(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 009 285 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
**31.12.2008 Bulletin 2009/01**

(21) Application number: **07741682.4**

(22) Date of filing: **16.04.2007**

(51) Int Cl.:
***F04C 29/02** (2006.01)* ***F04B 39/02** (2006.01)*

(86) International application number:
**PCT/JP2007/058246**

(87) International publication number:
**WO 2007/123074 (01.11.2007 Gazette 2007/44)**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR**
Designated Extension States:
**AL BA HR MK RS**

(30) Priority: **19.04.2006 JP 2006116226**

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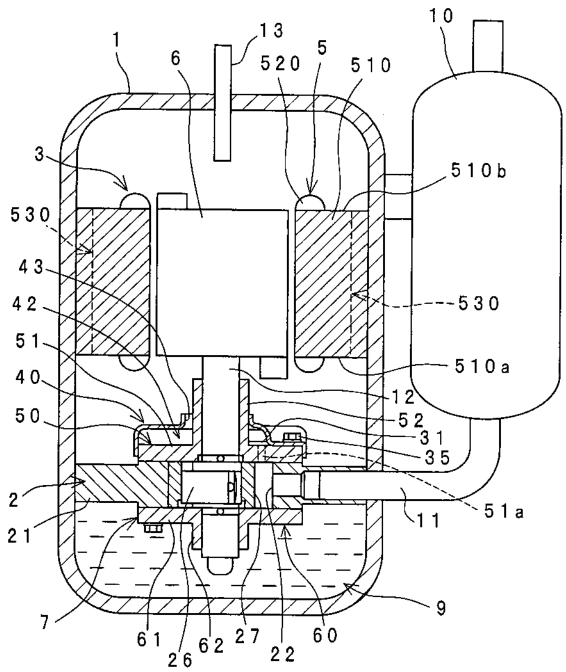
(54) **COMPRESSOR**

(57) A stator core 510 of a motor 3 has a plurality of oil return passages 530 extending through one surface 510a and the other surface 510b of the core. On the other surface 510b of the stator core 510, a hydraulic diameter of each oil return passage 530 is 5 mm or larger, and a ratio of a total area of the oil return passages 530 to an area of a virtual circle having a diameter equal to a maximum outer diameter of the stator core 510 is 5 to 15%. Thereby, lubricating oil accumulated on the other surface 510b side of the stator core 510 is returned to an oil reservoir 9 through the oil return passages 530, and shortage of oil in the oil reservoir 9 is prevented. Furthermore, a cross sectional area of the stator core 510 can be securely kept, and motor efficiency is maintained.

*Fig.1*

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## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to a compressor to be used for, for example, air conditioners, refrigerators and the like.

### BACKGROUND ART

**[0002]** Conventionally, a compressor includes a closed container, a compression element placed within the closed container, and a motor placed in the closed container and acting to drive the compression element via a shaft, with an oil reservoir formed at a bottom portion of the closed container so that lubricating oil is accumulated in the oil reservoir (see JP 2003-262192 A).

**[0003]** However, in the conventional compressor described above, because passages extending through from upper to lower portions of the motor are small, lubricating oil accumulated in the upper portion of the motor less returns to the oil reservoir located lower than the motor. This would cause occurrence of shortage of oil in the oil reservoir, as a problem. As a result of this shortage of oil, it would be impossible to effectively feed the lubricating oil in the oil reservoir via the shaft to sliding parts such as the compression element or the bearing of the motor, resulting in deteriorated reliability of the compressor. In particular, when carbon dioxide is used as the refrigerant, involving use of a high-viscosity lubricating oil as the lubricating oil, the lubricating oil would be even less return to the oil reservoir.

### SUMMARY OF THE INVENTION

**[0004]** Accordingly, an object of the present invention is to provide a compressor which is prevented from shortage of oil in the oil reservoir while motor efficiency of a motor is maintained.

**[0005]** In order to achieve the above object, the present invention provides a compressor comprising:

a closed container having an oil reservoir;
a compression element placed within the closed container; and
a motor which is placed within the closed container and which drives the compression element via a shaft, wherein
a stator core of the motor has a plurality of oil return passages extending through one surface of the stator core located on its one side closer to the oil reservoir and the other surface of the stator core located on its another side opposite to the oil reservoir, and on the other surface of the stator core,
a hydraulic diameter of each of the oil return passages is 5 mm or larger, and a ratio of a total area of the plurality of oil return passages to an area of a virtual circle having a diameter equal to a maximum outer diameter of the stator core is 5 to 15%.

**[0006]** In the compressor of the present invention, in the other surface of the stator core, the hydraulic diameter of each of the oil return passages is 5 mm or larger, and the ratio of the total area of the plurality of oil return passages to the area of the virtual circle having the diameter equal to the maximum outer diameter of the stator core is 5 to 15%. Therefore, lubricating oil accumulated on the other surface side of the stator core can be returned to the oil reservoir located on the one surface side of the stator core via the plurality of oil return passages, so that oil shortage in the oil reservoir can be prevented. Moreover, the cross-sectional area of the stator core can be ensured, and the motor efficiency can be maintained. Particularly when carbon dioxide is used as the refrigerant, in which use of a high-viscosity lubricating oil is involved, the lubricating oil can effectively be returned to the oil reservoir.

**[0007]** In one embodiment, the stator core is placed radially outside of a rotor of the motor, and
the oil return passages are located on an outer circumferential side of the stator core.

**[0008]** In the compressor of this embodiment, since the oil return passages are located on the outer circumferential side of the stator core, lubricating oil that has been scattered radially outward by the rotor or lubricating oil that has stuck to the inner circumferential surface of the closed container can effectively be led to the oil return passages, so that oil shortage in the oil reservoir can be prevented more reliably.

**[0009]** In one embodiment, a refrigerant in the closed container is carbon dioxide.

**[0010]** In the compressor of this embodiment, since the refrigerant within the closed container is carbon dioxide, in which use of a high-viscosity lubricating oil is involved, the lubricating oil can effectively be returned to the oil reservoir.

