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(54) **Capacity modulated compressor**

(57) A heat pump system may include first and second heat exchangers, a compressor, and a fluid conduit. The compressor may include a capacity modulation system providing first, second, and third capacities of the compressor. The second capacity may be less than the first capacity and greater than the third capacity. The fluid conduit may provide fluid communication between the first and second heat exchangers and the compressor. The fluid conduit may define a first flow path from the compressor to the first heat exchanger and from the first heat exchanger to the second heat exchanger during a cooling mode and a second flow path from the compressor to the second heat exchanger and from the second heat exchanger to the first heat exchanger during a heating mode. The compressor may operate at the first capacity during the heating mode and at the second capacity during the cooling mode.

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Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 60/958,063, filed on July 2, 2007. The disclosure of the above application is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to heat pump systems, and more specifically to a compressor in a heat pump system including a capacity modulation system.

BACKGROUND

[0003] The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

[0004] A heat pump system with a two-step capacity modulation system may provide improved system operation when operating in a cooling mode. More specifically, the first compressor capacity may be associated with a system operating capacity when operated in a cooling mode and the second capacity may be used to reduce the compressor capacity for improved light load performance during the cooling mode. Operation of the heat pump system in the heating mode may require more compressor capacity than required for the cooling mode. As such, an additional heat source may be required to provide the heat required for the heating mode. Alternatively, the system rated capacity for a compressor may be sized larger than what is required for the cooling mode so that the compressor can provide adequate heating performance in the heating mode. However, this oversized system-rated capacity may result in inefficient compressor operation in the cooling mode.

SUMMARY

[0005] Accordingly, a compressor may include a shell and a compression mechanism contained within the shell. The compression mechanism may include first and second scroll members supported for relative orbital displacement therebetween. The first and second scroll members may each include an end plate having spiral wraps extending therefrom and meshingly engaged with one another to form a plurality of pockets. A first passage may be disposed in the first scroll member and extend from an exterior portion of the first scroll member into a first of the pockets. A second passage may be disposed in the first scroll member and extend into a second of the pockets disposed radially inwardly relative to the first pocket. The compressor may also include a valve assembly to selectively open and close the first and second passages to provide a first operating capacity wherein both of the first and second passages are closed, a second operating capacity wherein the first passage is open and the second passage is closed, and a third operating capacity wherein the second passage is open. The compressor may be disposed in a heat pump system wherein the first operating capacity corresponds to a heating mode of the heat pump system and the third operating capacity corresponds to a cooling mode of the heat pump system.

[0006] A heat pump system may include first and second heat exchangers, a compressor, and a fluid conduit. The compressor may include a capacity modulation system providing first, second, and third operating capacities of the compressor. The second operating capacity may be less than the first operating capacity and greater than the third operating capacity. The fluid conduit may provide fluid communication between the first heat exchanger, the second heat exchanger, and the compressor. The fluid conduit may define a first flow path from the compressor to the first heat exchanger and from the first heat exchanger to the second heat exchanger when operating in a cooling mode and a second flow path from the compressor to the second heat exchanger and from the second heat exchanger to the first heat exchanger when operating in a heating mode. The compressor may operate at the first operating capacity during the heating mode and at the second operating capacity during the cooling mode.

[0007] A method of operating a scroll compressor in a heat pump system may include sealing a first leak path in communication with a first of pockets formed by meshingly engaged wraps of first and second scroll members of the scroll compressor operating at a first pressure and sealing a second leak path in communication with a second of the pockets formed by the meshingly engaged wraps of the first and second scroll members of the scroll compressor operating at a second pressure greater than the first pressure to operate the compressor at a first operating capacity during a heating mode of the heat pump system. The method may further include opening the first leak path and closing the second leak path to operate the compressor at a second operating capacity that is reduced from the first operating capacity during a cooling mode of the heat pump system. The method may further include opening the second leak path to operate the compressor at a third operating capacity that is reduced from the second operating capacity during the cooling mode.

[0008] Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0009] The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

[0010] Figure 1 is a schematic illustration of a heat pump system according to the present disclosure;

[0011] Figure 2 is a section view of the compressor of the heat pump system of Figure 1;

[0012] Figure 3 is a section view of the non-orbiting scroll and capacity modulation system of the compressor of Figure 2;

[0013] Figure 4 is an additional section view of the non-orbiting scroll and capacity modulation system of the compressor of Figure 2;

[0014] Figure 5 is an additional section view of the non-orbiting scroll and capacity modulation system of the compressor of Figure 2; and

[0015] Figure 6 is a perspective view of the non-orbiting scroll and capacity modulation system of the compressor of Figure 2.

DETAILED DESCRIPTION

[0016] The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.

