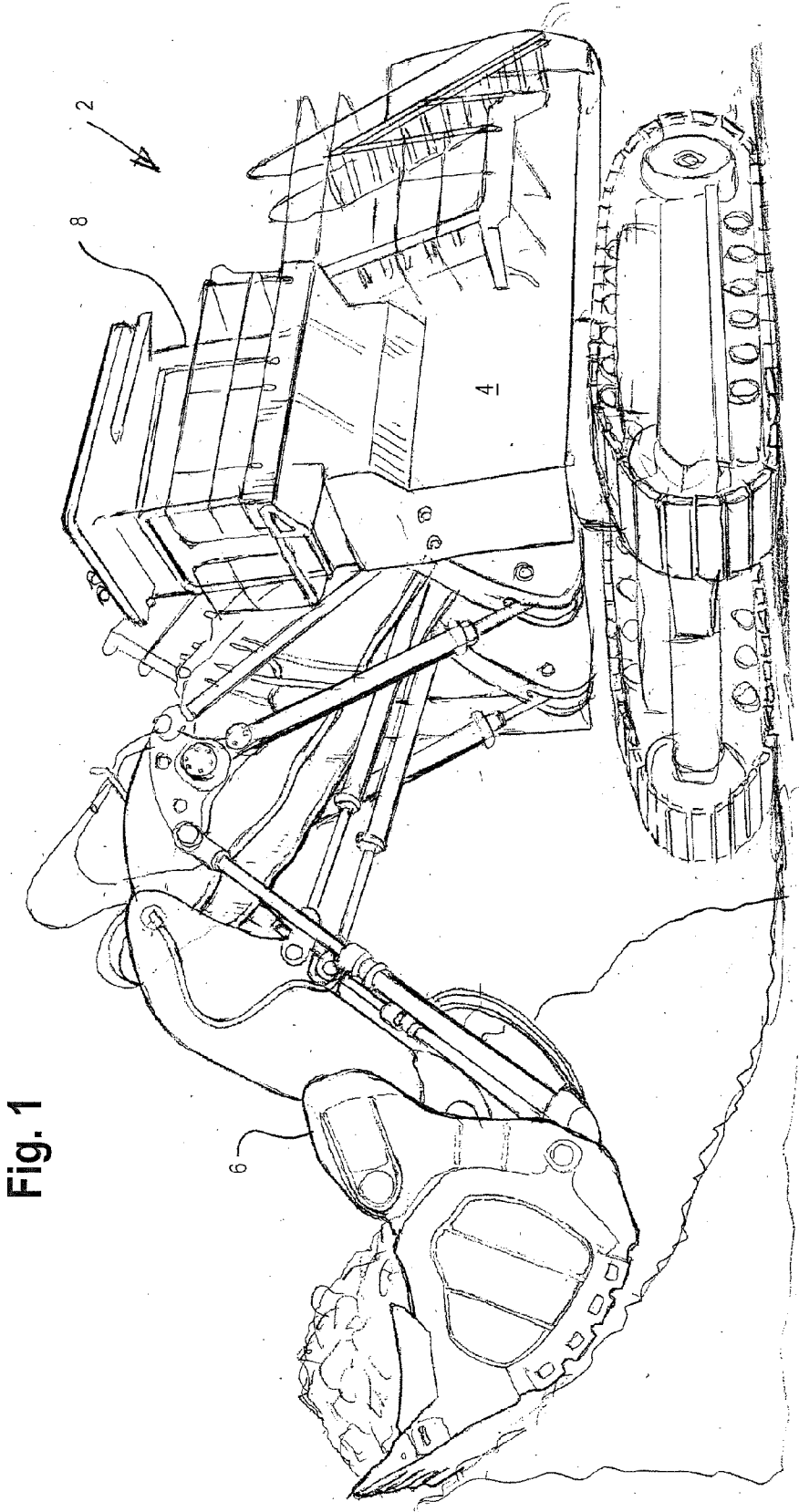


Fig. 1

Fig. 2

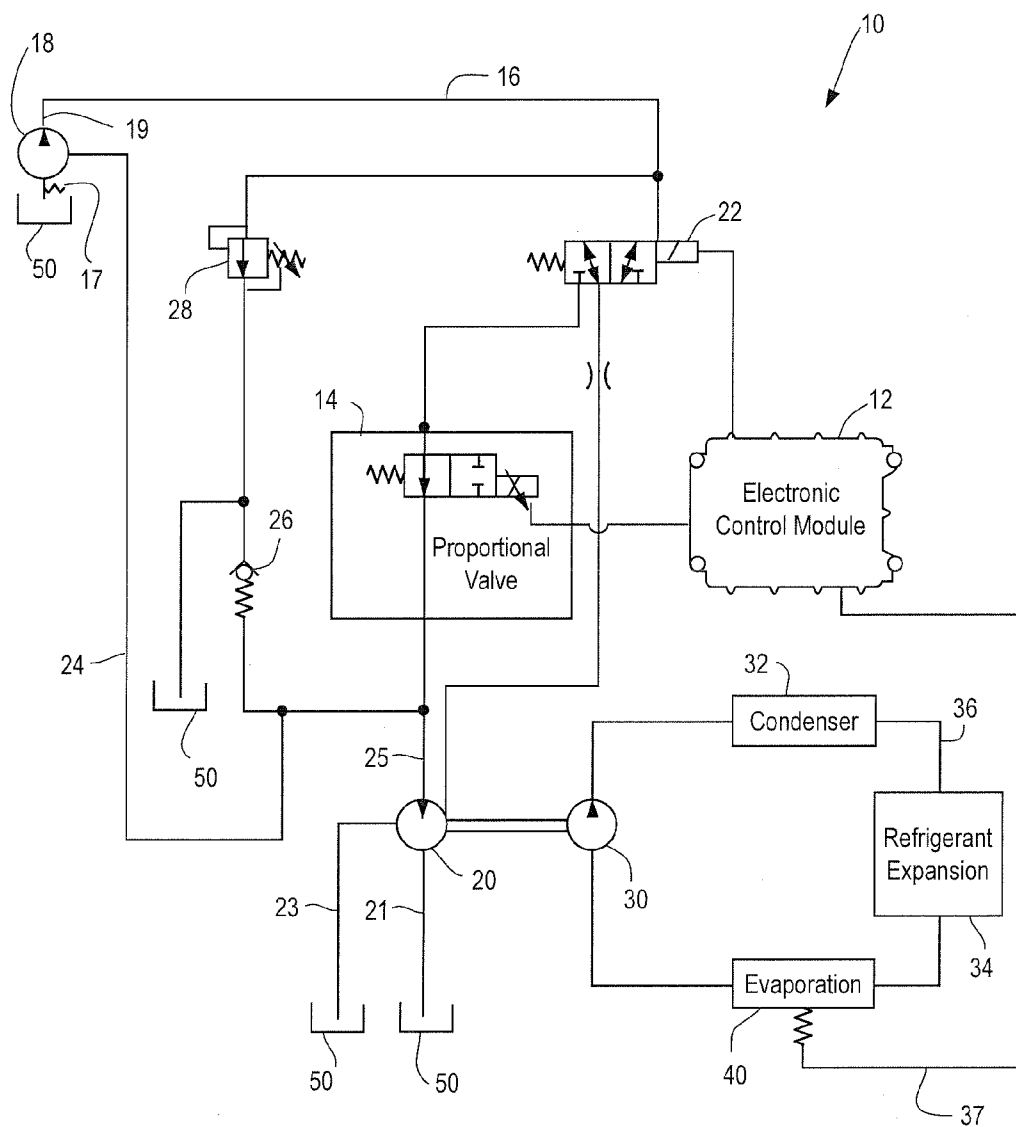


