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(54) SCREW COMPRESSOR

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(57) **ABSTRACT**

The present invention provides a screw compressor in which an oil path is provided within the casing body such that the oil for sealing gaps in the compression chamber and lubricating the bearings is circulated to the vicinity of the low pressure side, allowing the compressor to have high adiabatic efficiency and high volumetric efficiency. The present invention also provides a screw compressor in which an oil path is provided in the screw bore outer circumferential portion of the casing body to prevent contact between the screw rotor and the screw bore portion of the casing body. The present invention also provides a screw compressor which includes a heat sink to increase the heat transfer area for exchanging heat between the oil and refrigerant gas or liquid refrigerant, thereby achieving increased resistance to returned liquid refrigerant.

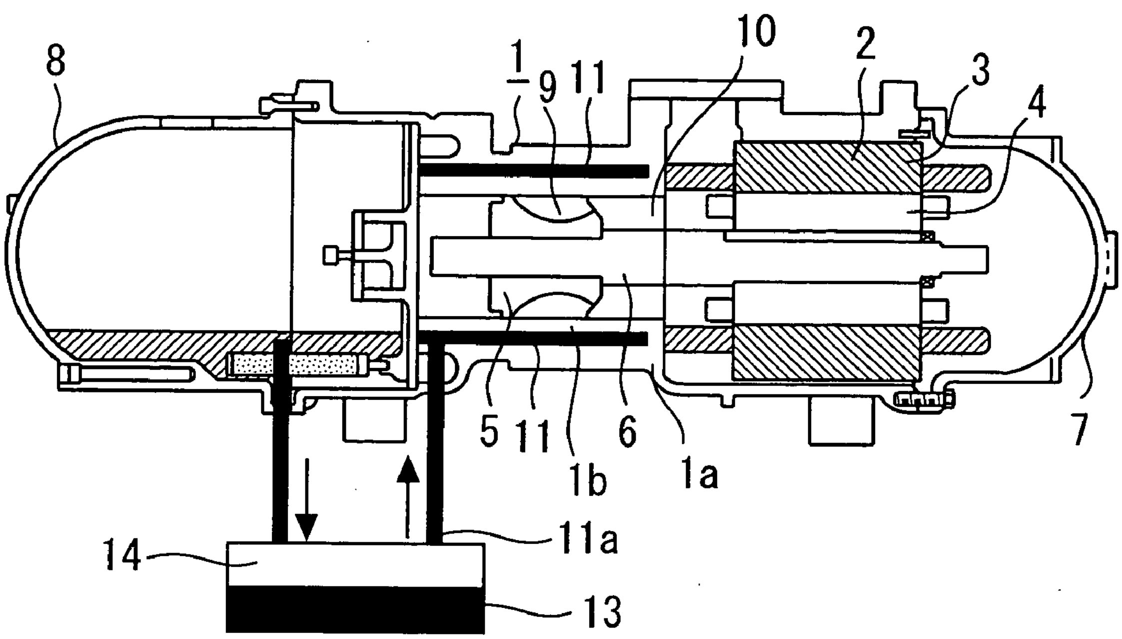


Fig. 1

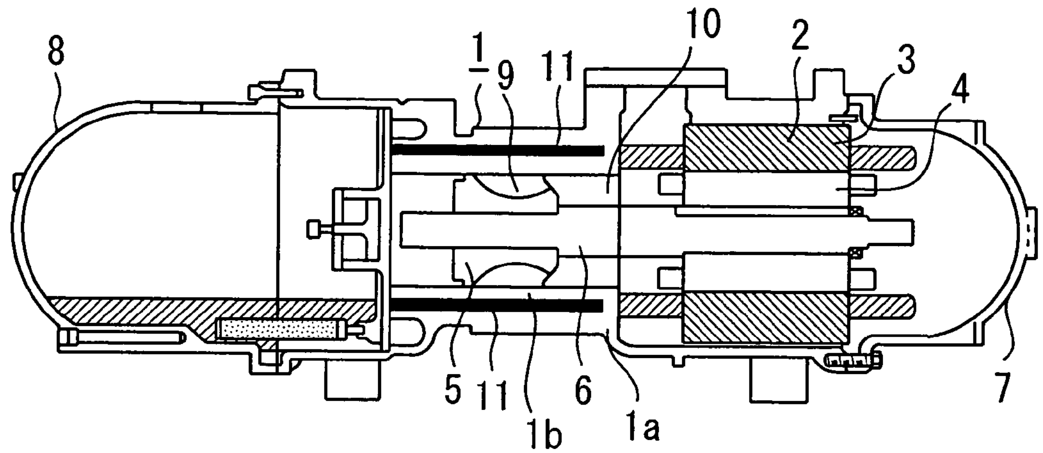


Fig. 2

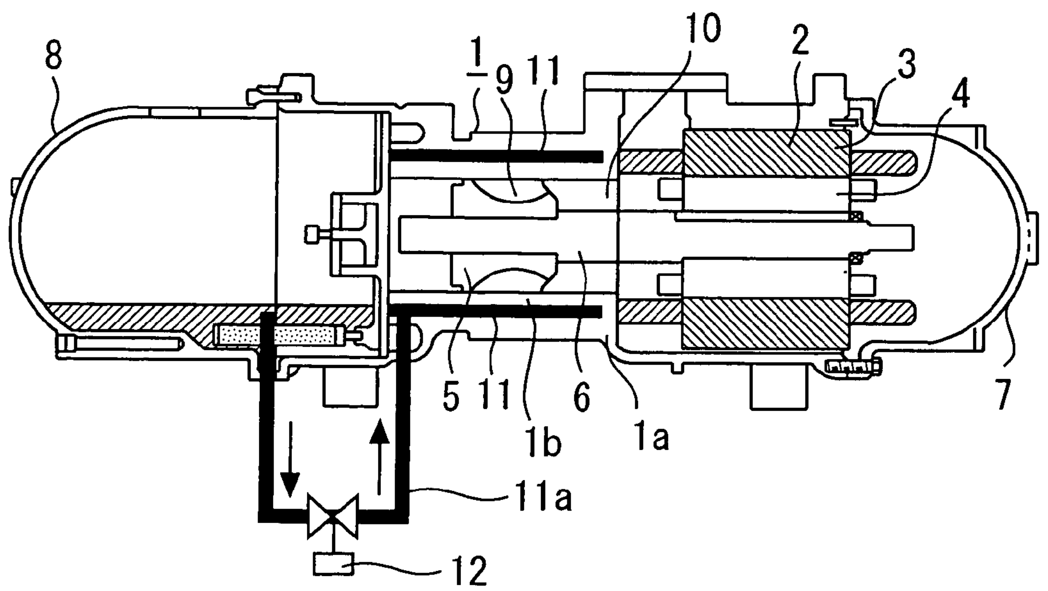


Fig. 3

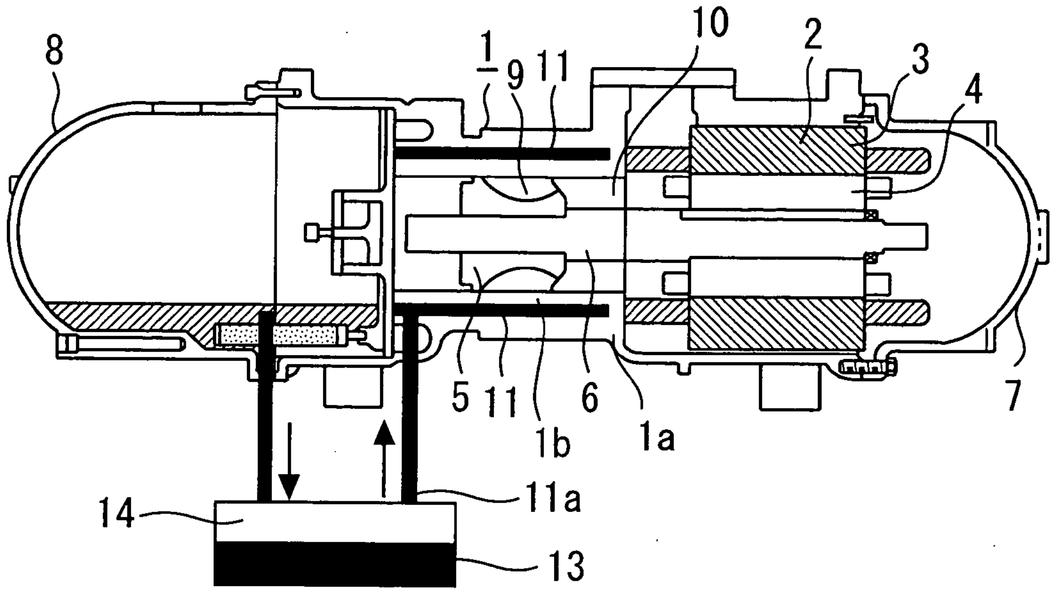


Fig. 4

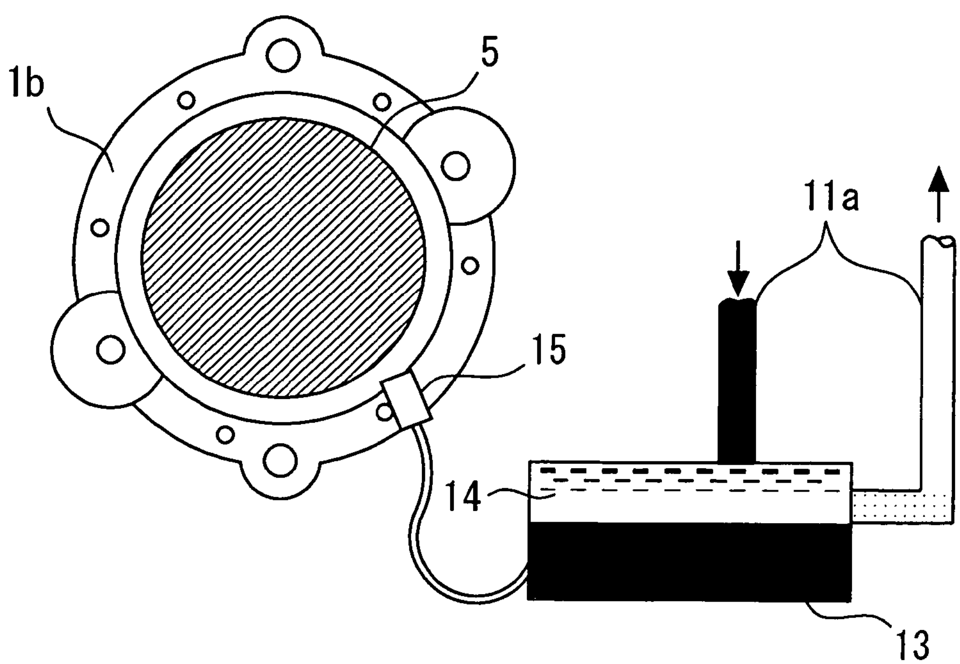


Fig. 5

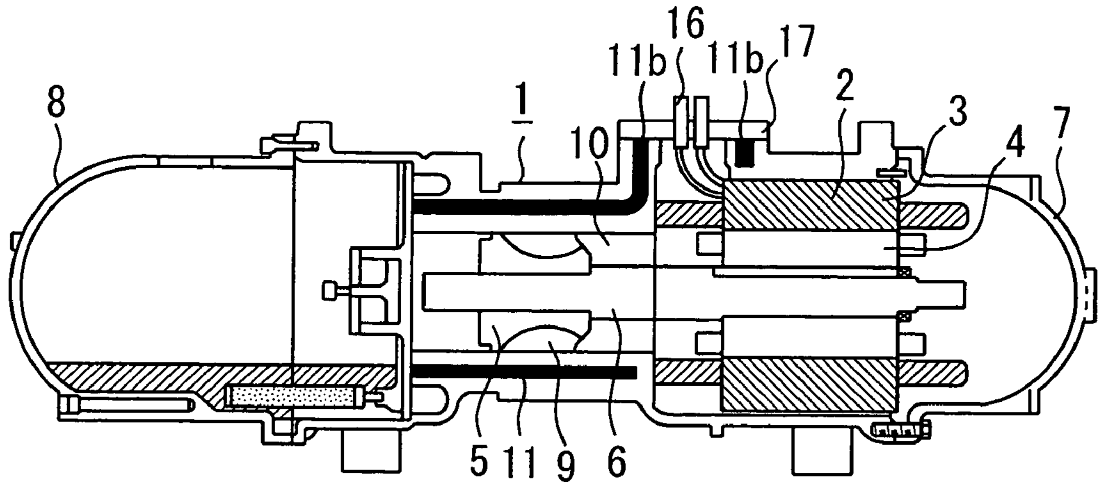
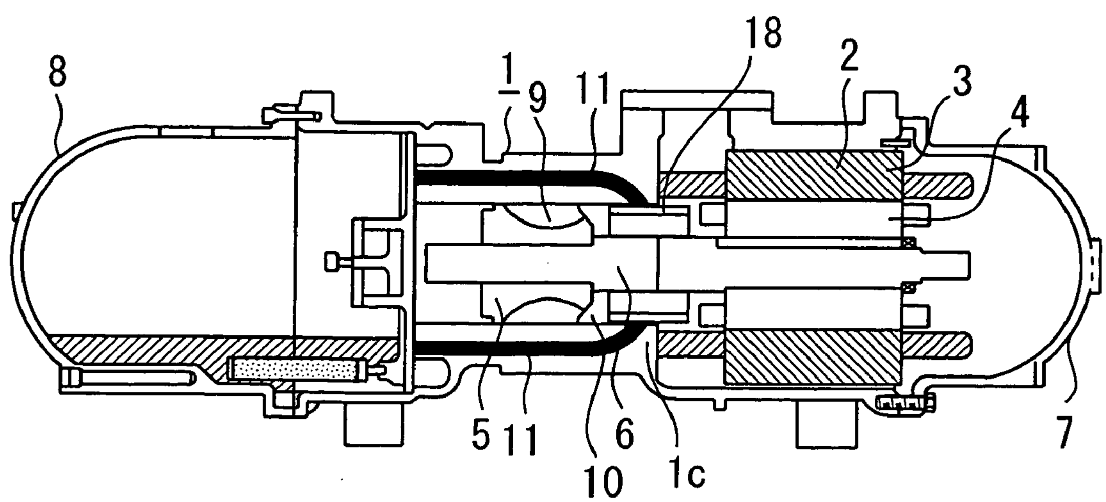