**[0011]** According to the compressor of the present invention, in the other surface of the stator core, the hydraulic diameter of each of the oil return passages is 5 mm or larger, and the ratio of the total area of the plurality of oil return passages to the area of the virtual circle having the diameter equal to the maximum outer diameter of the stator core is 5 to 15% so that oil shortage in the oil reservoir can be prevented and the motor efficiency can be maintained.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]**

Fig. 1 is a longitudinal sectional view showing an embodiment of a compressor of the invention;
Fig. 2 is a plan view of main part of the compressor;
Fig. 3 is a cross-sectional view of a vicinity of a motor in the compressor;
Fig. 4 is an enlarged view of part A of Fig. 3;

Fig. 5 is a graph showing relationships of oil shortage and motor efficiency with hydraulic diameter and area ratio;

Fig. 6A is a graph showing a relationship between area ratio and motor-efficiency decreasing rate;

Fig. 6B is a graph showing a relationship between area ratio and oil-level decreasing rate;

Fig. 7A is a graph showing a relationship between hydraulic diameter and motor-efficiency decreasing rate;

Fig. 7B is a graph showing a relationship between hydraulic diameter and oil-level decreasing rate.

## DETAILED DESCRIPTION OF THE INVENTION

**[0013]** Hereinbelow, the present invention will be described in detail by way of embodiments thereof illustrated in the accompanying drawings.

**[0014]** Fig. 1 shows a longitudinal sectional view which is an embodiment of a compressor of the invention. This compressor includes a closed container 1, a compression element 2 placed within the closed container 1, and a motor 3 placed in the closed container 1 and acting to drive the compression element 2 via a shaft 12.

**[0015]** This compressor is a so-called vertical high-pressure dome-type rotary compressor, in which the compression element 2 is placed below and the motor 3 is placed above within the closed container 1. The compression element 2 is driven by a rotor 6 of the motor 3 via the shaft 12.

**[0016]** The compression element 2 sucks in a refrigerant gas from an accumulator 10 through a suction pipe 11. The refrigerant gas can be obtained by controlling unshown condenser, expansion mechanism and evaporator that constitute an air conditioner as an example of a refrigeration system in combination with the compressor.

**[0017]** The refrigerant gas, which is carbon dioxide, becomes as high a pressure as about 12 MPa within the closed container 1. Alternatively, R410A or R22 or other like refrigerant may be used as the refrigerant.

**[0018]** In this compressor, a compressed high-temperature, high-pressure refrigerant gas is discharged from the compression element 2 to fill the closed container 1 therewith internally, while the refrigerant gas is passed through a gap between the stator 5 and the rotor 6 of the motor 3 to cool the motor 3. The refrigerant gas is thereafter discharged outside from a discharge pipe 13 provided on the upper side of the motor 3.

**[0019]** In lower portion of a high-pressure region within the closed container 1 is formed an oil reservoir 9 in which lubricating oil is accumulated. This lubricating oil moves from the oil reservoir 9 through oil passages (not shown) provided in the shaft 12 to sliding parts such as the compression element 2 and a bearing of the motor 3, thus lubricating the sliding parts.

**[0020]** When carbon dioxide is used as the refrigerant, the lubricating oil to be used is a high-viscosity one. As this lubricating oil, a lubricating oil having a viscosity of 5 - 300 cSt at 40°C is used. This lubricating oil is exemplified by polyalkylene glycol oil (such as polyethylene glycol and polypropylene glycol), ether oil, ester oil, and mineral oil.

**[0021]** The compression element 2 includes a cylinder 21 fitted to an inner surface of the closed container 1, and an upper-side end plate member 50 and a lower-side end plate member 60 fitted to upper and lower opening ends of the cylinder 21, respectively. A cylinder chamber 22 is defined by the cylinder 21, the upper-side end plate member 50 and the lower-side end plate member 60.

**[0022]** The upper-side end plate member 50 has a disc-shaped body portion 51, and a boss portion 52 provided upwardly at a center of the body portion 51. The shaft 12 is inserted into the body portion 51 and the boss portion 52. In the body portion 51 is provided a discharge hole 51a communicating with the cylinder chamber 22.

**[0023]** A discharge valve 31 is fitted to the body portion 51 so as to be positioned on one side of the body portion 51 opposite to the side on which the cylinder 21 is provided. This discharge valve 31 is, for example, a reed valve which opens and closes the discharge hole 51a.

**[0024]** A cup-type muffler cover 40 is fitted on the body portion 51 on its one side opposite to the cylinder 21 so as to cover the discharge valve 31. The muffler cover 40 is fixed to the body portion 51 by fixing members 35 (e.g., bolt). The boss portion 52 is inserted into the muffler cover 40.

**[0025]** The muffler cover 40 and the upper-side end plate member 50 define a muffler chamber 42. The muffler chamber 42 and the cylinder chamber 22 are communicated with each other via the discharge hole 51a.

**[0026]** The muffler cover 40 has a hole portion 43. By the hole portion 43, the muffler chamber 42 and an outer side of the muffler cover 40 are communicated with each other.

**[0027]** The lower-side end plate member 60 has a disc-shaped body portion 61, and a boss portion 62 provided downwardly at a center of the body portion 61. The shaft 12 is inserted into the body portion 61 and the boss portion 62.

**[0028]** In short, one end portion of the shaft 12 is supported by the upper-side end plate member 50 and the lower-side end plate member 60. That is, the shaft 12 cantilevers. One end portion (on the support end side) of the shaft 12 intrudes into the cylinder chamber 22.

**[0029]** On the support end side of the shaft 12, an eccentric pin 26 is provided so as to be positioned within the cylinder chamber 22 of the compression element 2. The eccentric pin 26 is fitted into a roller 27. The roller 27 is placed revolvable in the cylinder chamber 22 so that compression action is exerted by revolving motion of the roller 27.

**[0030]** In other words, one end portion of the shaft 12 is supported by a housing 7 of the compression element 2 on both sides of the eccentric pin 26. The housing 7 includes the upper-side end plate member 50 and the lower-side end plate member 60.

**[0031]** Next, compression action of the cylinder chamber 22 is explained.

**[0032]** As shown in Fig. 2, the cylinder chamber 22 is internally partitioned by a blade 28 integrally provided with the roller 27. That is, in a chamber on the right side of the blade 28, the suction pipe 11 is opened in the inner surface of the cylinder chamber 22 to form a suction chamber (low-pressure chamber) 22a. In a chamber on the left side of the blade 28, the discharge hole 51a (shown in Fig. 1) is opened in the inner surface of the cylinder chamber 22 to form a discharge chamber (high-pressure chamber) 22b.