Fig. 3

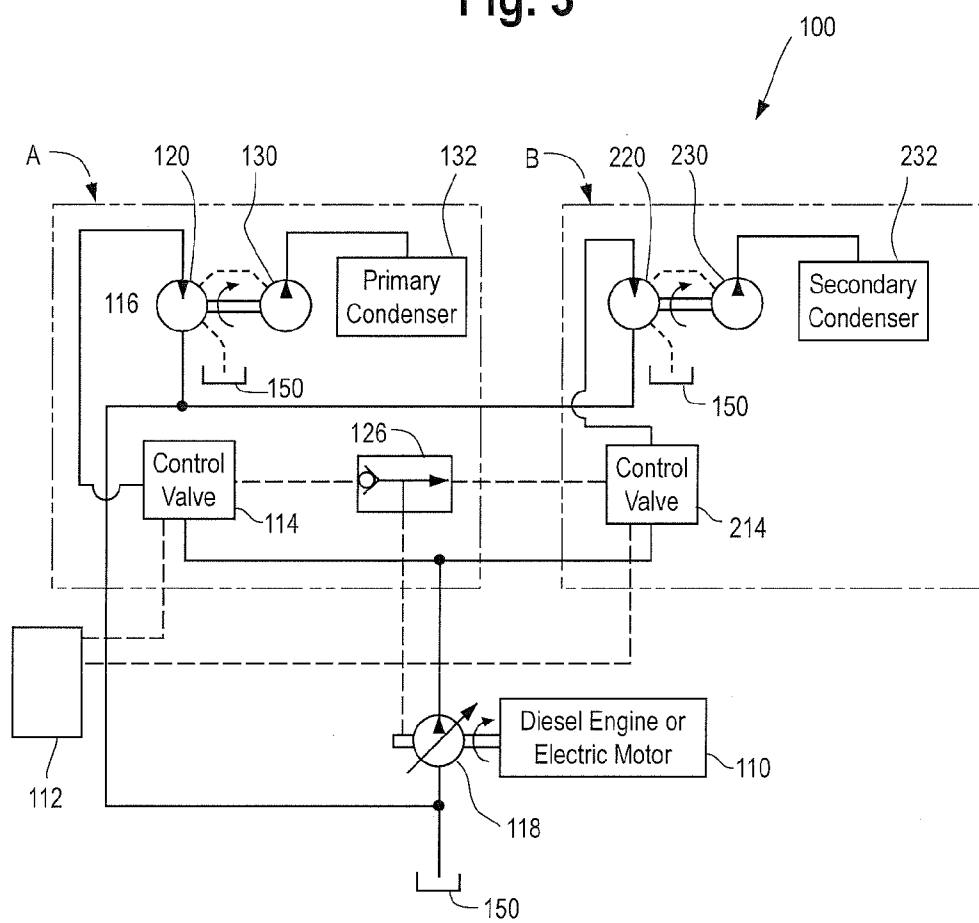


Fig. 4