Fig. 6



SCREW COMPRESSOR

TECHNICAL FIELD

[0001] The present invention relates to a screw compressor for compressing refrigerant gas. In particular, the invention relates to a screw compressor in which the oil to be introduced into the compression chamber and bearings to seal gaps in the compression chamber and lubricate the bearings is cooled to achieve high adiabatic efficiency and high volumetric efficiency. The present invention also relates to a screw compressor in which the difference in thermal expansion between the screw rotor and the screw bore portion of the casing body due to their temperature difference is reduced to prevent contact between the screw rotor and the screw bore portion due to a reduction in the gap between them. The present invention also relates to a screw compressor which prevents liquid compression by causing the liquid refrigerant to exchange heat when it flows into the compressor, thereby achieving increased resistance to returned liquid refrigerant.

BACKGROUND ART

[0002] Conventional screw compressors have been configured such that the oil for sealing gaps in the compression chamber and lubricating the bearings is introduced from the high pressure side into the compression chamber and the bearings at nearly the discharge gas temperature. Since a conventional screw compressor has a configuration in which the oil for sealing gaps in the compression chamber and lubricating the bearings is introduced from the high pressure side into the compression chamber and the bearings at nearly the discharge gas temperature, the temperature of the compression chamber becomes higher than necessary, which increases the discharge gas temperature and hence the oil temperature, falling into a vicious circle. If liquid refrigerant is injected into the compressor to prevent this, the adiabatic efficiency and volumetric efficiency of the compressor decreases. The reduction in the viscosity of the oil at high temperatures also leads to a decrease in the adiabatic and volumetric efficiency. Furthermore, when the oil is introduced into the compression chamber at nearly the discharge gas temperature, the screw rotor thermally expands more quickly than the screw bore portion of the casing since the screw rotor has smaller heat capacity. Consequently, the gap between the screw rotor and the screw bore portion of the casing decreases, which might lead to contact between the screw rotor and the screw bore portion and hence an inability to operate the screw compressor properly if the initial gap is set too small.

[0003] Some conventional screw compressors use the discharge gas to heat the screw bore portion of the casing to reduce the difference in thermal expansion between the screw rotor and the screw bore portion of the casing. For example, Japanese Laid-Open Patent Publication No. 6-42474 discloses a screw compressor in which the discharge gas path is extended close to the edge of the screw rotor in the axial direction on the suction side. This structure can prevent the temperature of the low pressure chamber from greatly affecting the inner cylinder of the casing which covers the outer circumferential surface of the screw rotor, thereby preventing seizure between the screw rotor and the inner cylinder of the casing while maintaining high performance without increasing the seal gap between the screw rotor and the inner cylinder.