[0017] As seen in Figure 1, a heat pump system 10 may include an indoor unit 12 and an outdoor unit 14. Indoor unit 12 may include an indoor coil or heat exchanger 16 and a variable speed indoor fan 18 driven by a motor 20. Indoor coil 16 and fan 18 may be enclosed in a cabinet 22 so that fan 18 forces ambient air across indoor coil 16. Outdoor unit 14 may include an outdoor coil or heat exchanger 24 and a variable speed outdoor fan 26 driven by a motor 28. Outdoor coil 24 and fan 26 may be enclosed in a protective housing 30 so that fan 26 will draw ambient outdoor air across outdoor coil 24 to improve heat transfer. Outdoor unit 14 may further include a compressor 32 in communication with indoor coil 16 and outdoor coil 24.

[0018] Communication between compressor 32, indoor coil 16, and outdoor coil 24 may generally form a loop, wherein compressor 32, indoor coil 16, and outdoor coil 24 are arranged in series with one another with an expansion device 33 located between indoor coil 16 and outdoor coil 24. The heat pump system 10 may include a reversing valve 34 disposed between compressor 32 and indoor and outdoor coils 16, 24, such that the direction of flow between compressor 32, indoor coil 16, and outdoor coil 24 may be reversed between first and second directions. In the first direction, heat pump system 10 operates in a cooling mode providing a flow in a direction indicated by the "cooling" arrow. In the cooling mode, compressor 32 provides a fluid to outdoor coil 24. The fluid then travels to indoor coil 16 and then back to compressor 32. In the cooling mode, indoor coil 16 functions as an evaporator coil and outdoor coil 24 functions as a condenser coil. In the second direction, heat pump system 10 operates in a heating mode providing a flow in a direction indicated by the "heating" arrow. In the heating mode, flow is reversed, traveling from compressor 32 to indoor coil 16 to outdoor coil 24, and then back to compressor 32. In the heating mode, indoor coil 16 functions as a condenser coil and outdoor coil 24 functions as an evaporator coil.

[0019] For exemplary purposes, compressor 32 is shown as a hermetic scroll refrigerant-compressor of the low-side type, i.e., where the motor and compressor are cooled by suction gas in the hermetic shell, as illustrated in the vertical section shown in Figure 2. Compressor 32 may include a cylindrical hermetic shell 116, a compression mechanism 118, a main bearing housing 120, a motor assembly 122, a refrigerant discharge fitting 124, and a suction gas inlet fitting 126. The hermetic shell 116 may house the compression mechanism 118, main bearing housing 120, and motor assembly 122. Shell 116 may include an end cap 128 at the upper end thereof and a transversely extending partition 129. The refrigerant discharge fitting 124 may be attached to shell 116 at opening 130 in end cap 128. The suction gas inlet fitting 126 may be attached to shell 116 at opening 132. The compression mechanism 118 may be driven by motor assembly 122 and supported by main bearing housing 120. The main bearing housing 120 may be affixed to shell 116 at a plurality of points in any desirable manner.

[0020] The motor assembly 122 may generally include a motor 134, a frame 136 and a drive shaft 138. The motor 134 may include a motor stator 140 and a rotor 142. The motor stator 140 may be press fit into frame 136, which may in turn be press fit into shell 116. Drive shaft 138 may be rotatably driven by rotor 142. Windings 144 may pass through stator 140. Rotor 142 may be press fit on drive shaft 138. A motor protector 146 may be provided in close proximity to windings 144 so that motor protector 146 will de-energize motor 134 if windings 144 exceed their normal temperature range.

[0021] Drive shaft 138 may include an eccentric crank pin 148 having a flat 149 thereon and a counter-weight 150 at an upper end 152. Drive shaft 138 may include a first journal portion 153 rotatably journaled in a first bearing 154 in main bearing housing 120 and a second journal portion 155 rotatably journaled in a second bearing 156 in frame 136. Drive shaft 138 may include an oil-pumping concentric bore 158 and a counterweight 159 at a lower end 160. Concentric bore 158 may communicate with a radially outwardly inclined and relatively smaller diameter bore 162 extending to the upper end 152 of drive shaft 138. The lower interior portion of shell 116 may be filled with lubricating oil. Concentric bore 158 may provide pump action in conjunction with bore 162 to distribute lubricating fluid to various portions of compressor 32.

[0022] Compression mechanism 118 may generally include an orbiting scroll 164 and a non-orbiting scroll 166. Orbiting scroll 164 may include an end plate 168 having a spiral vane or wrap 170 on the upper surface thereof and an annular flat thrust surface 172 on the lower surface. Thrust surface 172 may interface with an annular flat thrust bearing surface 174 on an upper surface of main bearing housing 120. A cylindrical hub 176 may project downwardly from thrust surface 172 and may include a journal bearing 178 having a drive bushing 180 rotatively disposed therein. Drive bushing 180 may include an inner bore in which crank pin 148 is drivingly disposed. Crank pin flat 149 may drivingly engage a flat surface in a portion of the inner bore of drive bushing 180 to provide a radially compliant driving arrangement.