**[0033]** Semicolumnar-shaped bushes 25, 25 are set in close contact with both surfaces of the blade 28 to provide a seal. Lubrication with the lubricating oil is implemented between the blade 28 and the bushes 25, 25.

**[0034]** Then, as the eccentric pin 26 eccentrically rotates along with the shaft 12, the roller 27 fitted to the eccentric pin 26 revolves while the outer circumferential surface of the roller 27 keeps in contact with the inner circumferential surface of the cylinder chamber 22.

**[0035]** As the roller 27 revolves in the cylinder chamber 22, the blade 28 moves back and forth while both side faces of the blade 28 are held by the bushes 25, 25. Then, the low-pressure refrigerant gas is sucked from the suction pipe 11 into the suction chamber 22a and compressed into a high pressure in the discharge chamber 22b, so that a high-pressure refrigerant gas is discharged from the discharge hole 51a (shown in Fig. 1).

**[0036]** Thereafter, as shown in Fig. 1, the refrigerant gas discharged from the discharge hole 51a is discharged via the muffler chamber 42 outward of the muffler cover 40.

**[0037]** As shown in Figs. 1 and 3, the motor 3 has the rotor 6, and the stator 5 placed radially outside of the rotor 6 with an air gap interposed therebetween.

**[0038]** The rotor 6 has a rotor body 610, and magnets 620 embedded in the rotor body 610. The rotor body 610 is cylindrical shaped and formed of, for example, multilayered electromagnetic steel plates. The shaft 12 is fitted to a hole portion at a center of the rotor body 610. Each of the magnets 620 is a flat permanent magnet. Six of the magnets 620 are arrayed at center angles of equal intervals in the circumferential direction of the rotor body 610.

**[0039]** The stator 5 has a stator core 510, and coils 520 wound around the stator core 510. In Fig. 3, the coils 520 are partly omitted in illustration.

**[0040]** The stator core 510 has an annular portion 511, and nine teeth 512 protruding radially inwardly from an inner circumferential surface of the annular portion 511 and arrayed circumferentially at equal intervals. The stator core 510 is formed of a plurality of multilayered steel plates. The coils 520 are wound around the individual teeth 512, respectively, and not wound over the plurality of teeth 512, hence a concentrated winding.

**[0041]** The motor 3 is a so-called 6-pole, 9-slot type one. By electromagnetic force generated in the stator 5 caused by passing a current through the coils 520, the rotor 6 is rotated along with the shaft 12.

**[0042]** The stator core 510 has a plurality of oil return passages 530 extending through one surface (lower surface) 510a of the stator core 510 located on its one side closer to the oil reservoir 9 and the other surface (upper surface) 510b of the stator core 510 located on the other side opposite to the oil reservoir 9.

**[0043]** The oil return passages 530 are located on the outer circumferential side of the stator core 510. The oil return passages 530 are formed by so-called core cuts of recessed grooves or D-cut surfaces or the like formed in the outer circumferential surface of the stator core 510. That is, the oil return passages 530 are spaces each surrounded by an inner surface of a core cut and an inner circumferential surface 1b of the closed container 1.

**[0044]** The oil return passages 530 are provided radially outside of the teeth 512, respectively, counting nine equal to that of the teeth 512. The oil return passages 530 are formed each into a generally rectangular shape as viewed along a center axis 1a of the closed container 1.

**[0045]** In the other surface 510b of the stator core 510, the hydraulic diameter of each oil return passage 530 is 5 mm or larger, and the ratio of the total area of the plural oil return passages 530 to the area of the virtual circle having a diameter equal to the maximum outer diameter of the stator core 510 (hereinafter, referred to as area ratio) is 5 to 15%.

**[0046]** Given an area S of the oil return passage 530 on the other surface 510b and a circumferential length L of the oil return passage 530 on the other surface 510b as shown in Fig. 4, the hydraulic diameter of the oil return passage 530 can be expressed as 4S/L. Fig. 4 is an enlarged view of part A of Fig. 3.

**[0047]** The area S of the oil return passage 530 is, as shown by hatching in Fig. 4, an area surrounded by the inner surface of the recessed groove of the stator core 510 and the inner circumferential surface 1b of the closed container 1. The circumferential length L of the oil return passage 530 is, as shown by bold line in Fig. 4, a value resulting from adding up a length of the inner surface of the recessed groove of the stator core 510 and a length of the inner circumferential surface 1b of the closed container 1.

**[0048]** The virtual circle having a diameter equal to the maximum outer diameter of the stator core 510 is, as shown in Fig. 3, coincident with the inner circumferential surface 1b of the closed container 1. That is, the area of this virtual circle is coincident with a cross-sectional area of the inside of the closed container 1 on the other surface 510b. The total area of the plurality of oil return passages 530 refers to a total sum of areas S of the oil return passages 530 on the other surface 510b.

**[0049]** According to the compressor constructed as described above, the hydraulic diameter of each oil return passage 530 on the other surface 510b of the stator core

510 is 5 mm or larger, and the area ratio is 5 to 15%. Therefore, lubricating oil that has flowed to the downstream side (upper side) of the motor 3 along with the refrigerant gas so as to be accumulated on the other surface 510b side of the stator core 510 can be returned to the oil reservoir 9 on the one surface 510a side of the stator core 510 via the plurality of oil return passages 530, so that oil shortage in the oil reservoir 9 can be prevented. Thus, by this prevention of oil shortage, lubricating oil in the oil reservoir 9 can effectively be fed via the shaft 12 to sliding parts such as the compression element 2 and the bearing of the motor 3, so that the reliability of the compressor is improved.

**[0050]** Moreover, the cross-sectional area of the stator core 510 can be ensured, and the motor efficiency can be maintained. Particularly when carbon dioxide is used as the refrigerant, in which use of a high-viscosity lubricating oil is involved, the lubricating oil can effectively be returned to the oil reservoir 9.

**[0051]** In this case, if the hydraulic diameter of each oil return passage 530 satisfies to be 5 mm only on the other surface 510b of the stator core 510, the lubricating oil overcomes the viscosity by its dead weight to move down along the oil return passages 530 up to the oil reservoir 9.