[0004] With this conventional screw compressor, however, the pressure differential may increase depending on the operating conditions, resulting in a reduced discharge gas rate. This reduces the effect of the above structure for improving the thermal response of the screw bore portion of the casing and thereby increases the difference in thermal expansion between the screw rotor and the screw bore portion of the casing, which might lead to their contact.

[0005] The present invention has been devised to solve the above problems. It is, therefore, an object of the present invention to provide a screw compressor in which the oil to be introduced into the compression chamber and bearings to seal gaps in the compression chamber and lubricate the bearings is cooled to achieve high adiabatic efficiency and high volumetric efficiency.

[0006] Another object of the present invention is to provide a screw compressor in which the difference in thermal expansion between the screw rotor and the screw bore portion of the casing body due to their temperature difference is reduced to prevent contact between the screw rotor and the screw bore portion due to a reduction in the gap between them.

[0007] Still another object of the present invention is to provide a screw compressor which prevents liquid compression by causing the liquid refrigerant to exchange heat when it flows into the compressor, thereby achieving increased resistance to returned liquid refrigerant.

[0008] Yet another object of the present invention is to provide a screw compressor in which dew is prevented from being formed on the power terminal portion of the motor disposed in the casing body.

DISCLOSURE OF THE INVENTION

[0009] In a screw compressor of the present invention, an oil path is provided in the casing body such that the oil for sealing gaps in the compression chamber and lubricating the bearings is circulated to the vicinity of the low pressure side.

[0010] In another screw compressor of the present invention, the above oil path is provided in the screw bore outer circumferential portion of the casing body.

[0011] In still another screw compressor of the present invention, a heat sink is provided to increase the heat transfer area for exchanging heat with refrigerant gas or liquid refrigerant passed through the motor chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** is a cross-sectional view of a screw compressor according to a first embodiment of the present invention.

[0013] **FIG. 2** is a cross-sectional view of a screw compressor according to a second embodiment of the present invention.

[0014] **FIG. 3** is a cross-sectional view of a screw compressor according to a third embodiment of the present invention.

[0015] **FIG. 4** is a partial structural view of the screw compressor according to the third embodiment of the present invention.

[0016] **FIG. 5** is a cross-sectional view of a screw compressor according to a fourth embodiment of the present invention.

[0017] **FIG. 6** is a cross-sectional view of a screw compressor according to a fifth embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0018] The present invention will be described in detail with reference to the accompanying drawings.

First Embodiment

[0019] **FIG. 1** is a cross-sectional view of a screw compressor according to a first embodiment of the present invention. As shown in the figure, a motor **2** is fixed to the inside walls of a cylindrical casing body **1** constituting the body of the screw compressor. The motor **2** includes: a stator **3** fixed to the inside walls of the casing body **1**; and a rotor **4** disposed inside the stator **3**. A screw rotor **5** is also disposed within the casing body **1**. The screw rotor **5** and the motor rotor **4** are attached to a screw shaft **6** such that their axes are aligned. The screw rotor **5** has a plurality of spiral compression grooves formed therein and is connected through the screw shaft **6** to the motor **2**, which rotates the screw rotor **5**. Further, a motor cover **7** and an oil separator **8** are each fixed to a respective end of the casing body **1**.

[0020] In the screw compressor configured as described above, the oil to be introduced into a compression chamber **9** to seal the gap between the inner circumferential surface of the casing body **1** and the outer circumferential surface of the screw rotor **5** in the compression chamber **9** is circulated to the vicinity of the low pressure side such as a low pressure chamber **10** of the compressor. More specifically, within the casing body **1**, an oil path **11** is formed in a screw bore outer circumferential portion **1***b* of a screw casing portion **1***a* (inside of which the screw rotor **5** is disposed) such that the oil path **11** extends from the compression chamber **9** to the low pressure chamber **10** of the compressor. With this, the oil to be introduced into the compression chamber **9** is cooled by the cool refrigerant near the low pressure side, making it possible to remove the heat of compression when the cooled oil is put into the compression chamber **9**. This arrangement also prevents the reduction in the adiabatic and volumetric efficiency due to the liquid refrigerant injected to remove the heat of compression. The reduction in the temperature of the oil increases the viscosity of the oil and hence improves gap sealing performance, allowing the screw compressor to have high efficiency.

