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(54) **Methods and apparatus for preventing degradation of electrical insulation properties within air conditioning circuits**

(57) Compressors (1) for air conditioning systems may compress fluids that contain a mixture of a refrigerant and a lubricating oil. The lubricating oil may pri-

marily consist of polyvinyl ether (PVE) oil and may be used for an air conditioning system. Such fluids preferably minimize the degradation of the electrical insulation properties of a vehicle air conditioning circuit.

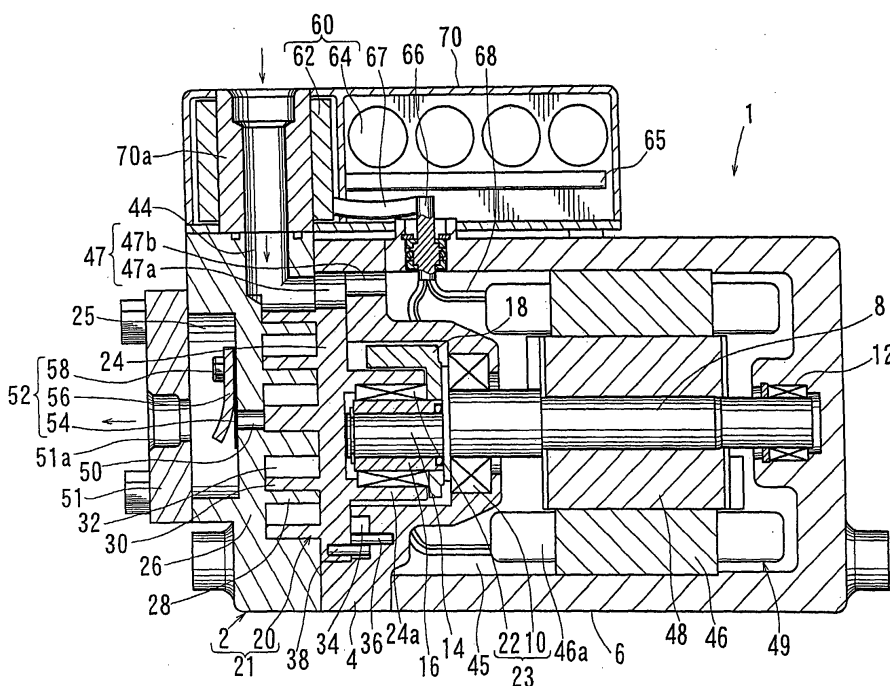


FIG. 2

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## Description

**[0001]** The present invention relates to compressors for use with vehicle air conditioning systems, in which a mixture of a refrigerant and a lubricating oil is compressed and highly pressurized by the compressor and is then discharged into an air conditioning circuit.

**[0002]** Japanese Laid-open Patent Publication No. 10-338891 teaches an air conditioning system that is generally used for a room air conditioner. The air conditioning system serves to compress and highly pressurize a refrigerant and then discharge the refrigerant into an air conditioning circuit, so that the refrigerant is circulated within the air conditioning circuit in order to perform an air conditioning operation. In order to provide good lubrication properties to the refrigerant, polyvinyl ether (PVE) was mixed with the refrigerant as a lubricating oil.

**[0003]** In the air conditioning system of above-identified Japanese publication, the lubricating oil (PVE) also absorbs moisture that has been drawn into the air conditioning circuit. Thus, the lubricating oil (PVE) serves a dual function of providing lubricating properties and serving as a desiccant. Therefore, the lubricating properties of the refrigerant can be maintained while also removing moisture within the system without adding an additional desiccant solely for the purpose of desiccation. In addition, the above-noted, dual function lubricating oil is advantageous, because the air conditioning system may be prevented from clogging due to the generation of fine-grained particles, which is a problem with common desiccants.

**[0004]** However, the above-identified Japanese publication only describes a technique for using the lubricating oil to provide lubricating properties and to absorb moisture that has been drawn into the air conditioning circuit. Thus, the above-identified Japanese publication does not propose any techniques that are particularly directed to electrical insulation properties that may be influenced by moisture within the air control system. In general, if moisture enters into the air conditioning circuit, the electrical insulation properties may be degraded. This may cause various problems, such as current leakage along connections of electric lines within a motor circuit. The current leakage problem is particularly serious in the case of vehicle air conditioning circuits, because vehicle air conditioning circuits are exposed to the outside environment. Thus, there is a high likelihood that moisture will enter into the air conditioning circuit.

**[0005]** Therefore, the inventors of the present invention have focused on the fact that a lubricating oil, which is intrinsically mixed with a refrigerant in order to provide lubrication, also can be effective to ensure proper electrical insulation. Consequently, the inventors have studied changes in electrical insulation properties (insulation resistance) in relation to changes in the type of lubricating oil that is mixed with the refrigerant. As a result, the inventors have found that the use of a PVE lubricating

oil, which primarily consists of PVE, may solve the problem of degradation of the electrical insulation properties in the air conditioning circuit. In addition, the lubricating oil can provide useful lubrication properties.

**[0006]** Therefore, one object of the present teachings is to provide improved vehicle air conditioning system that can effectively prevent degradation of electrical insulation properties within air conditioning circuits.

**[0007]** In one of the aspect of the present teachings, compressors for air conditioning systems are taught that use a fluid that contains a mixture of a refrigerant and a lubricating oil. The lubricating oil may primarily consist of polyvinyl ether (PVE) oil and may be used for an air conditioning system. Such a fluid minimizes the degradation of electrical insulation properties of a vehicle air conditioning circuit. This technique is not a simple application of a polyvinyl ether (PVE) oil as a lubricating oil, but is a special application of the lubricating oil, which primarily consists of the PVE oil, based on the newly found effectiveness of the PVE oil for minimizing the degradation of the electrical insulation properties. In particular, this technique can minimize or eliminate possible current leakage that may be caused at electrically conductive portions of an electric motor within a vehicle air conditioning circuit.