**[0052]** In contrast to this, if the hydraulic diameter of each oil return passage 530 is smaller than 5 mm, then the oil return passages 530 are each formed into, for example, a slit shape as its planar shape, so that the lubricating oil sticks to the other surface 510b of the stator core 510 by its viscosity, thus not going down along the oil return passages 530, and not moving to the oil reservoir 9. That is, there is a problem of occurrence of oil shortage. On the other hand, if the hydraulic diameter of each oil return passage 530 is larger than 15 mm, then the effective surface area of the annular portion 511 of the stator core 510 becomes smaller, resulting in a deteriorated motor efficiency.

**[0053]** Further, if the area ratio is smaller than 5%, then the number of oil return passages 530 becomes smaller, so that lubricating oil cannot effectively be returned to the oil reservoir 9, giving rise to occurrence of oil shortage as a problem. On the other hand, if the area ratio is larger than 15%, then the number or area of the oil return passages 530 becomes larger, causing the surface area of the stator core 510 to be smaller, so that the motor efficiency decreases as a problem.

**[0054]** In this invention, preferably, the hydraulic diameter of each oil return passage 530 is not more than 20 mm (more preferably, not more than 15 mm), in which case the cross-sectional area of the stator core 510 can more reliably be ensured and the motor efficiency can more reliably be maintained.

**[0055]** Further, since the oil return passages 530 are located on the outer circumferential side of the stator core 510, lubricating oil that has been scattered radially outward by the rotor 6 or lubricating oil that has stuck to the inner circumferential surface 1b of the closed container 1 can effectively be led to the oil return passages 530, so that oil shortage in the oil reservoir 9 can more reliably be prevented.

**[0056]** Next, Fig. 5 shows relationships of oil shortage and motor efficiency with hydraulic diameter and area ratio. In the figure, the horizontal axis represents the hydraulic diameter of each oil return passage, and the vertical axis represents the area ratio (the ratio of the total area of the oil return passages to an outer-diametral area of the stator core, i.e., the area of a circle having a diameter equal to the outer diameter of the stator core).

**[0057]** In a first region Z1, i.e., on condition that the hydraulic diameter is 5 to 15 mm and the area ratio is 5 to 15%, then there is no problem in oil shortage or motor efficiency.

**[0058]** In a second region Z2, i.e., on condition that the hydraulic diameter is larger than 15 mm and that the area ratio is 5 to 15%, there is a slight problem in motor efficiency, but no problem in oil shortage.

**[0059]** In a third region Z3, i.e., on condition that the hydraulic diameter is 5 mm or larger and the area ratio is larger than 15%, there is no problem in oil shortage but is a problem in motor efficiency.

**[0060]** In a fourth region Z4, i.e., on condition at least either that the hydraulic diameter is smaller than 5 mm or that the area ratio is smaller than 5%, there is no problem in motor efficiency but is a problem in oil shortage.

**[0061]** Next, grounds of the graph of Fig. 5 are shown in Figs. 6A, 6B, 7A and 7B.

**[0062]** Fig. 6A shows a relationship between area ratio (ratio of the total area of the oil return passages to the outer-diametral area of the stator core) and motor-efficiency decreasing rate. In the figure, the vertical axis represents motor-efficiency decreasing rate, where the motor efficiency decreases more and more downward of the vertical axis. As can be seen from Fig. 6A, with the area ratio over 15%, the motor efficiency is extremely decreases.

**[0063]** Fig. 6B shows a relationship between area ratio (ratio of the total area of the oil return passages to the outer-diametral area of the stator core) and oil-level decreasing rate. In the figure, the vertical axis represents oil-level decreasing rate, where the oil level decreases more and more downward of the vertical axis. As can be seen from Fig. 6B, with the area ratio under 5%, the oil level extremely decreases.

**[0064]** In other words, since the motor efficiency decreases with increasing total area of the oil return passages, the area ratio (ratio of total area of oil return passages / outer-diametral area of stator core) needs to be smaller than 15%. Also, since a smaller total area of the oil return passages causes oil returnability to worsen, enough oil level cannot be ensured. Therefore, the area ratio (ratio of total area of oil return passages / outer-diametral area of stator core) needs to be larger than 5%.

**[0065]** Fig. 7A shows a relationship between hydraulic diameter of the oil return passages and motor-efficiency decreasing rate. In the figure, the vertical axis represents motor-efficiency decreasing rate, where the motor efficiency decreases more and more downward of the vertical axis. As can be seen from Fig. 7A, hydraulic diameters larger than 15 mm lead to occurrence of a problem in motor efficiency.

**[0066]** Fig. 7B shows a relationship between hydraulic diameter of the oil return passages and oil-level decreasing rate. In the figure, the vertical axis represents oil-level decreasing rate, where the oil level decreases more and more downward of the vertical axis. As can be seen from Fig. 7B, with the hydraulic diameter under 5 mm, the oil level extremely decreases.

**[0067]** In other words, a larger hydraulic diameter causes the surface area of the annular portion 511 of the stator core 510 to become smaller, so that the motor efficiency decreases. Therefore, the hydraulic diameter needs to be smaller than 15 mm. Also, since a smaller hydraulic diameter causes oil returnability to worsen, enough oil level cannot be ensured. Therefore, the hydraulic diameter needs to be larger than 5 mm.

**[0068]** It is noted that the present invention is not limited to the above-described embodiment. For example, the compression element 2 may also be a rotary type one in which its roller and blade are provided independent of each other. The compression element 2 may further be a scroll type or reciprocating type one other than the rotary type. The compression element 2 may also be a two-cylinder type one having two cylinder chambers. The coils 520 may be of the so-called distributed winding in which the coils 520 are wound over the plurality of teeth 512.

**[0069]** Further, it is also allowable that the compression element 2 is provided above while the motor 3 is provided below. The oil return passages 530 may be provided on the inner circumferential side of the stator core 510, or provided at an intermediate portion between the inner circumferential surface and the outer circumferential surface of the stator core 510. Furthermore, the oil return passages 530 may be provided at any position in the circumferential direction of the stator core 510, and may be provided at equal or unequal pitches.