[0021] With conventional screw compressors, when oil of nearly the discharge gas temperature is put into the compression chamber, the screw rotor **5** thermally expands more quickly than the casing body **1** since the screw rotor **5** has smaller heat capacity. This reduces the gap between the casing body **1** and the screw rotor **5**. In the screw compressor of the present embodiment, on the other hand, the oil is cooled in the vicinity of the low pressure side, as described above, reducing the difference in thermal expansion between the casing body **1** and the screw rotor **5** due to their heat capacity difference. This can prevent contact between the screw rotor **5** and the casing body **1** even when the initial gap is set small, allowing the screw compressor to achieve high reliability.

[0022] Further, since the oil path **11** for circulating the oil to the vicinity of the low pressure side is formed in the screw bore outer circumferential portion **1***b* of the screw casing portion **1***a*, the oil of nearly the discharge gas temperature warms the screw bore outer circumferential portion **1***b* until it reaches the vicinity of the low pressure side (i.e., the low temperature portion) of the screw casing portion **1***a*. This improves the thermal response of the screw casing portion **1***a* with respect to the discharge gas temperature, making it possible to reduce the difference in thermal expansion between the screw rotor **5** and the screw casing portion **1***a*.

[0023] Further, since the oil path **11** is formed in the screw bore outer circumferential portion **1***b* of the screw casing portion **1***a* so as to warm the screw casing portion **1***a* by the oil, as described above, a sufficient amount of oil is supplied even when the pressure differential is large and hence the discharge gas rate is reduced, meaning that the effect of warming the screw casing portion **1***a* is not reduced. Therefore, it is possible to reduce the difference in thermal expansion between the screw rotor **5** and the screw casing portion **1***a*, allowing the screw compressor to have high reliability.

[0024] Further, the oil circulation path **11** may be formed to have the following configuration. The oil path **11** runs from the oil separator **8** through the screw bore outer circumferential portion **1***b* of the screw casing portion **1***a* to warm the screw bore portion **4***b* with the oil. Then, the path goes to the low pressure side (the low pressure chamber **10** of the compressor, the motor chamber, etc.) to cool the oil, which is then put into the compression chamber **9**. Such an arrangement achieves the effect of warming the screw casing portion **1***a* with the oil, as described above, as well as increasing the adiabatic efficiency and volumetric efficiency by cooling the oil, allowing the screw compressor to have high efficiency and high reliability.

Second Embodiment

[0025] **FIG. 2** is a cross-sectional view of a screw compressor according to a second embodiment of the present invention. As shown in the figure, an external oil path **11***a* protruding externally of the casing body **1** is added to the oil path **11**. A solenoid valve **12** is attached to this external oil path **11***a* so as to control the oil flow, allowing or not allowing the oil to pass. With this arrangement, when the thermal expansion of the screw rotor **5** is small as in normal operation and hence the screw casing portion **1***a* need not be warmed, the solenoid valve **12** may be closed to stop the oil flow in order to prevent an increase in the gap between the screw rotor **5** and the screw bore portion of the screw casing portion **1***a*. The oil may be allowed to flow through the oil path **11** only when the gap between the screw rotor **5** and the screw bore portion of the screw casing portion **1***a* is reduced due to the expansion of the screw rotor **5** caused by increased discharge gas temperature, etc. Thus, it is possible to ensure the reliability of the screw compressor while preventing the reduction in the volumetric efficiency due to an increase in the gap in normal operation.

Third Embodiment

[0026] **FIG. 3** is a cross-sectional view of a screw compressor according to a third embodiment of the present invention. In the first embodiment, the oil trapped in the oil separator **8** is drawn into the oil path **11**. The third embodiment, on the other hand, is configured such that an oil temperature control device **13** is provided on the inlet side of the oil path **11** and the oil is introduced to the oil path **11** through the oil temperature control device **13**. Even though **FIG. 3** shows an example in which the oil temperature control device **13** is provided in an oil tank **14** outside the compressor, it may be installed in the oil trapping portion (that is, the lower portion) of the oil separator **8** within the compressor. The oil temperature may be adjusted in the oil temperature control device **13** so as to heat the screw casing portion **1***a* and thereby expand the screw bore portion when the compression ratio or the discharge gas temperature is high, which makes it possible to minimize the difference in thermal expansion between the screw casing portion **1***a* and the screw rotor **5** and prevent their contact. Thus, it is possible to provide a highly reliable screw compressor. Further, after the oil is passed through the screw bore portion of the screw casing portion **1***a* to warm the screw casing **1***a*, the above oil temperature control may be performed so as to cool the oil, which then may be put into the compression chamber **9**. Such an arrangement allows prevention of seizure, etc. due to the expansion of the screw rotor **5**, achieving high reliability. Furthermore, the increase in the oil viscosity results in an increase in the sealing performance, allowing the screw compressor to have high efficiency.