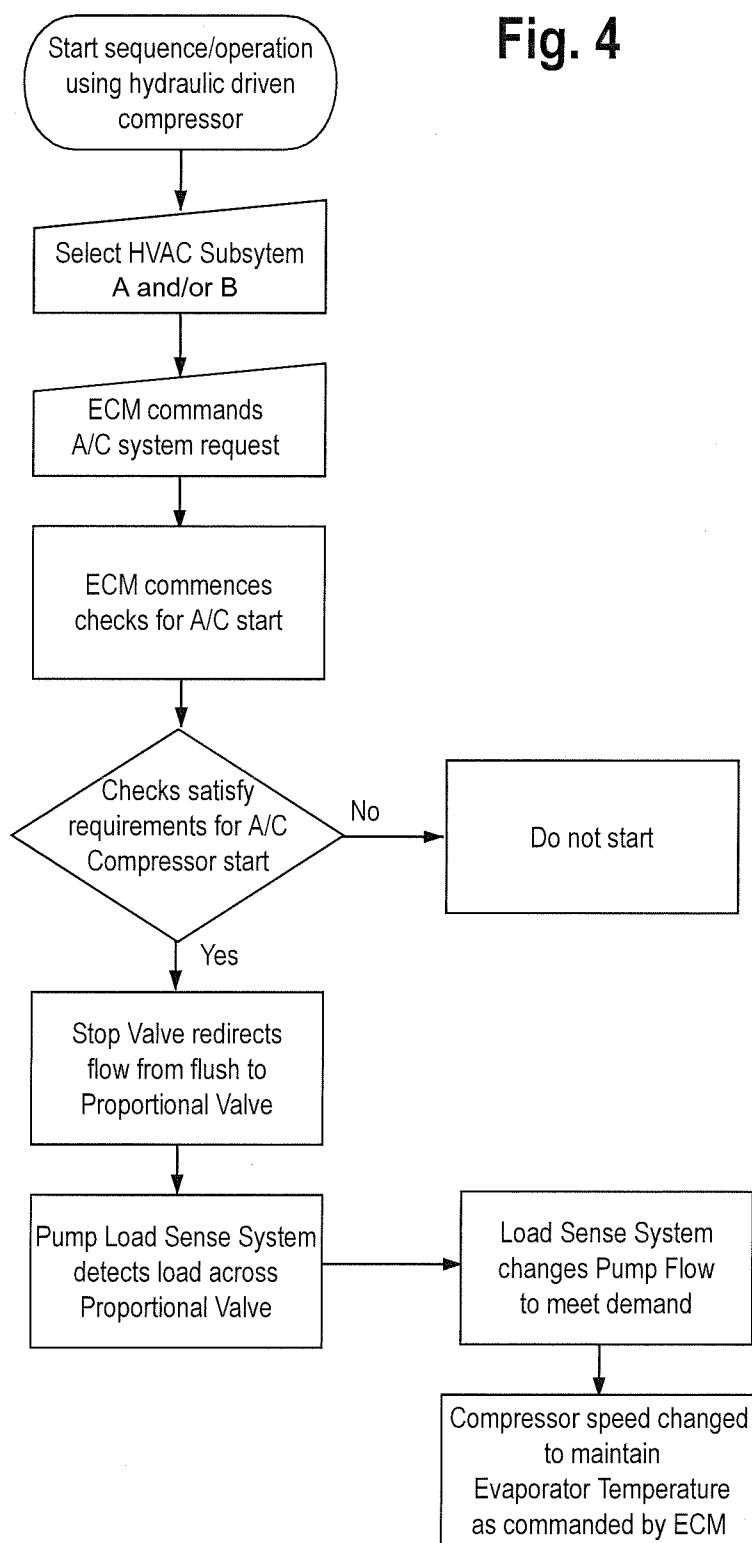
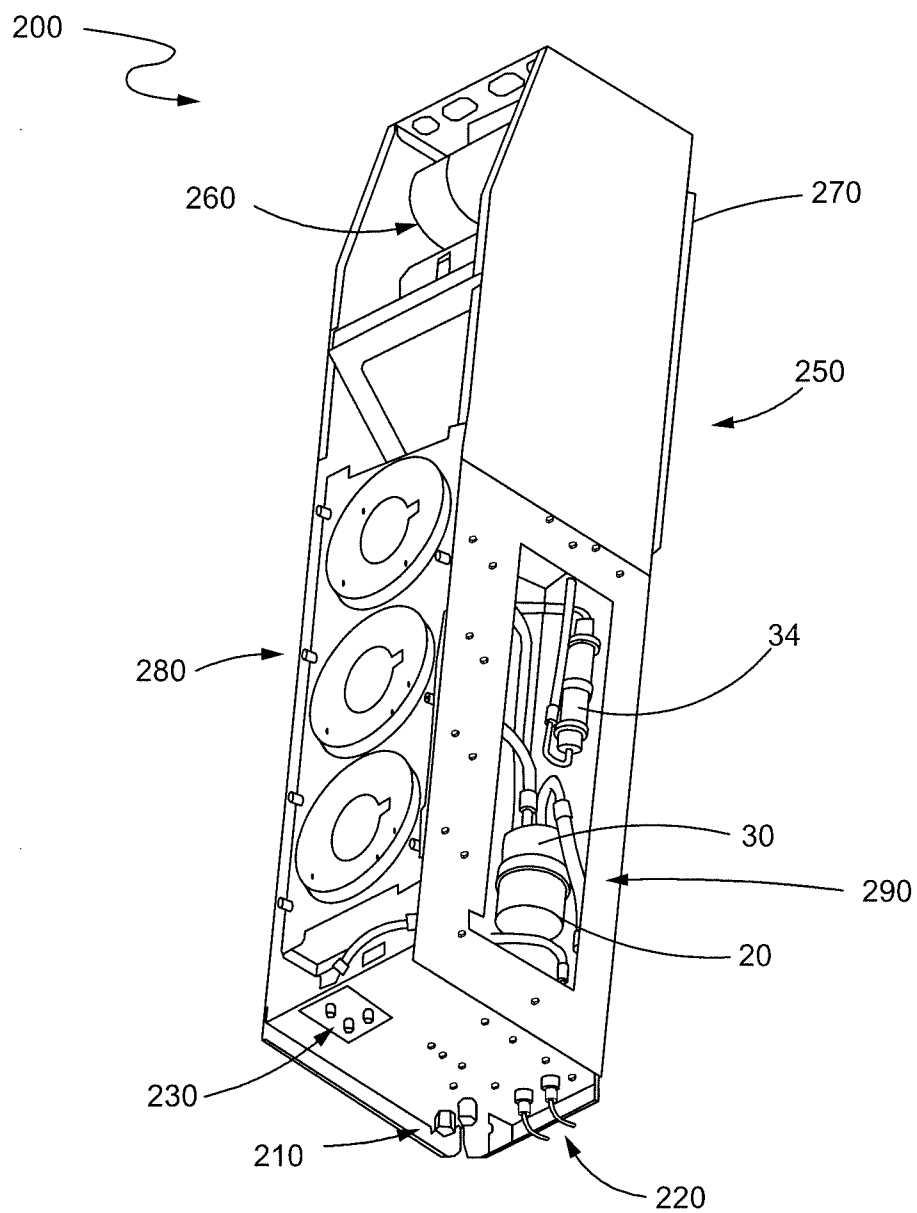