**[0008]** In another aspect of the present teachings, vehicle air conditioning systems are taught that may include such compressors and such fluid mixtures.

**[0009]** Additional objects, features and advantages of the present invention will be readily understood after reading the following detailed description together with the accompanying claims and drawings, in which:

FIG. 1 is a schematic view of a representative vehicle air conditioning system that is mounted within an engine compartment;

FIG. 2 is a vertical cross-sectional view of a representative scroll compressor; and

FIG. 3 is a graph showing the correlation between moisture concentration in PVE and insulation resistance.

**[0010]** In one embodiment of the present teachings, compressors for vehicle air conditioning systems may include a flow path that connects a suction region to a discharge region for a fluid. An electrically conductive portion may be disposed within the flow path. The fluid in the flow path may be compressed, highly pressurized and then discharged into a refrigerant circuit. The fluid may contain a mixture of a refrigerant and a lubricating oil, which primarily consists of polyvinyl ether oil. Preferably, the refrigerant may comprise a hydro fluorocarbon (HFC), e.g., an R-134a HFC refrigerant.

**[0011]** The electrically conductive portions may, generally speaking, include electrical connecting portions to electric motors or other electrical devices. When moisture enters the flow path, the electric insulation properties of the electrically conductive portion may be degraded.

ed and unintentionally result in current leakage. The electrically conductive portions may be positioned directly within the flow path or may be positioned in a channel that branches from the flow path.

**[0012]** The inventors have studied various lubricating oils and focused on the fact that PVE lubricating oils may provide excellent electrical insulation properties. Moreover, the inventors have studied the influence of moisture concentration within the PVE oil on the electrical insulation properties (electrical insulation resistance). As a result, the inventors have discovered that PVE lubricating oil provides excellent electric insulation properties when used in a vehicle air conditioning system. In addition, the PVE lubricating oil also imparts lubrication properties to the refrigerant. Experimental results have shown that the electrical insulation resistance of the PVE lubricating oil is higher than the electrical insulation resistance of an ester lubricating oil, which is typically used to impart lubrication properties to the refrigerant. Because the insulation resistance of the PVE lubricating oil is properly maintained, the possibility of current leakage at the electrically conductive portions may be minimized as long as the electrically conductive portions are disposed in communication with the PVE lubricating oil. Thus, even if moisture has entered the flow path in which the electrically conductive portions are positioned, degradation of the electrical insulation properties within the vehicle air conditioning circuit may be minimized or eliminated. In this specification, the term "vehicle" is intended to encompass electric trains, engine trains or any other types of vehicles, in addition to automobiles.

**[0013]** In another embodiment of the present teachings, the compressors may include a compression mechanism for compressing the fluid and an electric motor for driving the compression mechanism. Thus, in this embodiment, the compressor is constructed as an electrically driven compressor. Therefore, when the electric motor is started, the fluid (i.e., the mixture of the refrigerant and the lubricating oil) may be drawn into the compressor and compressed, thereby highly pressurizing the fluid. The pressurized fluid is then discharged into the refrigerant circuit. The compression mechanism may include, e.g., a scroll compression mechanism and a reciprocating compression mechanism. The scroll compression mechanism may include a movable scroll that revolves relative to a fixed scroll in order to compress the fluid. In the alternative, the reciprocating compression mechanism may include a piston that reciprocates within a cylinder in order to compress the fluid.

**[0014]** The compressor also may include an electric connecting section for the electric motor. The electric connecting section may be the electrically conductive portion, so that the electric connecting section communicates with the flow path. Therefore, the fluid (i.e., the mixture of the refrigerant and the lubricating oil) preferably contacts the electric connecting section of the motor. In this case, the electric connecting section may electrically connect the motor to an outside power

source and may include conductor lines and/or connection pins. Because the insulation resistance of the PVE lubricating oil is properly maintained, the possibility of current leakage may be minimized as long as the PVE lubricating oil contacts the electric connecting section. Thus, even if moisture has entered into the flow path in which the electric connecting section is positioned, the occurrence of current leakage at the electric connecting section, due to moisture entering into the vehicle air conditioning circuit, can be reliably avoided.

**[0015]** In another embodiment of the present teachings, the compressor may include a substantially sealed motor chamber that accommodates the electric motor, and a communication channel that connects the motor chamber to the flow path. The electric connecting section of the electric motor may communicate with the flow path via the communication channel. With this arrangement, a portion of the fluid that flows through the flow path may be brought into a condition known as "stagnation condition" within the motor chamber. In addition, when a difference in pressure exists between the flow path and the motor chamber, the fluid may flow so as to equalize the pressure differences. As a result, heat may be transferred between the fluid in the flow path and the fluid in the motor chamber. Thus, the fluid may effectively cool the electric motor within the motor chamber. Because the electric motor may be cooled by only a portion of the fluid that flows through the flow path, the temperature of the entire fluid may not be significantly increased. Therefore, an increase in the specific volume of the refrigerant drawn into the compressor may be avoided, thereby eliminating this influence on the compression work performed by the compressor. Consequently, the cooling operation of the electric motor using the fluid or the refrigerant can be efficiently performed.

**[0016]** In another embodiment of the present teachings, the compressor may be mounted to an engine, which serves as a drive source for the vehicle. In addition, the fluid flow path, through which the fluid or the mixture of the refrigerant and the PVE lubricating oil flows, is connected to a flow line, which flow line may be formed of rubber. In other words, the flow path may be connected to the flow line that is partially or entirely made of rubber. Such a flow line may be a relatively low pressure flow line that is connected to the suction side region of the flow path or may be a relatively high pressure flow line that is connected to the discharge side region of the flow path. In addition, the flow line on the side of the air conditioning circuit or on the side of the compressor may be partially or entirely formed of rubber.