[0023] Non-orbiting scroll member 166 may include an end plate 182 having a spiral wrap 184 on lower surface 186 thereof. Spiral wrap 184 may form a meshing engagement with wrap 170 of orbiting scroll member 164, thereby creating an inlet pocket 188, intermediate pockets 190, 192, 194, 196, and outlet pocket 198. Non-orbiting scroll 166 may have a centrally disposed discharge passageway 200 in communication with outlet pocket 198 and upwardly open recess 202 which may be in fluid communication with a discharge muffler 201 via an opening 203 in partition 129. Discharge muffler 201 may be in communication with discharge fitting 124 and may be defined by end cap 128 and partition 129.

[0024] Non-orbiting scroll member 166 may include an annular recess 204 in the upper surface thereof having parallel coaxial side walls in which an annular floating seal 205 is sealingly disposed for relative axial movement. The bottom of recess 204 may be isolated from the presence of gas under suction and discharge pressure by floating seal 205 so that it can be placed in fluid communication with a source of intermediate fluid pressure by means of a passageway 206 (shown in Figures 3-5). Passageway 206 may extend into an intermediate pocket 190, 192, 194, 196. Non-orbiting scroll member 166 may therefore be axially biased against orbiting scroll member 164 by the forces created by discharge pressure acting on the central portion of scroll member 166 and those created by intermediate fluid pressure acting on the bottom of recess 204. Various additional techniques for supporting scroll member 166 for limited axial movement may also be incorporated in compressor 32.

[0025] Relative rotation of the scroll members 164, 166 may be prevented by an Oldham coupling, which may generally include a ring 212 having a first pair of keys 214 (one of which is shown) slidably disposed in diametrically opposed slots 216 (one of which is shown) in non-orbiting scroll 166 and a second pair of keys (not shown) slidably disposed in diametrically opposed slots in orbiting scroll 164.

[0026] With additional reference to Figures 3-5, non-orbiting scroll member 166 may include first, second, third, and fourth passages 218, 220, 222, 224 extending through an exterior sidewall 226 thereof and into intermediate fluid pockets 190, 192, 194, 196. First, second, third and fourth passages 218, 220, 222, 224 may each include a seal 225 disposed in an outlet thereof. One or both of third and fourth passages 222, 224 may have a greater radially inward extent than both first and second passages 218, 220. With additional reference to Figure 6, a capacity modulation system 228 may be coupled to non-orbiting scroll member 166.

[0027] Capacity modulation system 228 may include a modulation ring 230 and an actuation mechanism 232. Seals 225 may be engaged with modulation ring 230. Modulation ring 230 may include a generally annular body rotatably disposed around exterior sidewall 226 of non-orbiting scroll member 166. Modulation ring 230 may include first and second portions 234, 236 each having a first flow path 238, 239 and a second flow path 240, 241 extending therethrough for selectively venting one or more of intermediate fluid pockets 190, 192, 194, 196, as discussed below. A pin 242 may extend from modulation ring 230 for engagement with actuation mechanism 232.

[0028] Actuation mechanism 232 may be in the form of a solenoid having an extendable and retractable arm 244. A biasing member (not shown), such as a coil spring, may normally urge arm 244 into an extended position. Arm 244 may include a recess 248 in an end 250 thereof. Pin 242 may extend into recess 248 for actuation of modulation ring 230, as discussed below.

[0029] Actuation mechanism 232 may rotate modulation ring 230 between three positions, seen in Figures 3-5. In the first position (shown in Figure 3) compressor 32 operates at a maximum capacity. At the maximum capacity, first and second portions 234, 236 of modulation ring 230 seal passages 218, 220, 222, 224 in non-orbiting scroll member 166. More specifically, in the first position, first flow paths 238, 239 are not in communication with first and second passages 218, 220, and second flow paths 240, 241 are not in communication with third and fourth passages 222, 224. Capacity may be modulated by retraction of arm 244 and therefore rotation of modulation ring 230 in a clockwise direction to a second position (shown in Figure 4) and by extension of arm 244 and therefore rotation of modulation ring 230 in a counter-clockwise direction to a third position (shown in Figure 5).

[0030] The second capacity is less than the first capacity. When in the second capacity, arm 244 may be in an innermost position and modulation ring 230 may have first flow paths 238, 239 aligned with first and second passages 218, 220 in non-orbiting scroll member 166. Capacity may additionally be modulated to a third capacity (seen in Figure 5), wherein modulation ring 230 is rotated to the third position. The third capacity is less than the second capacity. When in the third capacity, arm 244 may be extended to an outermost position to rotate modulation ring 230 in a counter-clockwise direction from the second position to the third position. The third position may provide alignment between first flow paths 238, 239 and third and forth passages 222, 224 in non-orbiting scroll member 166 and second flow paths 240, 241 and first and second passages 218, 220 in non-orbiting scroll member 166.