## Claims

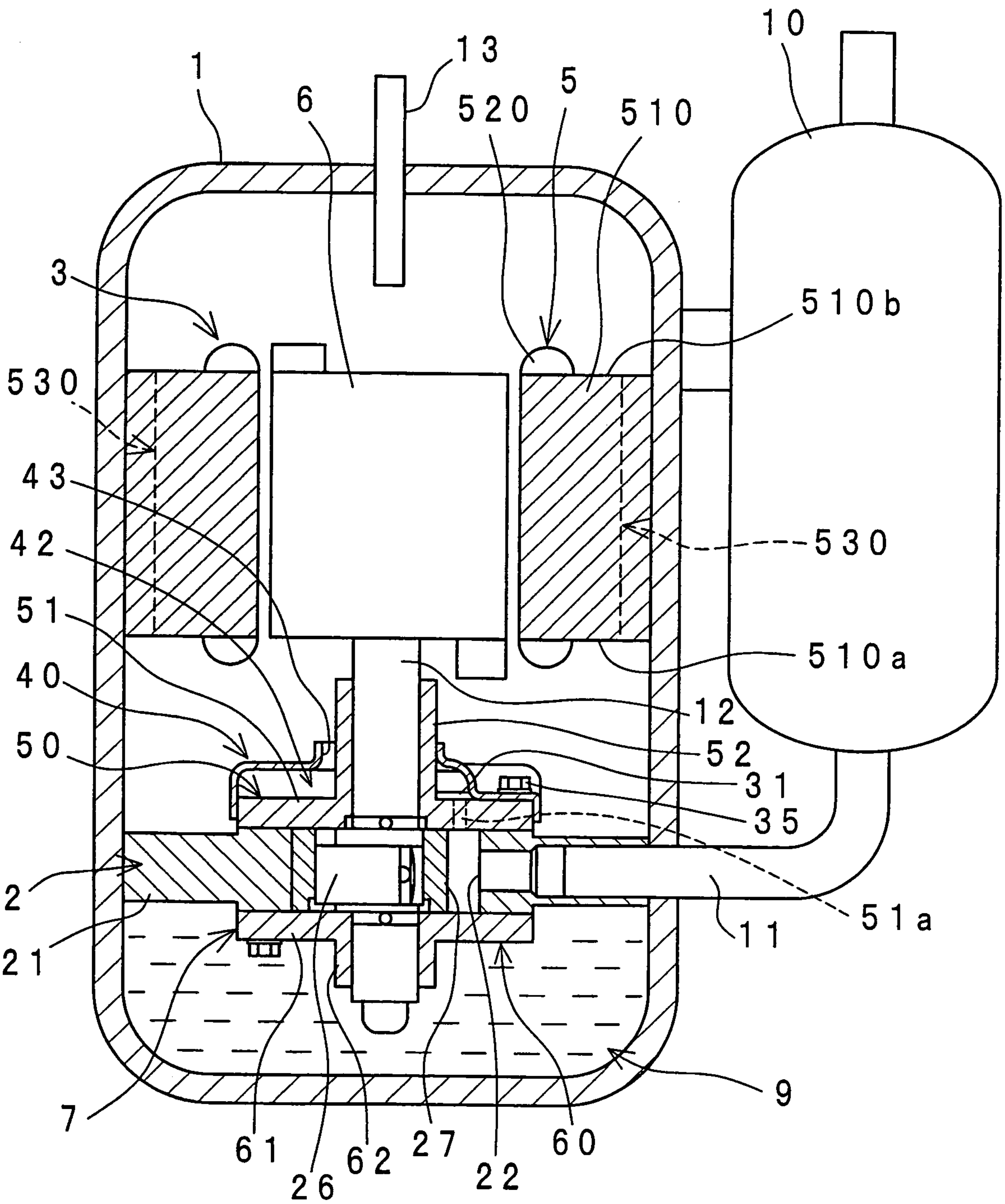
**1.** A compressor comprising:

a closed container (1) having an oil reservoir (9);
a compression element (2) placed within the closed container (1); and
a motor (3) which is placed within the closed container (1) and which drives the compression element (2) via a shaft (12), wherein
a stator core (510) of the motor (3) has a plurality of oil return passages (530) extending through one surface (510a) of the stator core (510) located on its one side closer to the oil reservoir (9) and the other surface (510b) of the stator core (510) located on its another side opposite to the oil reservoir (9), and
on the other surface (510b) of the stator core (510),
a hydraulic diameter of each of the oil return passages (530) is 5 mm or larger, and a ratio of a total area of the plurality of oil return passages (530) to an area of a virtual circle having a diameter equal to a maximum outer diameter of the stator core (510) is 5 to 15%.

**2.** The compressor as claimed in Claim 1, wherein the stator core (510) is placed radially outside of a rotor (6) of the motor (3), and
the oil return passages (530) are located on an outer circumferential side of the stator core (510).

**3.** The compressor as claimed in Claim 1, wherein a refrigerant in the closed container (1) is carbon dioxide.

*Fig.1*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10
6
520
5
510
3
510b
530
43
530
42
51
510a
40
12
50
52
31
35
2
51a
21
11
7
9
61
62
27
22
60
26