**[0017]** If the compressor of the air conditioning system is directly mounted to a vehicle engine that generates vibrations and noise, the vibrations and noises may be transmitted to the compressors or other parts. Therefore, a portion of a flow line around the compressor is typically formed of rubber in order to dampen such vibrations and noise. However, if a portion of the flow line

is formed of rubber, moisture from the ambient air may pass through the flow line and may enter into the air conditioning circuit. Entrance of moisture into the air conditioning circuit is inevitable as long as the flow line is formed of rubber. According to one embodiment of the present teachings, the conductor section, such as an electric connecting portion to the electric motor, is preferably in contact with the PVE lubricating oil within the fluid mixture. In this case, the possibility of the current leakage at the conductor section can be minimized, even when moisture has entered into the air conditioning circuit through the rubber flow line. Therefore, this embodiment is particularly advantageous for the arrangement in which the compressor is directly mounted to the vehicle engine when it is likely that moisture from the ambient air will enter into the refrigerant circuit.

**[0018]** In another embodiment of the present teachings, the air conditioning system may perform an air conditioning operation by circulating the fluid (i.e., the mixture of the refrigerant and the PVE lubricating oil) within the air conditioning circuit by means of the compressor.

**[0019]** Therefore, degradation in the electrical insulation properties of the air conditioning circuit can be minimized even if the electrically conductive portion of the compressor or any other electric device is positioned within the flow path of the compressor. Therefore, the possibility of current leakage at the electrically conductive portion due to moisture entering the refrigerant circuit can be minimized.

**[0020]** Each of the additional features and teachings disclosed above and below may be utilized separately or in conjunction with other features and teachings to provide improved compressors and air conditioning systems and methods for designing and using such compressors and air conditioning systems. A representative example of the present invention, which example utilizes many of these additional features and teachings both separately and in conjunction, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skill in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detail description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative example and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful embodiments of the present teachings.

**[0021]** The representative embodiment of the present teachings may be applied to a scroll compressor that increases the pressure of the introduced refrigerant by compression within a compression chamber that is defined between a fixed scroll and a movable scroll. The

refrigerant is then discharged as compressed refrigerant.

**[0022]** A representative embodiment of the present invention will now be described with reference to the drawings, which show a representative vehicle air conditioning system 100 that may include a compressor, e. g. a scroll compressor 1. The scroll compressor 1 may generally include a fixed scroll 2 and a movable scroll 20 that together define a compression chamber 32. Fluid, such as the refrigerant and the lubricating oil, may be compressed within the compression chamber 32 and the pressurized fluid may then be discharged from the compression chamber 32 as will be hereinafter described. The air conditioning system 100 may be installed within an automobile as schematically shown in FIG. 1. The scroll compressor 1 is shown in a vertical cross-sectional view in FIG. 2.

**[0023]** Referring to FIG. 1, the vehicle air conditioning system 100 may be disposed within an engine compartment of the automobile. Further, in addition to the scroll compressor 1, the air conditioning system 100 optionally may include a condenser 102, a receiver 103 and a cooling unit 104, as well as flow lines that connect these parts to each other. The cooling unit 104 may preferably be equipped with an expansion valve and an evaporator (not shown). The scroll compressor 1 may adiabatically compress the refrigerant and the highly pressurized refrigerant may be supplied to the condenser 102 via a discharge flow line 105. The refrigerant then may flow into the receiver 103. The refrigerant may be liquefied by the condenser 102 and the receiver 104 and then may be evaporated due to the throttling and expanding operation of the expansion valve. Thereafter, the refrigerant vapor may be heat-exchanged at the evaporator. Therefore, the air may be cooled, because the evaporated refrigerant vapor may absorb heat from the air to be conditioned. As a result, the refrigerant vapor may be converted into saturated vapor through isobaric vaporization and may be fed into the scroll compressor 1 via an inlet flow line 107. The scroll compressor 1 may again compress the vapor fed into the scroll compressor 1. The scroll compressor 1 and the various parts that are connected to the scroll compressor 1 via the corresponding flow lines may thus define the air conditioning circuit.

**[0024]** Preferably, the refrigerant may be a HFC refrigerant that primarily contains R-134a hydro-fluorocarbon. In addition, the PVE lubricating oil that primarily contains PVE is preferably mixed with the refrigerant before the mixture is introduced into the air conditioning system 100. Thus, in this representative embodiment, the mixture of the HFC refrigerant and the PVE lubricating oil may be compressed and highly pressurized by the scroll compressor 1 and then may be supplied into the air conditioning circuit. The PVE lubricating oil is known to have an excellent compatibility with the HFC refrigerant and may serve to provide a lubricating function to the HFC refrigerant due to the lubricating prop-

erties that are intrinsic to the lubricating oil.

**[0025]** The scroll compressor 1 may be directly mounted to an engine E of the automobile. The engine E may be mechanically coupled to an alternator (not shown) that generates electric current. The electric current may be supplied to an electric motor 49, which is associated with the scroll compressor 1, via an inverter 60.

**[0026]** The discharge flow line 105 may include a high pressure hose 106 made of rubber, in addition to a high pressure pipe made of metal. Further, the inlet flow line 107 may include a low pressure hose 108 made of rubber, in addition to a low pressure pipe made of metal. This arrangement may be advantageous to minimize the influence of vibrations or noise produced by the engine E on the other parts via the scroll compressor 1, which is directly mounted to the engine E. In general, rubber flow lines may be used rather than metal flow lines if the flow lines are used in places in which vibrations or noises will cause problems. However, it has been known that moisture within the ambient air can pass through the walls of rubber flow lines and may enter into the air conditioning circuit. In particular, in the case of vehicle air conditioning systems, e.g. the air conditioning system 100 as in this representative embodiment, which are exposed to the outside environment, there is a limitation on preventing the passage of moisture through the walls of the rubber flow lines when the flow lines are made of rubber.