[0031] As discussed above, the first capacity is greater than the second capacity and the third capacity is less than the second capacity due to the greater radially inward extent of third and fourth passages 222, 224 in non-orbiting scroll member 166. The radially inward extent of first, second, third, and fourth passages 218, 220, 222, 224 may effectively reduce the wrap length of non-orbiting scroll member 166. For example, non-orbiting scroll member 166 may have a wrap angle of approximately 1330 degrees. First and second passages 218, 220 may extend into non-orbiting scroll member to a wrap angle of approximately 1000 degrees from a base circle of the involute. As such, in the second capacity where first and second passages 218, 220 are in communication with first flow paths 238, 239, the wrap angle of non-orbiting scroll member 166 is effectively reduced to 1000 degrees. Third and fourth passages 222, 224 may extend into non-orbiting scroll member 166 to a wrap angle of approximately 660 degrees from the base circle of the involute. As such, in the third capacity where first and second passages 218, 220 are in communication with second flow paths 240, 241 and third and fourth passages 222, 224 are in communication with first flow paths 238, 239, the wrap angle of non-orbiting scroll member 166 is effectively reduced to 660 degrees.

[0032] Scroll pocket volume may be generally proportional to wrap angle. Therefore, according to the example above, the first capacity may generally be thirty-three percent greater than the second capacity and the third capacity may generally be thirty-three percent less than the second capacity. However, the first capacity may generally be ten to thirty-five percent greater than the second capacity and the third capacity may generally be ten to thirty-five percent less than the second capacity. Modulation ring 230 may be held in a constant position to provide the three capacities described above. Alternatively, modulation ring 230 may be cycled rapidly in order to provide an intermediate capacity.

[0033] Compressor 32 may be sized such that the second capacity corresponds to the system rated capacity of compressor 32 when heat pump system 10 is operated in a cooling mode. Compressor 32 may be operated in the first and second capacities when heat pump system 10 is operated in a heating mode. The first capacity may provide additional capacity for operation in a heating mode. More specifically, the additional capacity provided when compressor 32 is operated at the first capacity may reduce the need for back-up heat in heat pump system 10 and may improve the Heating Seasonal Performance Factor (HSPF). For example, if compressor 32 has been sized for a 3 ton cooling capacity at the second capacity and has a 4 ton cooling capacity at the first capacity, heat pump system 10 may have a HSPF value that is up to approximately six percent greater than a heat pump system with a fixed capacity compressor.

[0034] Compressor 32 may be operated in the second and third capacities when heat pump system 10 is operated in a cooling mode. More specifically, the third capacity may provide for more efficient operation of heat pump system 10 in the light load cooling mode. The reduced capacity provided when compressor 32 is operated at the third capacity may improve the Seasonal Energy Efficiency Ratio (SEER) when heat pump system 10 is operated in the cooling mode. For example, if compressor 32 has been sized for a 3 ton cooling capacity at the second capacity and has a 2 ton cooling capacity at the third capacity, heat pump system 10 may provide a SEER value that is up to approximately seven percent greater than the same system with a fixed capacity compressor. A combination of the reduced capacity and variable speed indoor and outdoor fans 18, 26 may produce a SEER value up to eighteen percent greater than the same system with a fixed capacity compressor and no variable speed indoor and outdoor fans.

Claims

1. A compressor comprising:

a shell;

a compression mechanism contained within said shell and including first and second scroll members supported for relative orbital displacement therebetween, said first and second scroll members each including an end plate having spiral wraps extending therefrom, said spiral wraps of said first and second scroll members meshingly engaged with one another and forming a plurality of pockets;

a first passage disposed in said first scroll member and extending from an exterior portion of said first scroll member into a first of said pockets;

a second passage disposed in said first scroll member and extending into a second of said pockets disposed radially inwardly relative to said first pocket; and

a valve assembly operable to selectively open and close said first and second passages to provide a first operating capacity wherein both of said first and second passages are closed, a second operating capacity wherein said first passage is open and said second passage is closed, and a third operating capacity wherein said second passage is open, said compressor being for use in a heat pump system wherein said first operating capacity corresponds to a heating mode of the heat pump system and said third operating capacity corresponds to a cooling mode of the heat pump system.

2. The compressor of claim 1, wherein said compression mechanism operates at a cooling mode system rated capacity when operated at said second operating capacity.

3. The compressor of claim 1 or 2, wherein said second operating capacity is less than said first operating capacity and greater than said third operating capacity.

4. The compressor according to any one of the preceding claims, wherein said first operating capacity is ten to thirty-five percent greater than said second operating capacity.

5. The compressor according to any one of the preceding claims, wherein said third operating capacity is ten to thirty-five percent less than said second operating capacity.

6. The compressor according to any one of the preceding claims, further comprising third and fourth passages disposed in said first scroll member, said third passage extending from an exterior portion of said first scroll member into a third of said pockets and said fourth passage extending from an exterior portion of said first scroll member into a fourth of said pockets, said fourth pocket being disposed radially inwardly relative to said first and third pockets.