[0027] Further, the above oil temperature control device **13** may be divided into two portions each disposed on a respective side of the screw bore outer circumferential portion **1***b* of the screw casing portion **1***a*. In such a configuration, the oil may be set at a high temperature before it is passed through the screw bore outer circumferential portion **1***b*. Then, after the oil is passed through the screw bore outer circumferential portion **1***b*, it may be set at a low temperature. This allows effectively providing increased adiabatic efficiency and volumetric efficiency through cooling of the oil, as well as increased reliability through warming of the casing.

[0028] Further, in the above oil temperature control, the discharge gas temperature may be detected and the oil temperature may be controlled according to the temperature or the degree of superheat of the discharge gas. For example, when the discharge gas temperature is high (exceeding 100° C.), the oil temperature may be increased to further expand the screw casing portion **1***a* and thereby prevent contact between the screw rotor **5** and the screw bore portion of the screw casing portion **1***a*.

[0029] Further, a noncontact/eddy current type gap detector **15**, etc. may be attached to detect the gap between the screw casing portion **1***a* and the screw rotor **5**, as shown in **FIG. 4**. Then, in the above oil temperature control, the oil temperature may be controlled while detecting the gap, allowing the gap between the screw rotor **5** and the screw casing portion **1***a* to be minimized. This allows the screw compressor to achieve reduced internal leak, as well as high performance and high reliability.

[0030] According to the first embodiment, the oil path **11** is formed in the screw bore outer circumferential portion **1***b*, as described above. In addition, the third embodiment is configured such that the temperature of the circulating oil is controlled, also as described above. Furthermore, according to the third embodiment, the oil path **11** may be divided into upper and lower paths. When liquid refrigerant or wet vapor refrigerant enters the screw compressor, the refrigerant tends to accumulate on the bottom of the compressor due to its own weight, making the temperature of the screw casing portion lower in the lower portion of the compressor than in the upper portion. To address this problem, the above lower path of the oil path **11** may be set to have a larger heat transfer area than the upper path, or the oil supplied to the lower path may be set at a higher temperature than the oil supplied to the upper path, or oil may be supplied to only the lower path, in order to warm the lower portion of the compressor. Such arrangements reduce the temperature difference between the upper and lower portions of the compressor, allowing the compressor to have resistance to returned liquid refrigerant and high reliability.

[0031] Further, when the suction gas contains a considerable amount of liquid refrigerant, the oil flow rate may be increased accordingly. Thus, appropriately controlling the oil flow rate enhances the resistance to returned liquid refrigerant.

Fourth Embodiment

[0032] **FIG. 5** is a cross-sectional view of a screw compressor according to a fourth embodiment of the present invention. According to the first embodiment, the oil path **11** is formed so as to circulate the high temperature oil to the vicinity of the low pressure side, as described above. The fourth embodiment, on the other hand, is configured such that part or all of the oil path, denoted by **11***b*, is extended so as to circulate the oil close to the power terminal portion **16** and the terminal block **17** of the motor **2** disposed in the casing body **1** of the compressor. When the screw compressor is operated under low temperature conditions, that is, when the suction gas temperature is low, dew may be formed on the terminal block **17** and the power terminal portion **16**, depending on the ambient temperature and humidity conditions, which might lead to a short circuit in the power supply. However, circulating the oil close to the power terminal portion **16** and the terminal block **17** and thereby warming them prevents dew from being formed thereon, allowing the screw compressor to have enhanced reliability.