Fig. 5



## HYDRAULIC POWER SYSTEM FOR HVAC COMPRESSOR

### RELATED APPLICATION AND CLAIM OF PRIORITY

[0001] The present application claims priority to provisional application 61/704,238 filed on Sep. 21, 2012, which is hereby incorporated by reference for all purposes.

### TECHNICAL FIELD

[0002] This disclosure relates to improvements in optimizing longevity, and/or for reducing maintenance and/or replacement, of components associated with heating, ventilating, and air conditioning (HVAC) compressors utilized in work machines. More particularly, the disclosure relates to a hydraulic HVAC power system that utilizes a variable displacement pump and hydraulic motor arrangement to drive a refrigerant compressor.

### BACKGROUND

[0003] Many air-conditioning units of the type utilized in work machines are powered by directly driven compressors with on/off clutches. Such compressors have tended to undergo considerable cycling, which is known to reduce their useful lives. Other compressors have been of variable displacement types; those also have not fared very well under rigors of field use. Although hydraulic options have been available, most have also involved cycling the compressor on and off using hydraulic valves.

[0004] U.S. Pat. No. 5,875,630 to Walsh et al. discloses a hydraulic drive assembly that includes a variable displacement pump fluidly connected in a closed loop circuit with a motor for driving an ancillary device. Although the ancillary device may be a compressor for providing air conditioning, the disclosure only addresses closed loop systems which may be subject to undesirable pressure spikes and/or do not readily accommodate HVAC system redundancy.

[0005] Accordingly, it may be beneficial to provide an improved hydraulic power system for an HVAC compressor to better accommodate open loop and redundancy aspects, and for greater HVAC system responsiveness.

### SUMMARY OF THE DISCLOSURE

[0006] In one aspect of the disclosure, a hydraulic power system is configured for powering and controlling an HVAC compressor for air-conditioning the cab of a work machine. The hydraulic power system may include an electronic controller and a variable displacement pump responsive to a load sensing feature aspect of a hydraulic circuit.

[0007] In accordance with another aspect of the disclosure, a refrigerant compressor may be driven by a hydraulic motor, and an evaporator performance sensor may be positioned within the work machine cab, the sensor being configured for providing feedback to the controller to achieve desired evaporator performance via a proportioning valve.