*Fig.2*

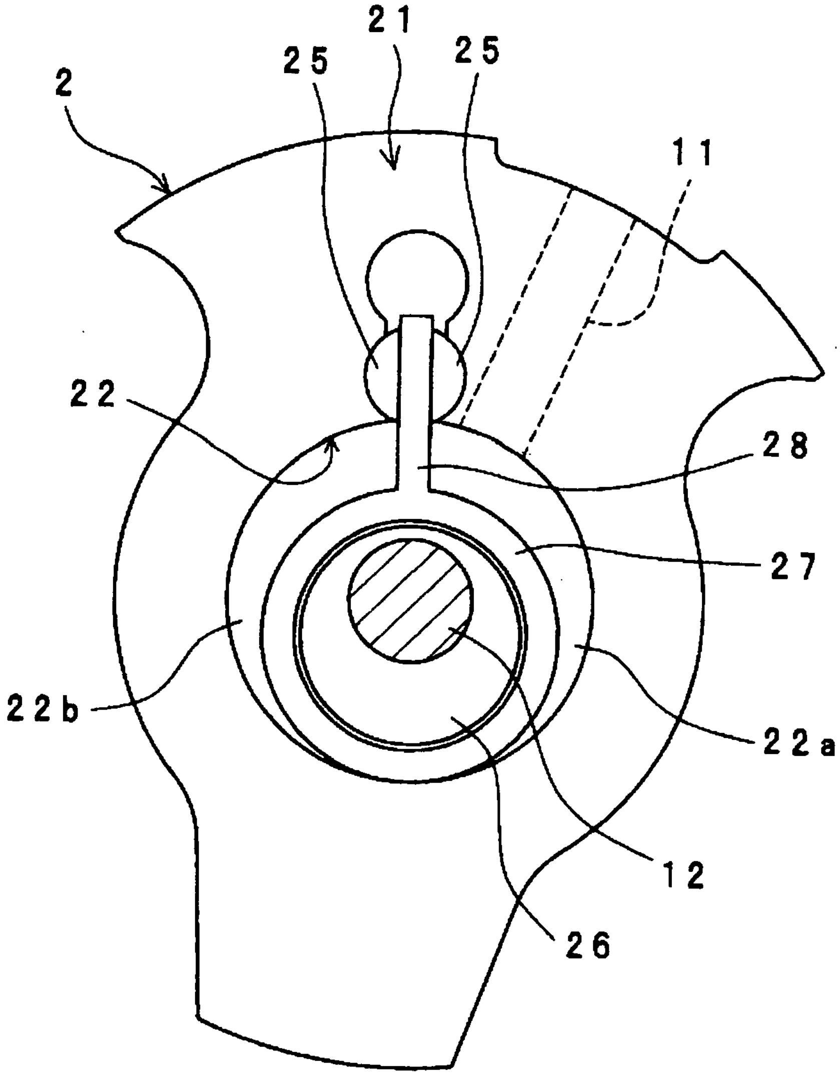
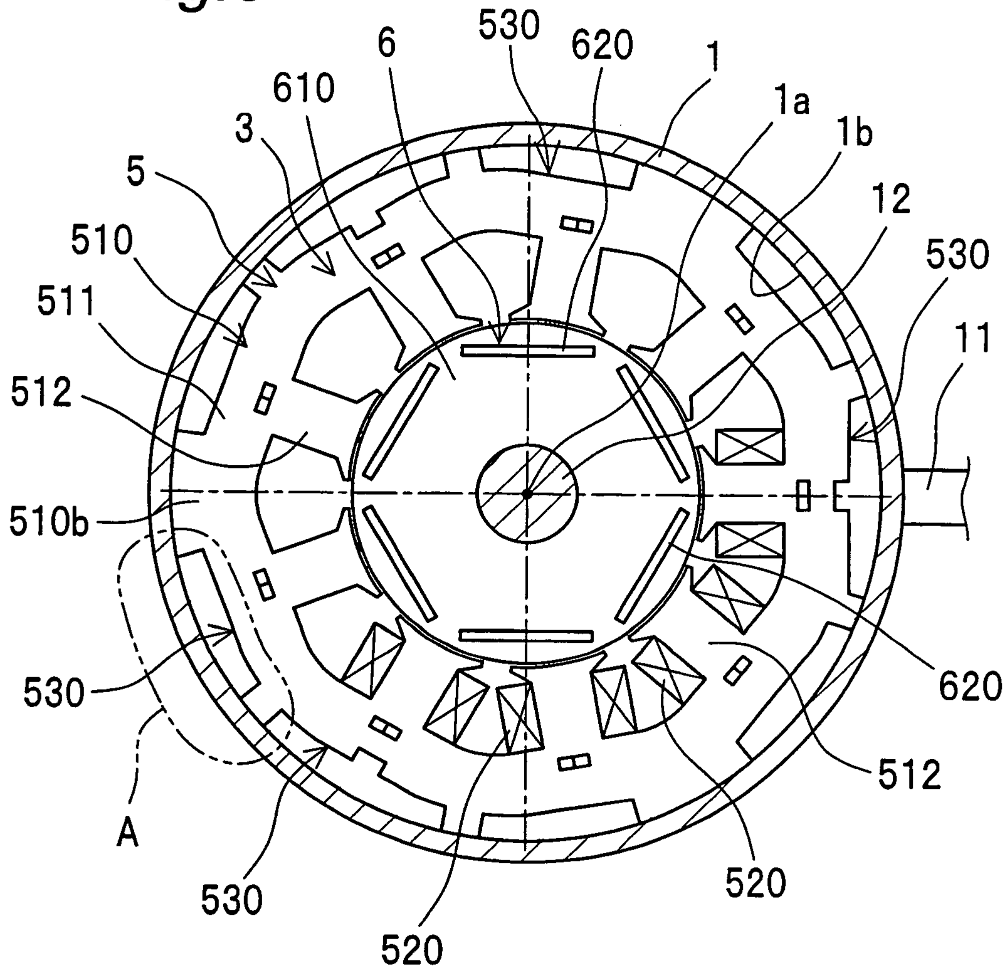


Fig.3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620
1
6
610
3
5
510
511
512
510b
530
A
530
520
520
512
620
11
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12
1b
1a