7. The compressor of claim 6, wherein said first operating capacity includes closing said first, second, third, and fourth passages.

8. The compressor of claim 6 or 7, wherein said second operating capacity includes closing said second and fourth passages and opening said first and third passages.

9. The compressor of claim 6, 7 or 8, wherein said third operating capacity includes opening said second and fourth passages.

10. The compressor of claim 9, wherein said third operating capacity includes opening said first and third passages.

11. The compressor according to any one of the preceding claims, wherein said first scroll member is a non-orbiting scroll member.

12. The compressor according to any one of the preceding claims, wherein said third operating capacity includes opening said first passage.

13. The compressor according to any one of the preceding claims, wherein said valve assembly includes a modulation ring disposed around an exterior sidewall of said first scroll member and displaceable between first, second, and third positions corresponding to said first, second, and third operating capacities to selectively open said first and second passages.

14. The compressor of claim 13, wherein said valve assembly includes a solenoid to displace said modulation ring between said first, second, and third positions.

15. A heat pump system comprising:

a first heat exchanger;
a second heat exchanger;
a compressor including a capacity modulation system providing first, second, and third operating capacities of said compressor, said second operating capacity being less than said first operating capacity and greater than said third operating capacity; and
a fluid conduit providing fluid communication between said first heat exchanger, said second heat exchanger, and said compressor, said fluid conduit defining a first flow path from said compressor to said first heat exchanger and from said first heat exchanger to said second heat exchanger when operating in a cooling mode and a second flow path from said compressor to said second heat exchanger and from said second heat exchanger to said first heat exchanger when operating in a heating mode, said compressor operating at said first operating capacity during said heating mode and operating at said second operating capacity during said cooling mode.

16. The heat pump system of claim 15, wherein said compressor includes a system rated capacity for said cooling mode corresponding to said second operating capacity.

17. The heat pump system of claim 15 or 16, wherein said first operating capacity is ten to thirty-five percent greater than said second operating capacity.

18. The heat pump system of any one of claims 15 to 17, wherein said third operating capacity is ten to thirty-five percent less than said second operating capacity.

19. The heat pump system of any one of claims 15 to 18, wherein said compressor is a scroll compressor.

20. A method comprising:

sealing a first leak path in communication with a first of pockets formed by meshingly engaged wraps of first and second scroll members of a scroll compressor operating at a first pressure and sealing a second leak path in communication with a second of the pockets formed by the meshingly engaged wraps of the first and second scroll members of the scroll compressor operating at a second pressure greater than the first pressure to operate the compressor at a first operating capacity during a heating mode of a

heat pump system;
opening the first leak path and closing the second leak path to operate the compressor at a second operating capacity that is reduced from the first operating capacity during a cooling mode of the heat pump system; and
opening the second leak path to operate the compressor at a third operating capacity that is reduced from the second operating capacity during the cooling mode.

21. The method of claim 20, wherein said operating the compressor at the first operating capacity includes operating the compressor at a capacity that is at least ten percent greater than the second operating capacity.

22. The method of claim 20 or 21, wherein said operating the compressor at the third operating capacity includes operating the compressor at a capacity that is at least ten percent less than the second operating capacity.

23. The method of any one of claims 20 to 22, wherein a seasonal energy efficiency ratio (SEER) rating is increased relative to operation at the second operating capacity during the cooling mode through operation of the compressor at the third operating capacity.

24. The method of any one of claims 20 to 23, wherein a heating seasonal performance factor (HSPF) rating is increased relative to operation at the second operating capacity during the heating mode through operation of the compressor at the first operating capacity.

25. The method of any one of claims 20 to 24, wherein the second operating capacity is a system rated capacity of the cooling mode.

26. The method of any one of claims 20 to 25, further comprising opening the first leak path to operate the compressor at the third operating capacity.