[0008] In accordance with another aspect of the disclosure, the electronic controller may be adapted to provide performance signals to the proportioning valve, and the variable displacement pump may utilize the hydraulic load sensing feature to vary the speed of the fixed displacement hydraulic motor, and hence of the refrigerant compressor, as a function of desired evaporator performance.

[0009] In accordance with yet another aspect of the disclosure, the sensor may be a temperature sensor adapted to measure fin temperature of the evaporator.

[0010] In accordance with another aspect of the disclosure, the hydraulic system may be an open loop system.

[0011] In accordance with yet another aspect of the disclosure, the open loop system may accommodate a redundant refrigeration system.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a view of a mining shovel machine that may be exemplary of a work machine adapted to utilize the disclosed hydraulic power system.

[0013] FIG. 2 is a schematic portrayal of one embodiment of the disclosed hydraulic power system utilized to power an HVAC compressor.

[0014] FIG. 3 is a schematic portrayal of another embodiment of the disclosed hydraulic power system utilized to power the HVAC compressors of redundant refrigeration subsystems.

[0015] FIG. 4 is a flowchart of one disclosed algorithm that may be employed in the utilization of the embodiment of FIG. 3.

[0016] FIG. 5 is a view of one embodiment of a modular housing package that may contain the disclosed hydraulic power system.

### DETAILED DESCRIPTION

[0017] Referring initially to FIG. 1, a work machine in the form of a mining shovel machine 2, used for digging and removing coal, rock and/or soil, as examples only, from a worksite, is displayed in a perspective view. The mining shovel machine 2 may include a translatable and rotatable main body 4, which may contain an engine, and hydraulic and electrical systems (not shown). The mining shovel machine 2 may also include a work tool such as, for example, a mining shovel 6 as depicted. An operator cab 8 may be situated atop of the main body 4; the operator cab may include an operator control station (not shown) of the type in which air-conditioning by way of an HVAC unit may be desirable.

[0018] Referring now to FIG. 2, a first embodiment of a hydraulically powered HVAC system 10 that may be configured in accordance with this disclosure is shown schematically. The HVAC system 10 may include an electronic control module (ECM) 12 adapted to control a hydraulic proportioning valve 14 adapted to receive electronic signals from the ECM 12. The ECM 12 may also be configured to control all aspects of the HVAC system 10, including a hydraulic circuit 16 and all hydraulic components associated therewith, as well as related electrical control functions to be further described herein.

[0019] Continuing reference to FIG. 2, the HVAC system 10 may further include a variable displacement pump 18 configured to drive a fixed displacement motor 20. The fixed displacement motor 20 may be coupled directly to a refrigerant compressor 30, and the ECM 12 may be adapted to control the proportioning valve 14 to ultimately control the speed of the compressor 30 in accordance with a desired fin temperature of an evaporator 40. To the extent that the motor 20 is of fixed displacement, any modulation of the proportioning valve 14 as directed by the ECM 12 may cause the variable displacement pump 18 to react to the corresponding change in

demand, resulting in a direct change in compressor speed as a function of desired evaporator performance.

[0020] For this purpose, the variable displacement pump 18 may be adapted to incorporate a hydraulic load sensing capability. Thus, a load sensing line 24 may be configured to read actual pressure on a high pressure side of the HVAC system 10, per the schematic of FIG. 2. The load sensing line 24, as part of the hydraulic circuit 16, may enable the pump 18 to be directly responsive to HVAC demand, as manifested via a modulation of the proportioning valve 14 upon command as signaled by the ECM 12.

[0021] As part of the hydraulic circuit 16, a one way check valve 26 may be situated between the high and low pressure sides of the circuit 16 as will be appreciated by those skilled in the art, and a relief valve 28 may be situated on the high pressure side of the hydraulic circuit 16 to potentially avoid damage due to any overpressuring of the circuit 16.

[0022] A combination hydraulic trickle flow and stop valve 22 may be situated in the hydraulic circuit 16 between a high-pressure discharge outlet 19 of the pump 18 and the proportioning valve 14 for reasons to be explained below.

[0023] Apart from being driven by a fixed displacement hydraulic motor 20 for controlling its speed, the compressor 30 is otherwise part of a separate refrigeration circuit 36, to be distinguished from the hydraulic circuit 16. The refrigeration circuit 36 utilizes a refrigerant fluid such as a type of Freon, and includes the compressor 30, as well as a condenser 32, a refrigerant expansion valve 34, and an evaporator 40, components that are generally adapted to work in concert to produce HVAC cooling, as will be appreciated by those skilled in the art.