**[0027]** Referring to FIG. 2, the scroll compressor 1 may have a center housing 4 that has one end surface and one end surface of the fixed scroll 2 is joined to the center housing 4. A motor housing 6 may be joined to the other end surface of the center housing 4. The center housing 4, the motor housing 6 and the fixed scroll 2 may constitute a body portion of the scroll compressor 1. A drive shaft 8 may be rotatably supported by the center housing 4 and the motor housing 6 by means of respective radial bearings 10 and 12. An eccentric shaft 14 may be integrally formed with a portion of the drive shaft 8 on the side of the center housing 4 and may have an axis that is offset from the axis of the drive shaft 8. A bush 16 may be fitted onto the eccentric shaft 14, so that the bush 16 can rotate together with the eccentric shaft 14. A balance weight 18 may be mounted on one end of the bush 16, so that the balance weight 18 can rotate together with the bush 16. The movable scroll 20 may be rotatably mounted on the other end of the bush 16 by means of a needle bearing 22 and may be disposed opposite to the fixed scroll 2. The fixed scroll 2 and the movable scroll 20 and their related elements may define a compression mechanism 21 that serves to compress the drawn fluid or the mixture of the refrigerant and the lubricating oil. The needle bearing 22 may be received within a tubular boss portion 24a that extends from a rear surface (right side surface as viewed in FIG. 1) of a disk-like base plate 24 of the movable scroll 20. The needle bearing 22 and the radial bearing

10 may define a bearing mechanism 23 for the movable scroll 20.

**[0028]** The fixed scroll 2 may include an involute-shaped scroll wall 28 that extends from and perpendicular to one side surface of a disk-like base plate 26. Similarly, the movable scroll 20 may include an involute-shaped scroll wall 30 that extends from and perpendicular to one side surface of the base plate 24. The fixed scroll 2 and the movable scroll 20 may be arranged such that the scroll wall 28 engages the scroll wall 30.

**[0029]** The scroll wall 28 of the fixed scroll 2 may slidably contact the scroll wall 30 of the movable scroll 20 at a plurality of positions. Further, a crescent-like compression chamber (sealed space) may be defined between the fixed scroll 2 (and its related base plate 26 and the scroll wall 28) and the movable scroll 20 (and its related base plate 24 and the scroll wall 30). The movable scroll 20 may revolve (orbit) as the eccentric shaft 14 revolves. The balance weight 18 may serve to cancel centrifugal force that may be produced when the movable scroll 20 revolves. Thus, the rotation of the drive shaft 8 may be transmitted to the movable scroll 20 so as to orbitally move the movable scroll 20 via the eccentric shaft 14 (that rotates with the drive shaft 8), the bush 16 and the needle bearing 22 that is disposed between the eccentric shaft 14 and the boss portion 24a of the movable scroll 20.

**[0030]** A plurality of recesses (e.g. four recesses) 34 may be formed in the end surface of the center housing 4. The recesses 34 may be equally spaced from each other in a circumferential direction along a circle. The recesses 34 may serve to prevent the movable scroll 20 from rotating around its own axis. For example, a plurality of sets of a first pin 36 and a second pin 38 may be fixedly mounted on the center housing 4 and the base plate 24 of the movable scroll 20, respectively. Both the first and second pins 36 and 38 of each set may extend into the corresponding recess 34. Therefore, the recess 34 and the related first and second pins 36 and 38 may cooperate to form a rotation prevention mechanism that prevents the movable scroll 20 from rotating around its axis even when the eccentric shaft 14 revolves.

**[0031]** A discharge valve 52 may be disposed on the base plate 26 of the fixed scroll 2 and may preferably be configured as a reed valve that is operable to open and close a discharge port 50. The discharge valve 52 may include a reed valve member 54, a valve retainer 56 and a fixing bolt 58 that serves to mount the reed valve member 54 and the valve retainer 56 onto the base plate 26 of the fixed scroll 2. The discharge valve 52 may be disposed within a discharge chamber 25 that is defined within the base plate 26 of the fixed scroll 2. The reed valve member 54 may open and close in response to the difference between the pressure within the compression chamber 32, which communicates with the discharge port 50, and the pressure within the discharge chamber 25. Thus, the reed valve member 54 may open when the pressure within the compression

chamber is higher than the pressure within the discharge chamber 25. On the other hand, the reed valve member 54 may close when the pressure within the compression chamber is lower than the pressure within the discharge chamber 25. The valve retainer 56 may serve to retain the reed valve member 54 and also may serve to limit the maximum open degree of the reed valve member 54. A rear cover 51 may cover the discharge chamber 25 and may have an outlet port 51a, to which the discharge flow line 105 of the air conditioning circuit is connected.

**[0032]** The fixed scroll 2, the center housing 4 and the motor housing 6 may constitute a casing that has an outer peripheral portion. The inverter 60 that controls the electric motor 49 may be mounted on the outer peripheral portion of the casing. Preferably, the inverter 60 may include, e.g., a switching element 62 and a capacitor 64. The switching element 62 may generate a relatively large amount of heat, while the capacitor 64 may generate a relatively small amount of heat. These components may be accommodated within an inverter casing 70, and the large-heat generating components may be separated from the small-heat generating components. The switching element 62 may be disposed on the periphery of a cylinder 70a, and the capacitor 64 may be disposed on a mounting plate 65. One end of the cylinder 70a of the inverter case 70 may be connected to the suction port 44, and the other end of the cylinder 70a may be connected to the suction flow line 107.

**[0033]** The switching element 62 within the inverter case 70 may be connected to the electric motor 49 within the motor housing 6 via three conductor pins 66 (that extend through the motor housing 6 and the inverter case 70) and conductor lines 67 and 68. In this case, the electric current for driving the electric motor 49 may be supplied via the conductor pins 66 and the conductor lines 67 and 68. Thus, the conductor pins 66 and the conductor lines 68 and the other associated elements may constitute an electrical connecting section for supplying the current to the electric motor 49.