Fig.4

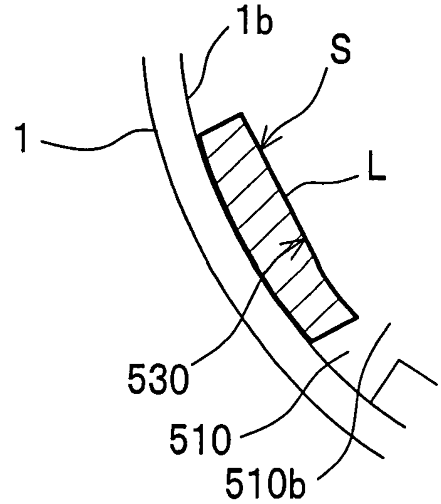

1b
S
1
L
530
510
510b

*Fig.5*

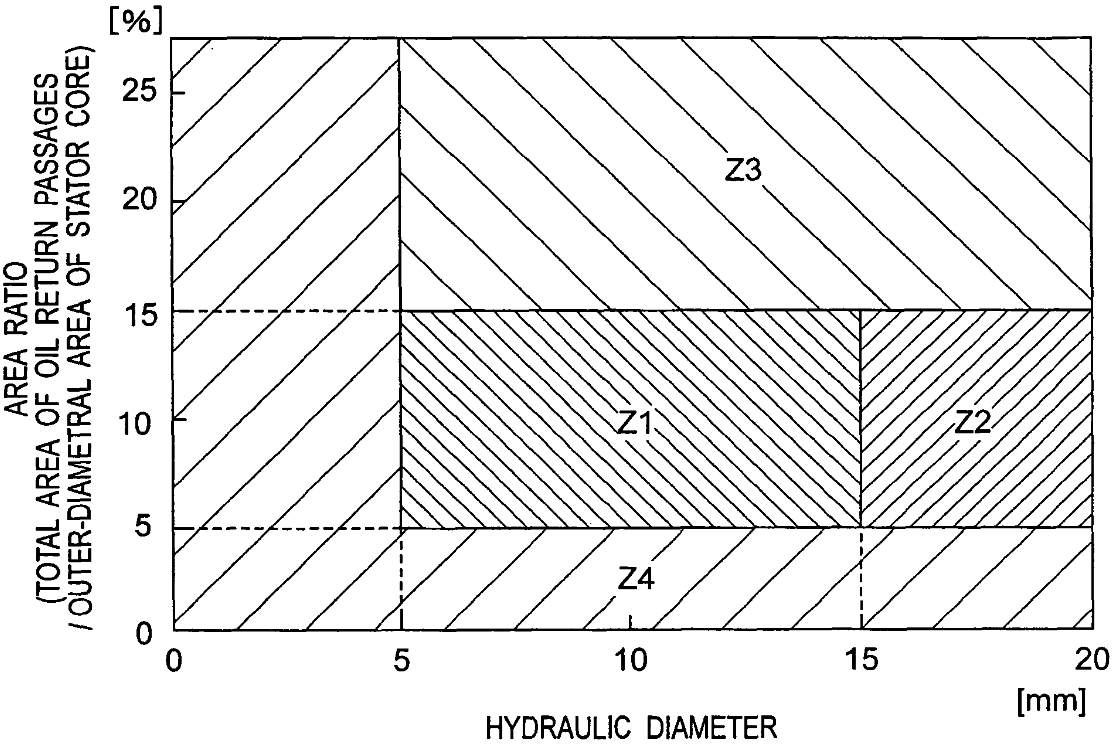

[%]
AREA RATIO
(TOTAL AREA OF OIL RETURN PASSAGES / OUTER-DIAMETRAL AREA OF STATOR CORE)
25
20
15
10
5
0
0
5
10
15
20
[mm]
HYDRAULIC DIAMETER
Z1
Z2
Z3
Z4

*Fig.6A*

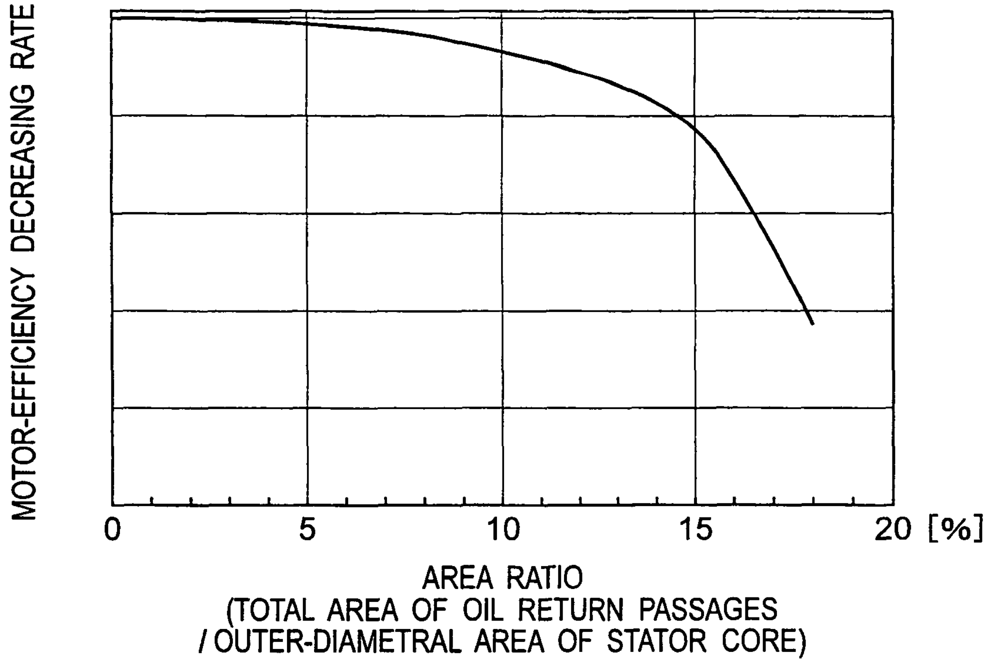
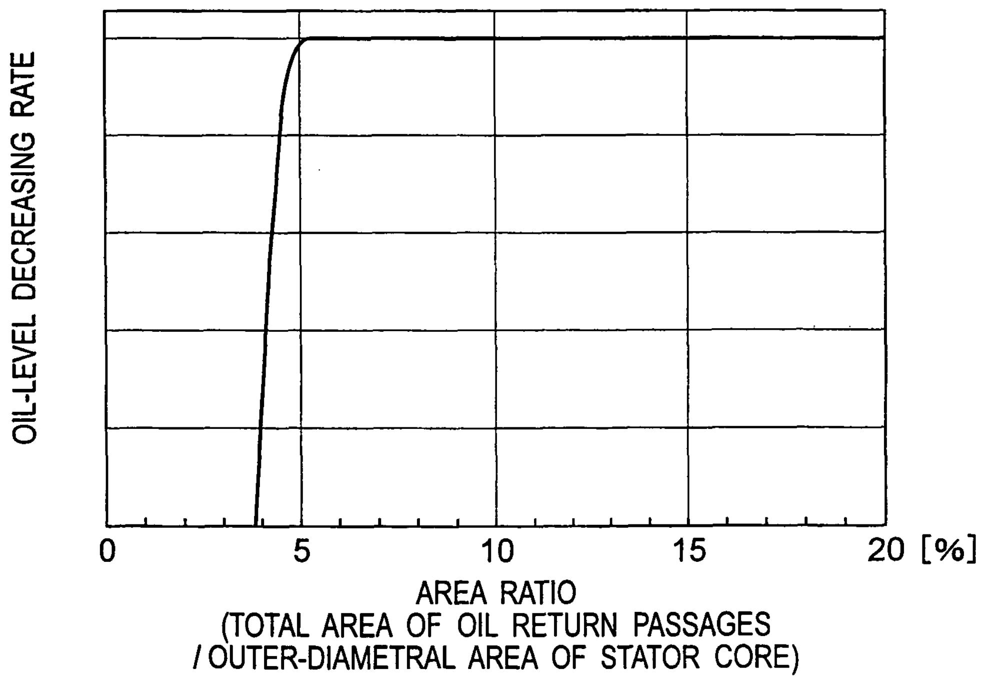