[0024] Several additional features of the hydraulic circuit 16 of the HVAC system 10 may include a hydraulic fluid reservoir 50 for containing and supplying hydraulic fluid as may be used in the various components of the hydraulic circuit 16, including the proportioning valve 14, the pump 18, and the motor 20. Among other things, the pump 18 has a suction or low pressure inlet 17 in communication with the reservoir 50. The hydraulic motor 20 receives hydraulic fluid directly from the proportioning valve 14, which then enters the motor 20 through a motor inlet 25, and after hydraulically driving the motor is discharged through a motor fluid outlet 21 and back into the reservoir 50. A case drain 23 allows a lesser amount of hydraulic fluid to return to the reservoir 50 from the motor 20, as part of a standby feature. However, whenever the motor 20 becomes operative the case drain 23 flow is reduced, as the bulk of the flow then becomes diverted to and through the motor fluid outlet 21.

[0025] Finally, any high-pressure hydraulic fluid which may escape through the relief valve 28 also passes back into the reservoir 50. Detailed operation of the HVAC system 10 is provided below.

[0026] Referring now to FIG. 3, an alternate embodiment 100 offering a dual HVAC system capability, as shown schematically. A diesel engine or electric motor 110 provides a motive source for driving a hydraulic pump 118 via a connection media such as a gear, belt, chain, or other coupling device (not shown). The hydraulic pump 118 is part of a unitary hydraulic circuit 116, and includes a hydraulic fluid reservoir 150. In the disclosed embodiment, an ECM 112, the circuit 116, and the reservoir 150 are not redundant or duplicated, though they could be if desired.

[0027] The ECM 112 is configured to control a pair of HVAC refrigeration subsystem units A and B, in accordance with at least one control algorithm described below.

[0028] Although only a single variable displacement pump 118 is utilized, the HVAC subsystem units, including evaporators (not shown), primary and secondary compressors 130, 230, and primary and secondary condensers 132, 232 are redundant, and may provide separate primary and backup HVAC systems for greater field reliability. With respect to the unitary hydraulic circuit 116, the proportioning valves 114, 214 are duplicated to permit switching from one subsystem system to the other by means of a reversible sensing shuttle valve 126. Although the valve 126 appears to be part of HVAC subsystem A, it may not be. Instead, the valve 126 may be a unitary component physically situated between the subsystems A and B. In addition and/or separately, there may be valves in each subsystem adapted to divert the fluid flows from respective case drains 23 to respective motor fluid outlets 21, so as to accommodate the full operation of either motor 120, 220.

[0029] The shuttle valve 126 may also provide a hydraulic fluid load sensing function for assuring that the pump is in communication with the appropriate system; i.e., with the primary proportioning valve 114 of subsystem A, or to the backup proportioning valve 214 of subsystem B. Primary and backup fixed displacement motors 120, 220, respectively, may be operative to drive primary and backup compressors 130, 230, respectively. Finally, primary and backup condensers 132, 232, as well as main and backup evaporators (not shown) are also included in the dual or redundant HVAC embodiment 100, as disclosed herein.

#### INDUSTRIAL APPLICABILITY

[0030] Operation of the HVAC system 10 may be explained with reference to FIG. 2, which schematically displays the single HVAC system 10. The dual HVAC system 100 of FIG. 3 includes redundant refrigeration units; as such, operation of the system 100 may be functionally similar to that of system 10.

[0031] Starting with the air-conditioning refrigeration circuit 36 turned off and otherwise inactive, and/or air-conditioning may not be desired, the combination hydraulic trickle flow and stop valve 22 may be in a closed position to generally prevent normal hydraulic fluid flow to the motor 20. However, the trickle flow (also called a motor flush) aspect of the stop valve 22 may allow the pump 22 to receive a small amount of hydraulic fluid flow to assure that the motor 20 remains in a standby condition; i.e. warmed up and ready for operation on demand. During the standby state, the variable displacement pump 18 is configured to provide a minimal displacement of fluid, which lowers horsepower requirements, and provides greater overall work machine fuel efficiency at a level that could not otherwise be achieved with a fixed displacement pump.

[0032] Upon a demand for air-conditioning, the ECM 12 will command the opening of the valve 22. Once the valve is opened, the proportioning valve 14 will be continuously adjusted, or modulated, as required to achieve desired compressor speed via commands from the ECM 12 based upon sensed evaporator fin temperature. The latter temperature information is made available to the ECM 12 via an evaporator temperature sensing line 37. For control purposes, the ECM 12 may be programmed to execute a specific algorithm designed for the particular size and operating parameters of

the HVAC system 10. As such, a given compressor speed may be correlated closely with a given control position of the proportioning valve 14.

[0033] With respect to hydraulic system pressure changes resulting from modulation of the proportioning valve 14, the hydraulic circuit 16 has both a high-pressure side, with highest system pressure being reflected at the high-pressure discharge outlet 19 of the pump 18, and a low-pressure side, with the lowest pressure being reflected at the pump inlet 17 while the pump is operating, or at atmosphere pressure reflective of the hydraulic reservoir 50, as part of the open loop circuit 16, whenever the pump is off or in a standby state.

[0034] The variable displacement pump 18 is adapted to read the pressure on the high-pressure side of the hydraulic circuit 16 through the load sensing line 24, as previously described. The load sensing feature may enable the pump 24 to either increase or decrease its rate of hydraulic fluid displacement in response to system demand changes resulting from modulation of the proportioning valve 14, as commanded by the ECM 12.