**[0034]** The conductor line 68 may be connected to a stator coil 46a of the electric motor 49 at one side of the electric motor 49 proximal to the compression mechanism. Preferably, the inverter 60 may be integrally coupled to the housing, and the inverter 60 may be connected to the electric motor 49 at an outer peripheral portion in a diametrical direction of the housing. This arrangement may minimize the size of the compression mechanism 1 in an axial direction of the housing in comparison with an arrangement, in which an inverter and its associated parts are disposed on the outer side of the housing in the axial direction.

**[0035]** The electrical connecting portions of the electric motor 49 and the inverter 60 may be positioned proximal to each other, so that the electric motor 49 may be connected to the inverter 60 using the shortest distance. Therefore, the wiring length between the electric motor 49 and the inverter 60 may be minimized. As a result,

the material cost and weight of the necessary connecting wires can be reduced, and a possible voltage drop can be suppressed, thereby improving the performance of the electric motor 49.

**[0036]** A stator 46 having the stator coil 46a may be secured to the inner wall of the motor housing 6. A rotor 48 may be secured to the drive shaft 8. Thus, the drive shaft 8, the stator 46 and the rotor 48 may constitute the electric motor 49, and the rotor 48 and the drive shaft 8 may rotate together when current is supplied to the stator coil 46a. The electric motor 49 thus constructed may be accommodated within a sealed motor chamber 45 that is defined by the motor housing 6 and the center housing 4.

**[0037]** The eccentric shaft 14 may rotate as the drive shaft 8 rotates, so that movable scroll 20 revolves or orbits around the drive shaft 8. As the movable scroll 20 revolves, a fluid, e.g., a refrigerant, may be drawn from the outer peripheral side of the fixed scroll 2 and the movable scroll 20 via the suction port 44 formed in the fixed scroll 2 and may enter between the base plate 26 of the fixed scroll 2 and the base plate 24 of the movable scroll 20. On the other hand, each second pin 38 slidably revolves around the periphery of the corresponding first pin 36 as the movable scroll 20 revolves. Therefore, the movable scroll 20 that is rotatably supported by the eccentric shaft 14 by means of the needle bearing 22 does not rotate around its own axis relative to the fixed scroll 2 as the eccentric shaft 13 rotates. As the movable scroll 20 thus revolves, the fluid drawn via the suction port 44 may flow into the compression chamber 32 and may move toward the center of the fixed scroll 2 while the degree of compression of the fluid is successively increased. Therefore, the fluid may be highly pressurized and such highly pressurized fluid may flow into the discharge port 50 that is formed in the central portion of the base plate 26 of the fixed scroll 2 and communicates with the compression chamber 32, where the fluid has the highest pressure. The highly pressurized fluid may then flow into the discharge flow line 105 of the air conditioning circuit via an outlet 51a.

**[0038]** The central housing 4 may separate the compression mechanism 21 from the motor chamber 45 and may include a communication channel 47. The communication channel 47 may connect the motor chamber 45 to a suction side region of the flow path formed in the compression mechanism 21 between the suction side region and a discharge side region. More specifically, the drawn fluid may enter a space 47a defined between the outer peripheral surface of the base plate 24 of the movable scroll 20 and the inner wall surface of the space for accommodating the base plate 24. The space 47a may further communicate with the motor chamber 45 via a communication hole 47b formed in the center housing 4. Thus, the space 47a and the communication hole 47b may define the communication channel 47. The communication channel 47 may be designed such that the communication channel 47 always permits fluid

flow through the flow path irrespective of changes in the position of the base plate 24 of the movable scroll 20 that revolves within the scroll accommodating space during the operation of the compressor 1. As a result, heat may be transferred between the fluid on the side of the flow path and the fluid on the side of the motor chamber 45 via the communication channel 47. More specifically, the heat of the fluid on the side of the motor chamber 45, which may be a high- temperature side, may be transferred to the side of the flow path. Due to this heat transfer, the electric motor 49 may be cooled. Thus, when a pressure difference exists between the motor chamber 45 and the suction side region, the fluid may flow through the communication channel 75. Therefore, the heat may be transferred with such fluid flow, so that the electric motor 49 may be cooled. As a result, the electric motor 49 may be prevented from overheating.

**[0039]** The cooling operation described above does not accompany the flow of a large volume of fluid as in known cooling systems, in which a motor chamber is designed to provide a fluid flow path, and may be referred to as a "stagnation cooling operation". In addition, because only a portion of the fluid that flows through the flow path may directly contribute to the "stagnation cooling operation", the temperature of the entire fluid may not be significantly increased. Therefore, an increase in the specific volume of the fluid can be avoided, and possible problems, e.g., degradation in the compression efficiency, can be eliminated.

**[0040]** This representative embodiment is designed to cool the inverter 60 using the drawn fluid. However, the amount of heat that may be generated by the inverter 60 may be considerably smaller than the amount of heat that may be generated by the electric motor 49. Therefore, the increase in temperature of the drawn fluid that cools the inverter 60 may be very small in comparison with the increase in temperature of the fluid in the case that all the fluid flows through and within the motor chamber 45 in order to cool the electric motor 45. As a result, the compression efficiency may not be reduced.

**[0041]** In addition, the high pressure hose 106 of the discharge flow line 105 and the low pressure hose 108 of the suction flow line 107 are preferably made of rubber in this representative embodiment. Therefore, in the case of the air conditioning system 100 that is adapted to be exposed to the outside environment, a small amount of moisture may enter into the air conditioning circuit through the high pressure hose 105 or the low pressure hose 108. Moisture may then circulate within the air conditioning circuit together with the HFC refrigerant and the PVE lubricating oil. If moisture enters the motor chamber 45 of the scroll compressor 1 via the communication channel 47, a possibility may exist that the insulation resistance will be reduced, thereby causing current leakage at the conductor line 68 itself or near the conductor line 68. However, because the PVE lubricating oil, which primarily consists of PVE, is used in this

representative embodiment, the reduction in the insulation resistance may be minimized even if moisture has entered into the air conditioning circuit.