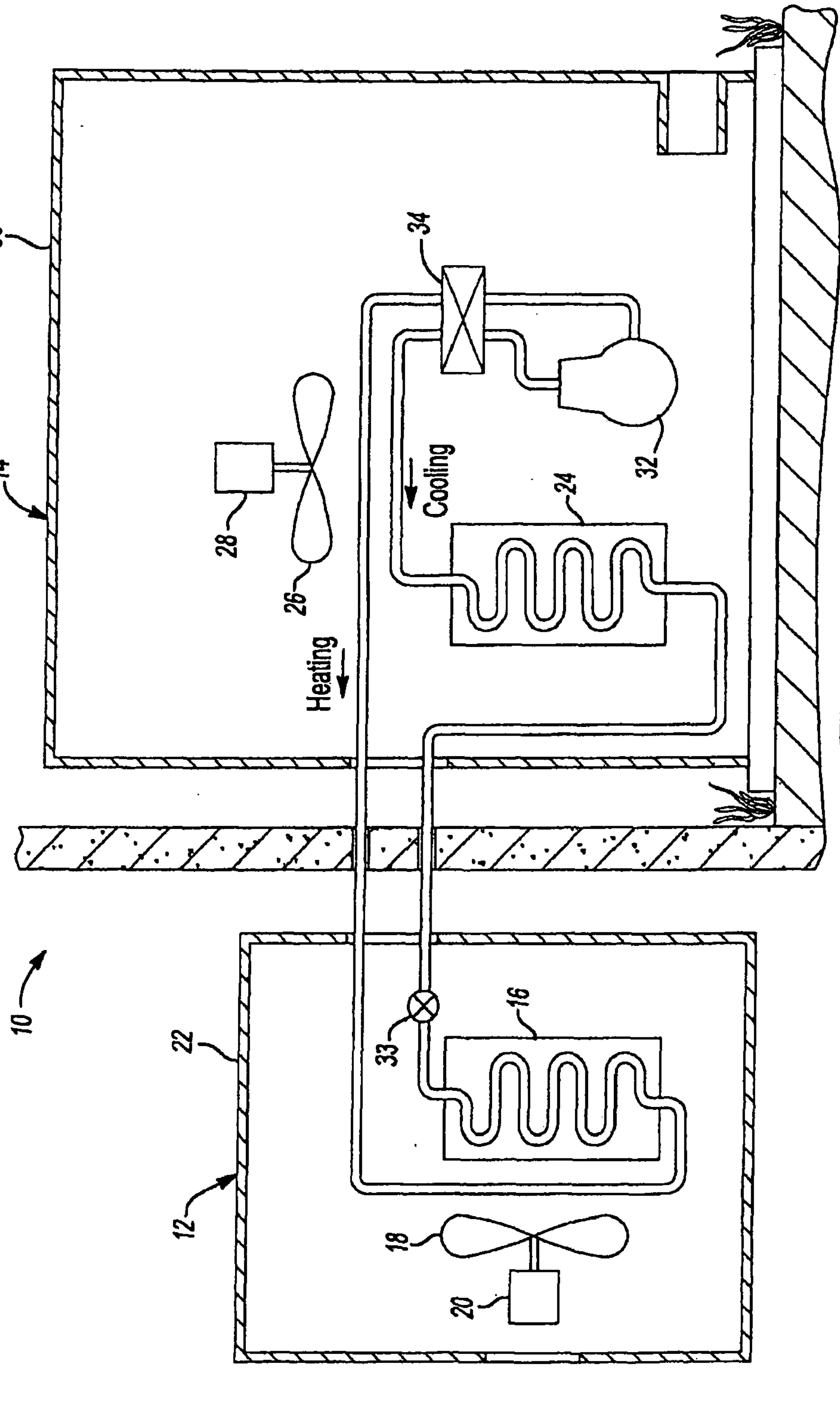

Fig-1

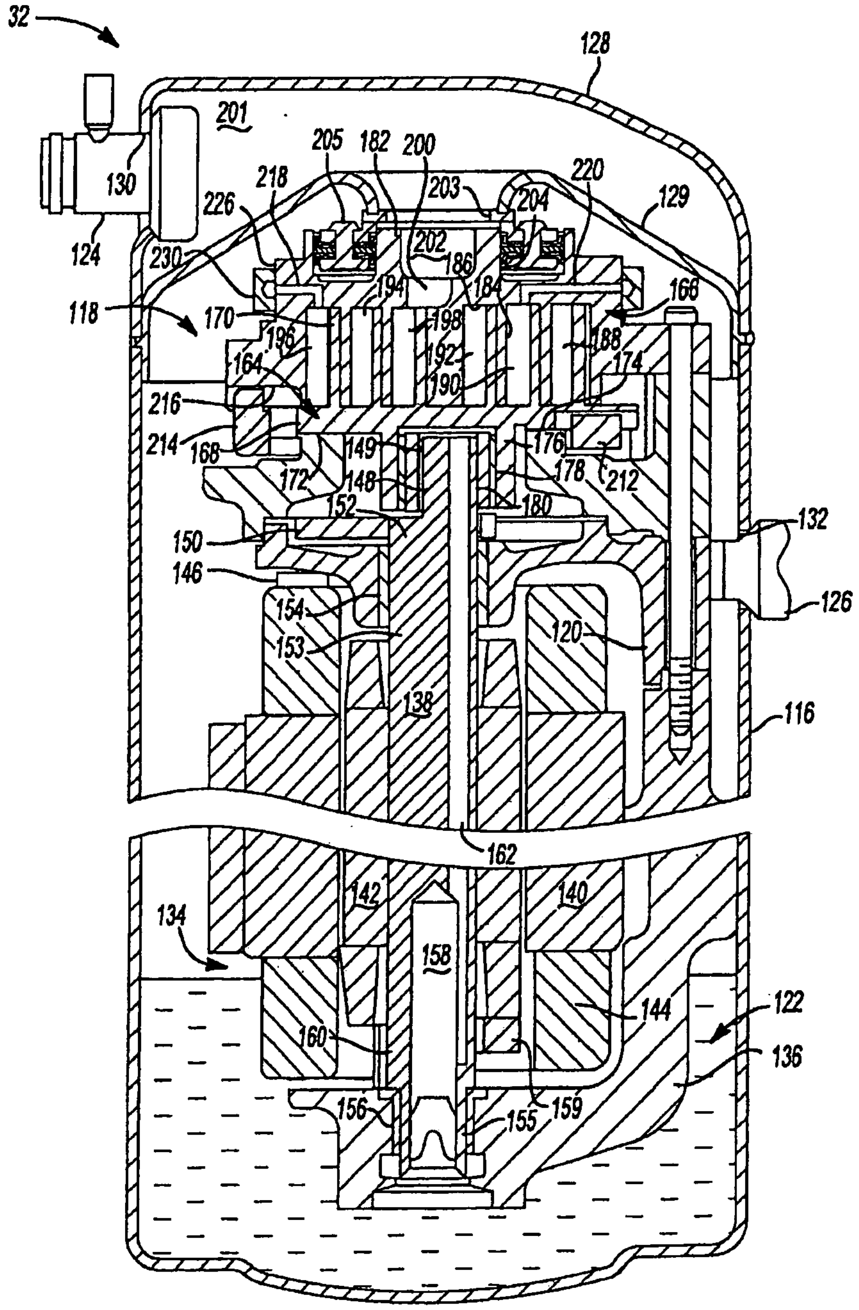
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Fig-2