[0035] To the extent that the proportioning valve 14 may be adjusted strictly as a function of a desired evaporator temperature, the HVAC system 10 is able to accommodate air-conditioning loads without shutting off, thus allowing the evaporator to maintain a greatly improved temperature distribution over systems that cycle on and off, particularly during periods of decreased air-conditioning demands. This improves the efficiency of the evaporator 40, and permits the compressor 30 to operate more slowly whenever higher or maximum air-conditioning levels are not required. To the extent that the pump 18 may be configured, via its load sensing capability, to lower the amount fluid displacement during periods of low air-conditioning demand, the system may require considerably less horsepower, and thus overall machine efficiency may be improved.

[0036] A principal advantage of utilizing a hydraulic power system for HVAC compressor control relates to how the hydraulic pump 18 may automatically adjust for significant or large changes in the pump demand. To the extent that the load sensing circuitry may be configured to automatically change the fluid displacement rate of the pump 18 to accommodate any desired compressor speed, the use of the hydraulic circuit 16 instead of the typical electrical control system to make large or significant valve adjustments or modulations may be avoided. Moreover, since the compressor 30 may be configured to run at higher speeds, even during periods of work machine engine idle, the HVAC system 10 may inherently have more capacity to meet cooling needs over other available systems.

[0037] As suggested above, the HVAC system 10 disclosed herein may also be configured to employ an open loop hydraulic circuit, which may facilitate the use of multiple air-conditioning units, as for example in the embodiment of FIG. 3. Such accommodation may be made with relatively inexpensive fixed displacement motors 20. Moreover, the dual air-conditioning subsystems A and B disclosed in the HVAC system 100 may be configured to run independently, although alternative embodiments envisioned hereunder may permit simultaneous subsystem operability.

[0038] The HVAC systems 10, 100 may be packaged in modular form for ease of handling and providing for easier field replacements. Referring now to FIG. 5, the physical HVAC systems may be contained in a simple modular housing package Y. The housing package Y may offer the convenience

of not having to discharge any refrigerant; i.e. the refrigerant lines do not need to be disturbed for removal or for replacement. For such purpose, only three sets of connections are required, including two heater hoses which are adapted to provide inlet and outlet connections for engine coolant, two electrical connectors, and a few hydraulic connectors, as shown. The back of the unit as indicated provides the mechanical structural connectors for attachment of the HVAC system 10, 100 to the backside of the cab 8.

[0039] In the modular package Y, a blower for the evaporator and heater cores, as well as a heater/evaporator subunit is provided at one end, while the electrical, heater, and hydraulic connectors are shown at the other. Intermediate of the ends are situated the condenser, condenser fans, refrigerant expansion valve, along with the compressor/hydraulic motor subassembly.

[0040] Thus, those skilled in the art will appreciate that the modular housing package Y may facilitate simpler replacements of defective units in remote field locations where the machines 2 are often utilized.

[0041] Either of the HVAC systems 10 and 100 may be utilized in large work machines, particularly hydraulic powered work machines such as mining shovels, mining trucks, excavators, and the like. The systems 10 and 100 may offer greater compressor reliability due to avoidance of the on-off compressor cycling involved in many existing HVAC system configurations. The higher compressor reliability may result in fewer downtime periods for maintenance and/or replacement of various HVAC system parts.

[0042] Finally, to the extent that higher compressor speeds can be maintained even during engine idle, greater operating efficiencies and lower noise levels may result. To the extent that evaporator temperature may directly be correlated to a given compressor speed, the HVAC systems 10 and 100 may offer systems subject to less temperature variations of the air-conditioned environments within the cab 8.

[0043] One control algorithm for use with the hydraulic HVAC system 100 of FIG. 3, which utilizes primary and secondary refrigeration subsystems A and B, respectively, wherein subsystem B refrigeration components have 200-series references, e.g., the hydraulic motor 220 and compressor 230, may be described as follows.

[0044] Assuming that subsystem A will act as a primary refrigeration subsystem by default, an initial HVAC systems check may be connected by the ECM 112. The systems check may include confirmation of whether the primary or secondary subsystem A or B is to be activated, and if so, whether the reversible shuttle valve 126 is properly oriented. For example, if the primary subsystem A is to be activated, the shuttle valve 126 should be configured to pressurize hydraulic fluid associated with the proportioning valve 114. In some embodiments, both A and B may be activated. Once confirmation is received that the shuttle valve 126 is in proper orientation, the variable displacement pump 118 may be fully activated; i.e., the stop valve 22 (not shown, but as earlier shown and described) may then be switched from trickle flow status through drain line 23 (FIG. 2) to fully open status to permit hydraulic fluid flows at normal operating volumes through drain line 21 (FIG. 2).

[0045] At this point the ECM 112 may initiate its modulation commands to the proportional valve 114, based upon real time fin temperature readings of the evaporator (not shown, but as earlier shown and described). For this purpose, the pump 118 may utilize its load sensing capability to meet

appropriate hydraulic system pressure demands necessary to ultimately control the speed of the fixed motor **120**, and hence to directly control the speed of the compressor **130** to which the motor **120** is coupled.