**[0042]** Thus, in order to prevent the degradation in the electrical insulation properties due to moisture that enters into the air conditioning circuit, the inventors studied changes in electrical insulation properties in relation to changes in the type of lubricating oil. As a result, the inventors have found that the use of a PVE lubricating oil, which primarily consists of PVE, may solve the problem of degradation in the electrical insulation properties of the fluid, while still imparting lubrication properties to the refrigerant.

**[0043]** The graph shown in FIG. 3 represents the correlation of moisture concentration in PVE with the insulation resistance in comparison with the correlation of moisture concentration in an ester with the insulation resistance. As will be seen from this graph, the PVE lubricating oil has a higher insulation resistance than the ester lubricating oil and will maintain the insulation resistance at a relatively higher value even if the moisture concentration has increased. In addition, the insulation resistance of the PVE lubricating oil may be consistently maintained to such a relatively higher value until the moisture reaches a saturation point. Therefore, it is recognized that the PVE lubricating oil is effective to minimize the reduction in the insulation resistance even if the flow lines of the air conditioning circuit are made of rubber, which rubber flow lines typically permit moisture to enter into the air conditioning circuit. Consequently, because of the relatively higher insulation resistance of the fluid imparted by the PVE lubricating oil, current leakage may be reliably prevented even if the electrical connecting portions of the electric motor 49, e.g., the conductor pin 66 and the conductor line 68 are directly expose to the fluid.

**[0044]** The inventors have confirmed the effective electrical insulation properties of the PVE refrigerator when used for the scroll compressor 1 of the representative embodiment under the following conditions: temperature: -30 to 150 °C, pressure: 0.2 to 2.5 MpaG, viscosity: 5 to 20 cSt (at 100°C).

**[0045]** As described above, according to the representative embodiment, the degradation in the electrical insulation properties of the air conditioning circuit in the vehicle air conditioning system 100, due to moisture entering into the air conditioning circuit, may be minimized. Therefore, current leakage, e.g. at the conductor pin 66 and the conductor line 68 or at the places in the vicinity of these parts, can be reliably avoided. In particular, the representative embodiment is advantageously applied in connection with the arrangement, in which ambient moisture may possibly enter into the air conditioning circuit (e.g., the arrangement in which the scroll compressor 1 is directly mounted on the engine E and the flow lines adjacent thereto are made of rubber).

**[0046]** The present invention is not limited to the above representative embodiment but may have vari-

ous applications and modifications. For example, the above representative embodiment may be modified in the following ways without departing from the scope of the present invention:

(A) Although the mixture of the HFC refrigerant and the PVE lubricating oil consisting primarily of PVE was used as a fluid that circulates within the air conditioning circuit in the representative embodiment, such a fluid also may contain the other types of compositions. For example, an extreme-pressure agent, e.g., tricresyl phosphate (TCP), may also be mixed with the fluid in order to prevent the compressor from seizing. Furthermore, an antioxidant agent, e.g., DBPC, may also be mixed with the fluid in order to prevent oxidization of the lubricating oil.

(B) Although the representative embodiment has been described in connection with a scroll compressor, the present invention also may be applied to the other kinds of compressors, e.g. reciprocating compressors, in which pistons reciprocally move within cylinder bores for compressing refrigerant.

(C) Although the representative embodiment has been described in connection with the vehicle air conditioning system 100, the present invention also may be applied to any other air conditioning systems that are not used for vehicles.

**[0047]** As explained above, the present invention can provide an improved air conditioning technique that can effectively minimize the degradation in the electrical insulation properties of the air conditioning circuit of the vehicle air conditioning system.

## Claims

1. Use of a lubricating oil that primarily consists of polyvinyl ether oil together with a refrigerant in a compressor for an air conditioning system, wherein the compressor comprises:

a fluid flow path connecting a suction region to a discharge region, the mixture of the lubricating oil and refrigerant flowing through the fluid flow path and being compressed and highly pressurized before being discharged into a refrigerant circuit; and

at least one electrically conductive portion that is in contact with the fluid flow path.

2. Use of a lubricating oil that primarily consists of a polyvinyl ether oil as in claim 1, wherein the compressor further includes a compression mechanism arranged and constructed to compress the fluid mixture, an electric motor arranged and constructed to drive the compression mechanism, and an electric connecting section for the electric motor, where-

in the electric connecting section comprises the electrically conductive portion, so that the electric connecting section is in contact with the flow path.

3. Use of a lubricating oil that primarily consists of a polyvinyl ether oil as in claim 2, wherein the compressor further includes a substantially sealed motor chamber that accommodates the electric motor, and a communication channel that connects the motor chamber to the flow path, wherein the electric connecting section of the electric motor communicates with the flow path via the communication channel.

4. Use of a lubricating oil that primarily consists of a polyvinyl ether oil as in any one of claims 1 to 3, wherein the compressor is mounted to an engine, which serves as a drive source of a vehicle, and the fluid flow path is connected to a flow line that is made of rubber.

5. Use of a lubricating oil that primarily consists of a polyvinyl ether oil as in as in any one of claims 1 to 4, wherein the air conditioning system being arranged and constructed to perform an air conditioning operation by circulating the fluid mixture within the refrigerant circuit by means of the compressor.