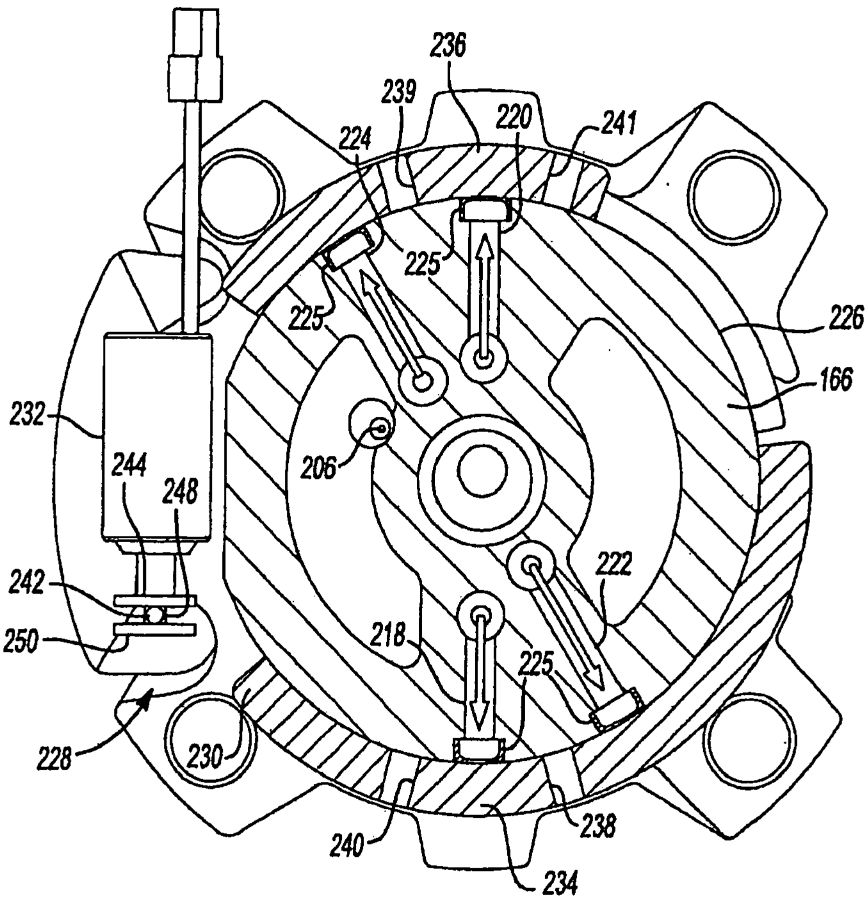
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Fig-3