MOTOR-EFFICIENCY DECREASING RATE
0
5
10
15
20 [%]
AREA RATIO
(TOTAL AREA OF OIL RETURN PASSAGES
/ OUTER-DIAMETRAL AREA OF STATOR CORE)

*Fig.6B*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0
5
10
15
20 [%]
AREA RATIO
(TOTAL AREA OF OIL RETURN PASSAGES
/ OUTER-DIAMETRAL AREA OF STATOR CORE)

Fig.7A

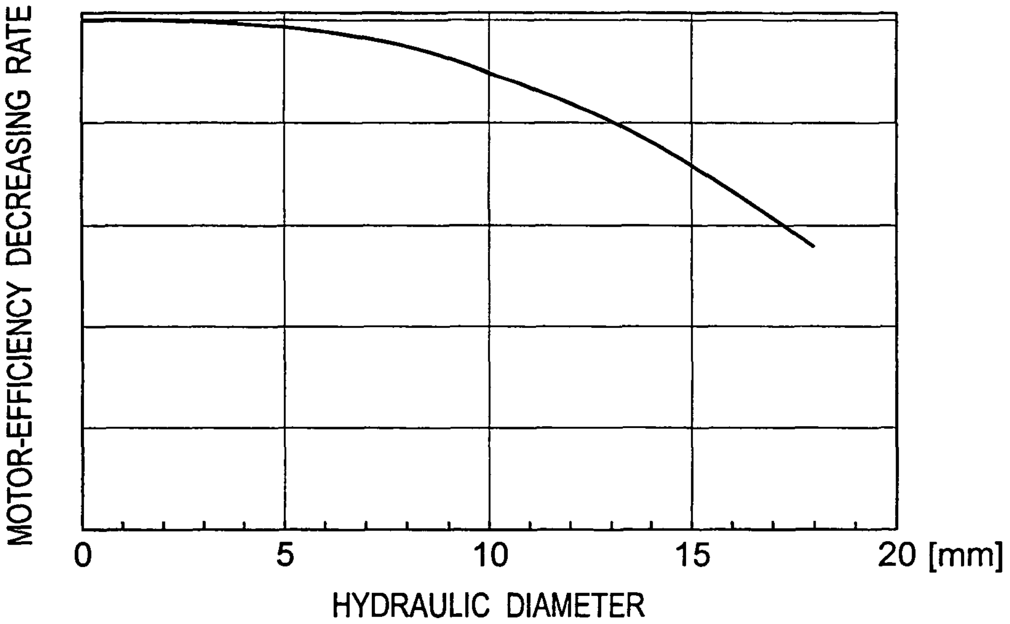
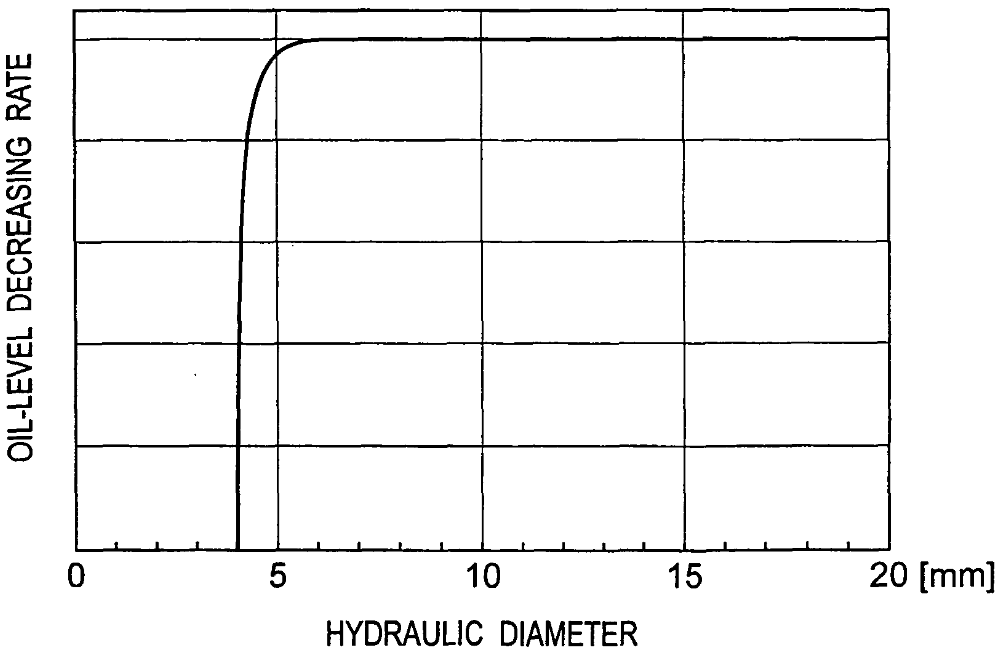

MOTOR-EFFICIENCY DECREASING RATE
0
5
10
15
20 [mm]
HYDRAULIC DIAMETER

Fig.7B


OIL-LEVEL DECREASING RATE
0
5
10
15
20 [mm]
HYDRAULIC DIAMETER

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2007/058246

A. CLASSIFICATION OF SUBJECT MATTER
*F04C29/02*(2006.01)i, *F04B39/02*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04C29/02, F04B39/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

| | | | |
|---|---|---|---|
| Jitsuyo Shinan Koho | 1922-1996 | Jitsuyo Shinan Toroku Koho | 1996-2007 |
| Kokai Jitsuyo Shinan Koho | 1971-2007 | Toroku Jitsuyo Shinan Koho | 1994-2007 |

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | JP 8-65961 A (Toshiba Corp.), 08 March, 1996 (08.03.96), Par. Nos. [0024] to [0052]; Figs. 1 to 5 (Family: none) | 1-3 |
| Y | JP 57-129287 A (Hitachi, Ltd.), 11 August, 1982 (11.08.82), Page 2, upper left column, line 13 to upper right column, line 6; Figs. 1 to 3 (Family: none) | 1-3 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 05 June, 2007 (05.06.07) | 19 June, 2007 (19.06.07) |
| Name and mailing address of the ISA/ Japanese Patent Office | Authorized officer |
| Facsimile No. | Telephone No. |

Form PCT/ISA/210 (second sheet) (April 2005)

## REFERENCES CITED IN THE DESCRIPTION



### Patent documents cited in the description

- JP 2003262192 A **[0002]**