6. A method for preventing degradation of insulating properties within an air conditioning system, comprising:

circulating a mixture of a refrigerant and a lubricating oil that primarily consists of a polyvinyl ether oil within a compressor for the air conditioning system, wherein the compressor comprises a fluid flow path connecting a suction region to a discharge region, the mixture of the lubricating oil and refrigerant flows through the fluid flow path and is compressed and highly pressurized within the compressor before being discharged into a refrigerant circuit and at least one electrically conductive portion is in contact with the fluid flow path.

7. A method as in claim 6, wherein the at least one electrically conductive portion is prevented from degrading by the circulating lubricating oil.

8. A method as in claim 6 or 7, wherein the compressor further includes a compression mechanism arranged and constructed to compress the fluid mixture, an electric motor arranged and constructed to drive the compression mechanism, and an electric connecting section for the electric motor, wherein the electric connecting section comprises the electrically conductive portion, so that the electric connecting section is in contact with the fluid flow path.

9. A method as in claim 8, wherein the compressor further includes a substantially sealed motor chamber that accommodates the electric motor, and a communication channel that connects the motor chamber to the fluid flow path, wherein the electric connecting section of the electric motor communicates with the fluid flow path via the communication channel. 5
10. A method as in any of claim 6-9, wherein the compressor is mounted to an engine, which serves as a drive source of a vehicle, and the fluid flow path is connected to a flow line that is made of rubber. 10
11. A method as in any of claims 6-10, wherein the air conditioning system is arranged and constructed to perform an air conditioning operation by circulating the fluid mixture within the refrigerant circuit by means of the compressor. 15

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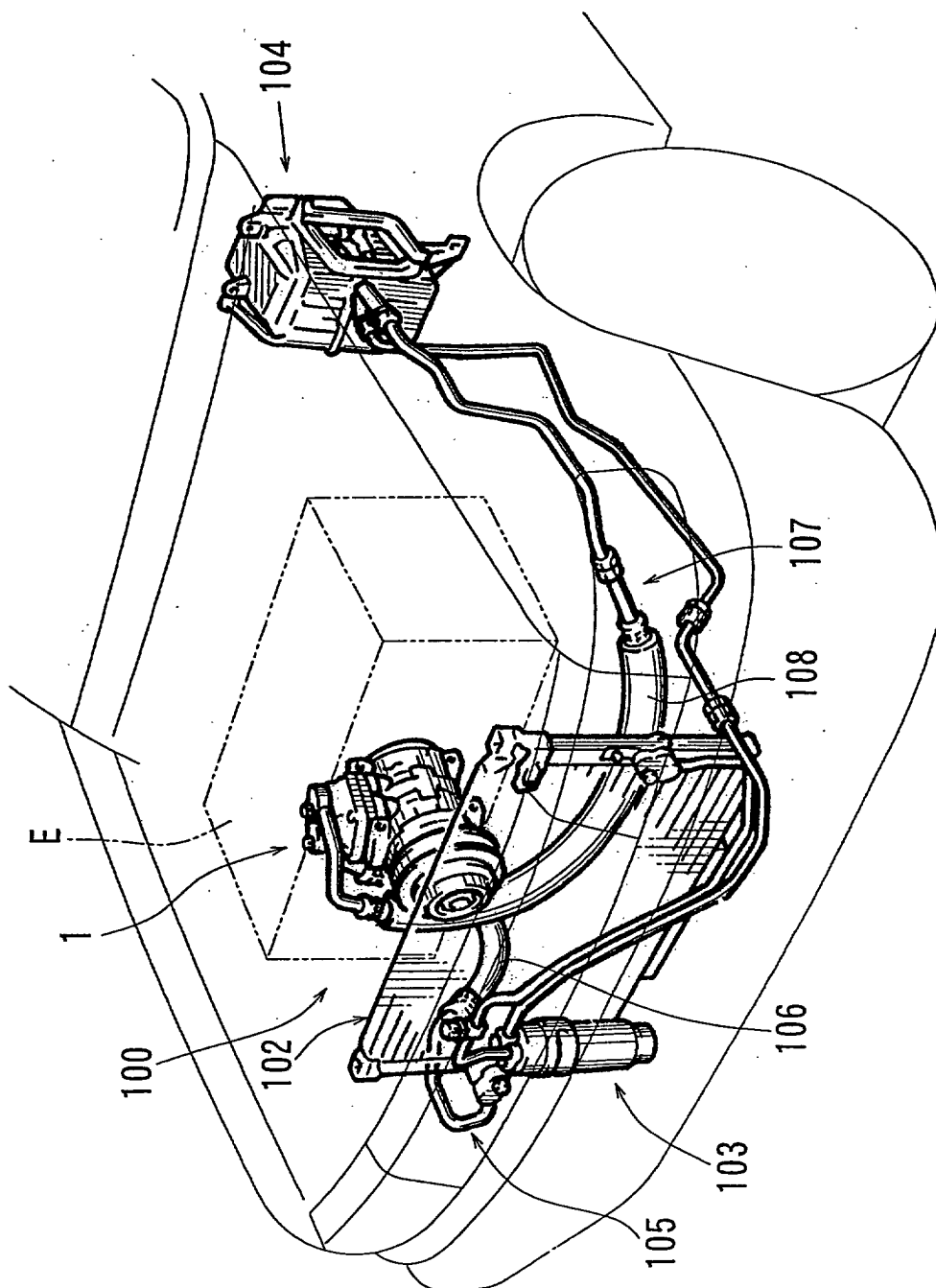