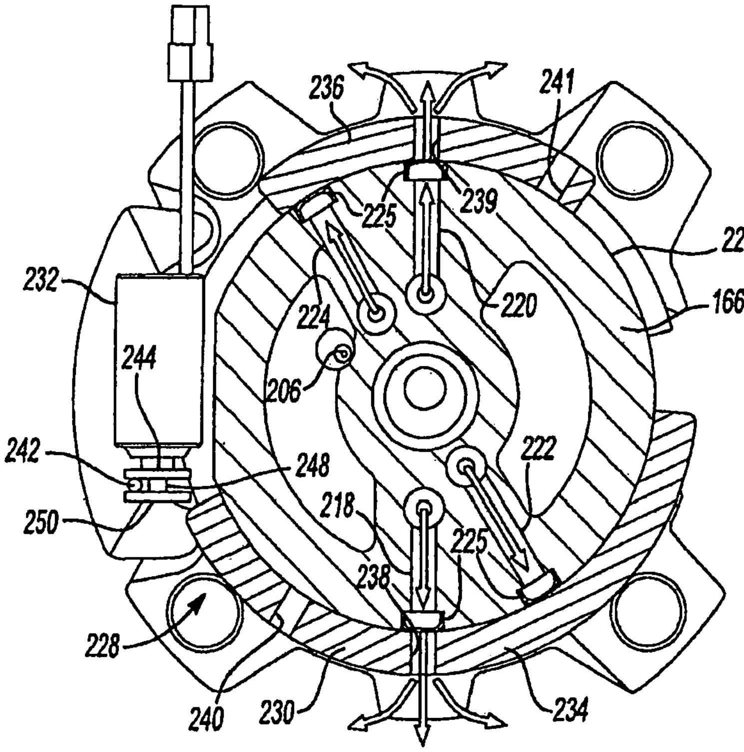
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Fig-4

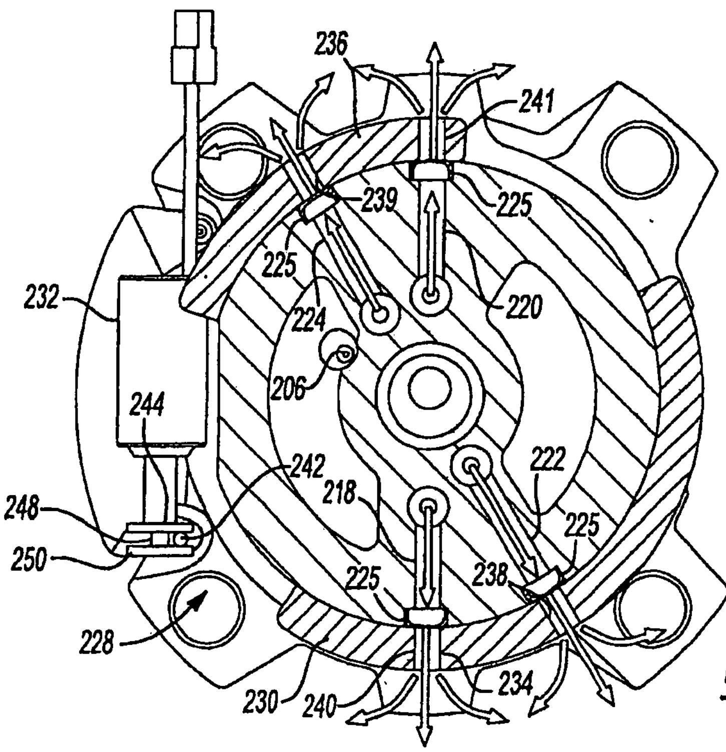
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Fig-5

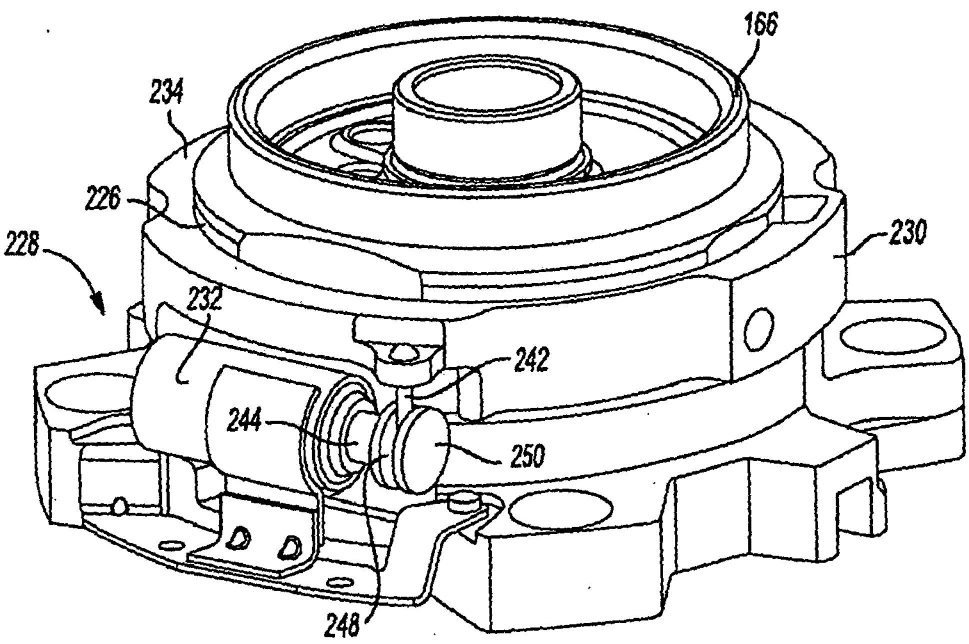

Fig-6

REFERENCES CITED IN THE DESCRIPTION

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