Fifth Embodiment

[0033] **FIG. 6** is a cross-sectional view of a screw compressor according to a fifth embodiment of the present invention. In the screw compressor of the first embodiment, the oil path **11** is formed so as to circulate the oil to the vicinity of the low pressure side, as described above. The fifth embodiment, on the other hand, is configured such that the oil path **11** is formed so as to circulate the oil to the vicinity of a boundary wall **1***c* of the casing body **1** constituting the boundary between the motor chamber **2** and the compressor low-pressure chamber **10** on the low pressure side, as shown in **FIG. 6**, for example. A heat sink **18** may be attached to the boundary wall **1***c* such that it sits on both the motor chamber **2** and the compressor low-pressure chamber **10** to increase the heat transfer area for cooling the oil circulated to the boundary wall **1***c*. Even when refrigerant in a liquid state is injected into the compressor, the high temperature oil circulated to the vicinity of the low pressure side heats the refrigerant (as in other embodiments). At that time, the above heat sink **18** increases the heat transfer area for exchanging heat between the refrigerant and the oil, allowing the screw compressor to have increased resistance to returned liquid refrigerant and high reliability.

[0034] Further, the heat sink **18** which is attached to the boundary wall **1***c* of the casing body **1** such that it sits on both the motor chamber **2** and the compressor low-pressure chamber **10** may be provided with cooling fins to improve its heat exchange performance.

INDUSTRIAL APPLICABILITY

[0035] According to the present invention described above, the oil to be introduced into the compression chamber is circulated to the vicinity of the low pressure side and thereby cooled. The cooled oil is put into the compression chamber so as to be able to remove the heat of compression and thereby prevent the adiabatic efficiency and volumetric efficiency from being reduced. The reduction in the oil temperature increases the viscosity of the oil and hence enhances the oil gap sealing performance, allowing the screw compressor to have high efficiency.

[0036] Further according to the present invention, a heat sink is attached near the boundary position between the motor chamber and the compressor lower-pressure chamber on the low pressure side to increase the heat transfer area for cooling the oil. As a result of circulating the oil to the vicinity of the low pressure side and providing the heat sink, it is possible to prevent liquid compression by causing the liquid refrigerant to exchange heat with the oil when the liquid refrigerant flows into the compressor, allowing the screw compressor to have increased resistance to returned liquid refrigerant.

1. A screw compressor comprising:

a casing body;

a motor disposed within said casing body;

a screw rotor disposed such that the screw rotor rotates together with a rotor of said motor within said casing body; and

a compression chamber formed between said screw rotor and said casing body;

wherein an oil path is provided within said casing body to circulate an oil to a vicinity of the low pressure side of said compressor, said oil being introduced into said compression chamber to seal gaps in said compression chamber or lubricate a bearing.

2. The screw compressor as claimed in claim 1, wherein said oil path is provided in a screw bore outer circumferential portion of said casing body.

3. The screw compressor as claimed in claim 1, wherein a portion of said oil path protrudes externally of said casing body and has a solenoid valve attached thereto.

4. The screw compressor as claimed in claim 1, wherein an oil temperature control device is provided on an inlet side of said oil path to control the temperature of said oil before said oil is introduced into said oil path.

5. The screw compressor as claimed in claim 4, wherein:

said oil temperature control device is divided into two portions each attached to said oil path on a respective side of a screw bore outer circumferential portion of said casing body;

said oil is set at a high temperature before it is passed through said screw bore outer circumferential portion; and

said oil is set at a low temperature after it is passed through said screw bore outer circumferential portion.

6. The screw compressor as claimed in claim 4, wherein:

a gap detector is provided to detect a gap between an inner circumferential portion of said casing body and said screw rotor; and

said temperature of said oil is controlled in accordance with detection results from said gap detector.

7. The screw compressor as claimed in claim 1, wherein said oil path is extended to a vicinity of a power terminal portion and a terminal block of said motor disposed within said casing body.

8. The screw compressor as claimed in claim 1, wherein:

said oil path is extended to a vicinity of a boundary wall of said casing body, said boundary wall constituting a boundary between a motor chamber and a low pressure chamber of said compressor; and

a heat sink is attached to said boundary wall such that said heat sink sits on both said motor chamber and said low pressure chamber of said compressor.

9. A screw compressor comprising:

a casing body;

a motor disposed within said casing body;

a screw rotor disposed such that the screw rotor rotates together with a rotor of said motor within said casing body;

a screw shaft connected between said screw rotor and said motor rotor so as to align the axes of said screw rotor and said motor rotor;

a bearing for supporting said screw shaft; and

a compression chamber formed between said screw rotor and said casing body;

wherein an oil path is provided within said casing body to circulate an oil to a vicinity of the low pressure side of said compressor, said oil being introduced into said compression chamber to seal gaps in said compression chamber or lubricate said bearing.

* * * * *