FIG. 1

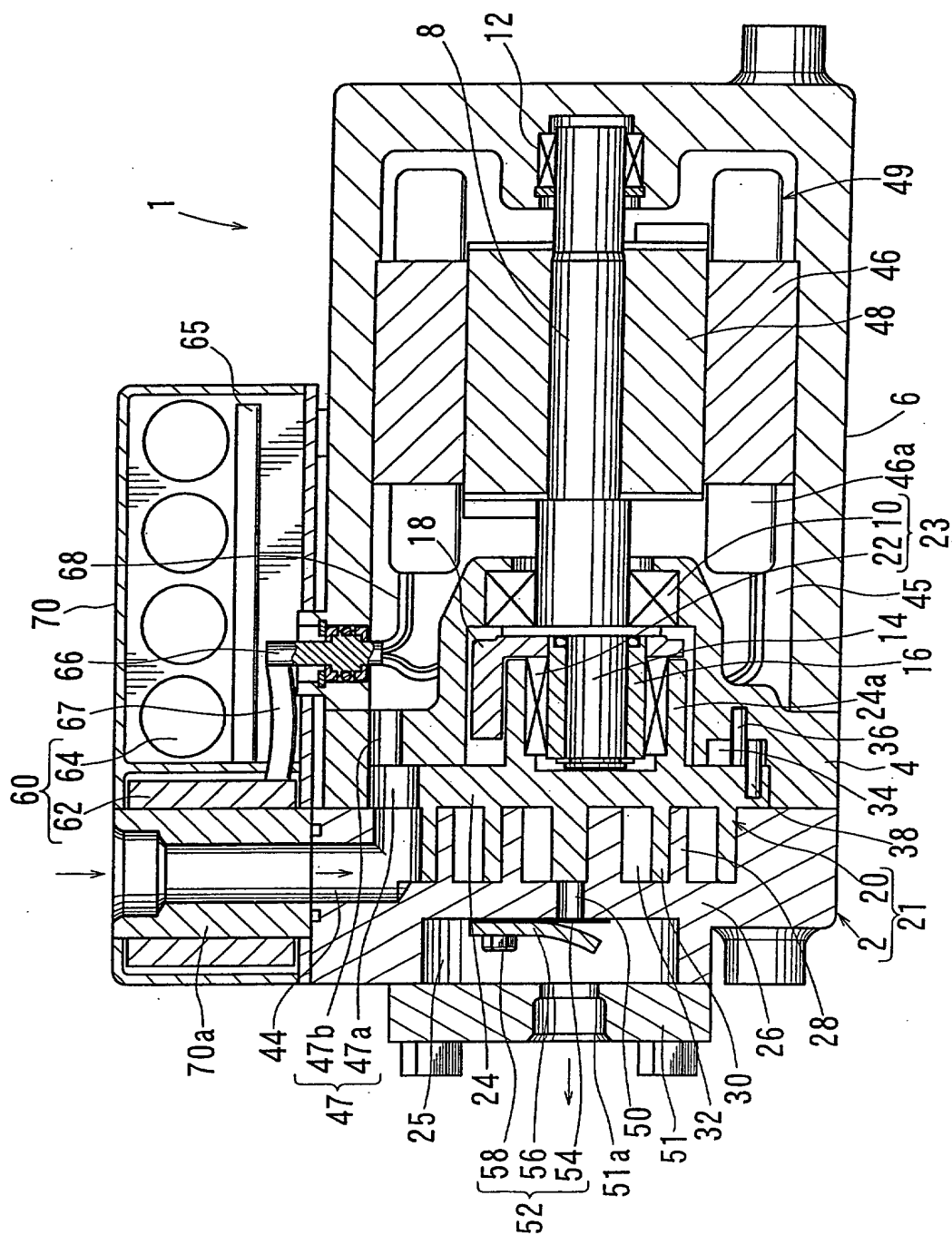


FIG. 2

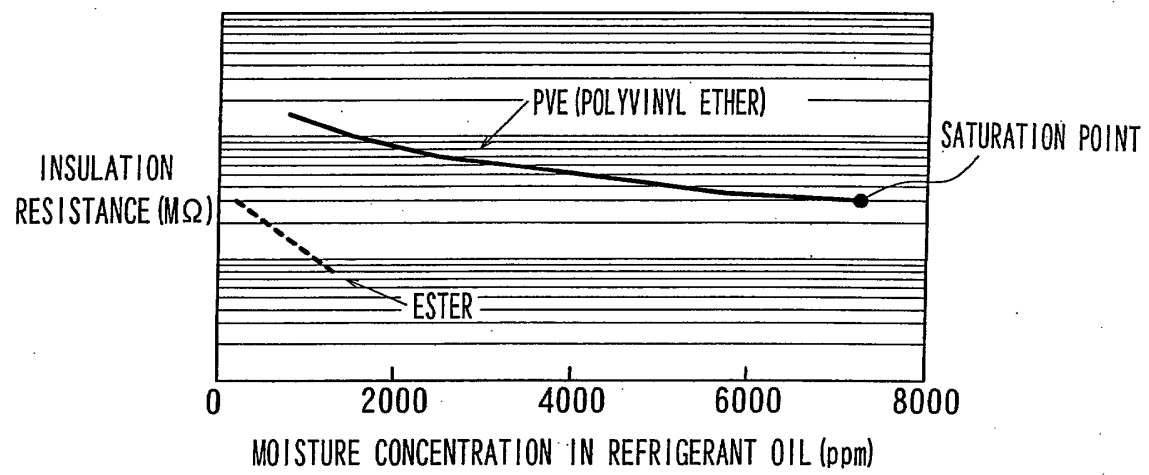


FIG. 3



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| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                             |                                                    |                                              |
| Place of search<br>MUNICH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                             | Date of completion of the search<br>23 August 2002 | Examiner<br>Kazemi, P                        |
| <p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone<br/>Y : particularly relevant if combined with another document of the same category<br/>A : technological background<br/>O : non-written disclosure<br/>P : intermediate document</p> <p>T : theory or principle underlying the invention<br/>E : earlier patent document, but published on, or after the filing date<br/>D : document cited in the application<br/>L : document cited for other reasons<br/>&amp; : member of the same patent family, corresponding document</p> |                                                                                                                                                                                                                             |                                                    |                                              |

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