**[0046]** Operation of the secondary refrigeration subsystem B is similar, except for operation of the sensing shuttle valve **126**. The orientation of the latter becomes changed so as to sense pressurization of the side of the hydraulic circuit **116** associated with the proportioning valve **214**, wherein the ECM **112** may then control the respective motor and compressor components, **220** and **230**, respectively. Although for brevity, the respective evaporators are not shown in FIG. 3, the respective primary and secondary refrigerant condensers **132** and **232** are in fact displayed. Once subsystem A, B or both are engaged, the hydraulic control aspects of the ECM **112** will apply as already described for the HVAC system **10** of FIG. 2.

**[0047]** The above describes a self-contained unit with an automatic control module that allows an improved level stability in control matching the capacity requirements of the cab and the increased stability increases compressor life and performance.

What is claimed is:

1. A fluid power system configured for supply operating power to, and control of, a refrigerant compressor in an HVAC unit adapted for air-conditioning a cab of a work machine, the fluid power system comprising:

an electronic controller;

a fluid circuit including a fluid proportioning valve configured to receive signals from the electronic controller;

the fluid circuit including a variable displacement pump actuated by the electronic controller, and a fixed displacement motor driven by the variable displacement pump;

a refrigerant compressor rotatably coupled to the fixed displacement motor; and

a sensor configured to measure performance of an HVAC evaporator;

wherein the electronic controller is adapted to receive signals from the sensor to modulate the fluid proportioning valve to vary hydraulic motor speed and, in turn, the speed of the refrigerant compressor as a direct function of desired evaporator performance.

2. The fluid power system of claim 1, wherein a fluid in the fluid circuit is a hydraulic fluid.

3. The fluid power system of claim 1, wherein the sensor is a temperature sensor.

4. The fluid power system of claim 1, wherein the motor and pump share a reservoir in an open loop circuit.

5. The fluid power system of claim 1, wherein the HVAC unit is a modular unit.

6. The fluid power system of claim 1, wherein the variable displacement pump includes a load sensing control aspect, whereby the pump is adapted to be automatically responsive to HVAC demand through sense of change in fluid circuit pressure.

7. The fluid power system of claim 1, wherein the electronic controller is directly responsive to sensed change in refrigerant evaporator temperature, and commands changes in the fluid proportioning valve in response.

8. An apparatus configured to power a refrigerant compressor of an HVAC unit adapted for air-conditioning a cab of a work machine, the apparatus comprising:

an electronic controller;

a fluid proportioning valve configured to receive signals from the electronic controller;

a variable displacement pump adapted to be responsive to movements of the fluid proportioning valve, whereby the variable displacement pump is configured to be responsive to HVAC system demand;

a fixed displacement fluid motor fluidly driven by the pump, the motor being adapted for being rotatably coupled to a refrigerant compressor;

a fluid circuit configured to fluidly interconnect the pump, motor, and the fluid proportioning valve;

a sensor configured to measure performance of an HVAC evaporator; and

wherein the electronic controller is adapted to receive signals from the sensor for modulating the fluid proportioning valve to produce variation in motor speed and, in turn, the speed of the refrigerant compressor as a direct function of desired evaporator performance.

9. The apparatus of claim 8, wherein a fluid in the fluid circuit is a hydraulic fluid.

10. The apparatus of claim 8, wherein the sensor is a temperature sensor.

11. The apparatus of claim 8, wherein the motor and pump share a common reservoir in an open loop circuit.

12. The apparatus of claim 8, wherein the HVAC unit is a modular unit.

13. The apparatus of claim 8, wherein the variable displacement pump includes a load sensing control aspect, whereby the pump is adapted to be automatically responsive to HVAC demand through sense of change in fluid circuit pressure.

14. The apparatus of claim 8, wherein the electronic controller is directly responsive to sensed change in refrigerant evaporator temperature, and commands changes in the fluid proportioning valve in response.

15. A control system for a hydraulically powered refrigerant compressor in an HVAC unit adapted for air-conditioning a cab of a work machine, the control system comprising:

an electronic controller;

a fluid circuit including a fluid proportioning valve configured to receive signals from the electronic controller;

the fluid circuit including a variable displacement pump having an automated load sensing feature, and a fixed displacement motor driven by the variable displacement pump;

the fixed displacement motor being adapted to be coupled to a refrigerant compressor; and

a sensor configured to measure performance of an HVAC evaporator;

wherein the electronic controller is adapted to receive signals from the sensor to modulate the fluid proportioning valve to vary hydraulic motor speed and, in turn, the speed of the refrigerant compressor as a direct function of desired evaporator performance.

16. The control system of claim 15, wherein a fluid in the fluid circuit is a hydraulic fluid.

17. The control system of claim 15, wherein the sensor is a temperature sensor.

18. The control system of claim 15, wherein the motor and pump share a common reservoir in an open loop circuit.

19. The control system of claim 15, wherein the HVAC unit is a modular unit.

**20.** The control system of claim **15**, wherein the electronic controller is directly responsive to sensed change in refrigerant evaporator temperature, and commands changes in the fluid proportioning valve in response.

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