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

(11) EP 2 863 060 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.04.2015 Bulletin 2015/17

(51) Int Cl.:
F04C 29/02 *(2006.01)* ***F04C 18/16*** *(2006.01)*

(21) Application number: **14181227.1**

(22) Date of filing: **18.08.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **15.10.2013 JP 2013214987**

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(54) Screw compressor and oil supply method thereof

(57) Screw compressor and oil supply method thereof, the compressor including: a compressor body (10) that includes a suction port (13) which suctions a gas, a female rotor (22) and a male rotor (24) which compress the gas in cooperation with a rotor chamber (11), and an discharge port (14) which discharges the gas; an oil collector (30) that includes a primary separation unit (34) and a secondary separation unit (32); a primary separation oil supply line (41) that is connected to a compression tooth groove space (27) of the female rotor (22) defined by an inner wall of the rotor chamber (11) and a pair of adjacent teeth of the female rotor (22) in a cross-section perpendicular to a rotor shaft and the oil collector (30) and supplies a primarily separated oil to the compression tooth groove space (27) of the female rotor (22); an oil drain line (54), and a secondary separation oil supply line (52) that supplies a secondarily separated oil to the compression tooth groove space (27) of the female rotor (22) and is connected to the primary separation oil supply line (41).

FIG.1A

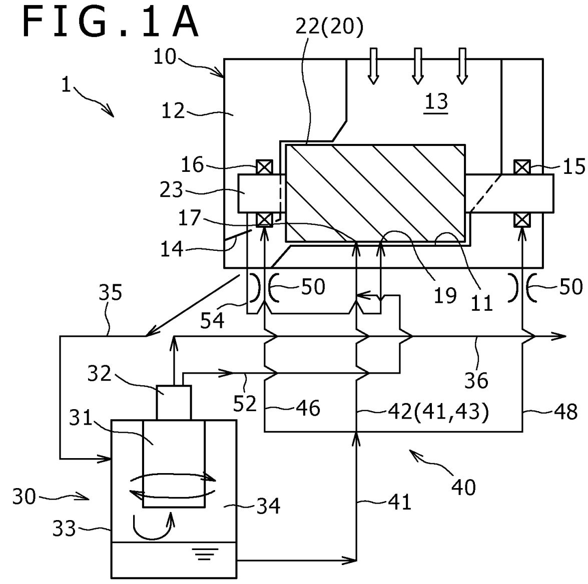

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FIG.1B

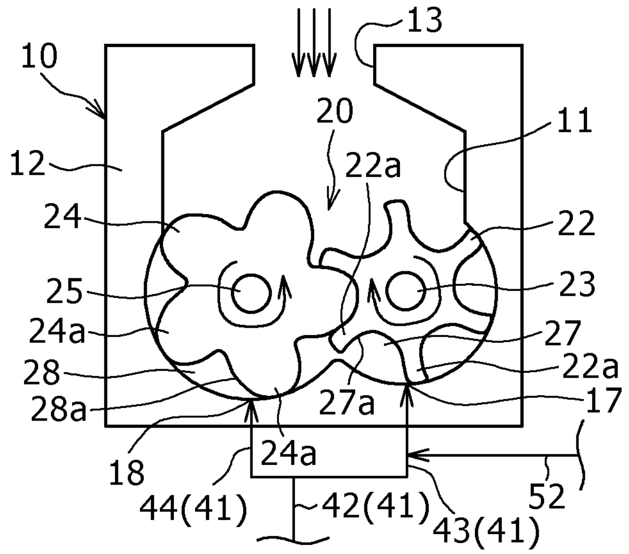
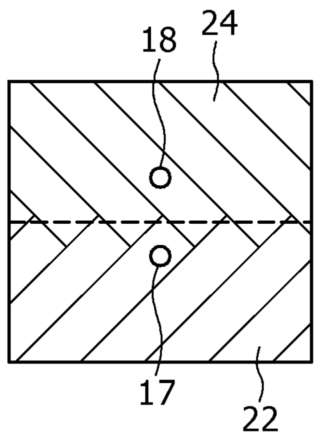

13
10
20
11
12
22a
24
22
25
23
24a
27
28
22a
28a
27a
17
18
24a
52
44(41)
42(41)
43(41)

FIG.1C


18
24
17
22

Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to an oil cooling type screw compressor and an oil supply method thereof.

(DESCRIPTION OF THE RELATED ART)

[0002] In an oil cooling type screw compressor, a secondary separation is performed by a filter in addition to a primary separation performed by a centrifugal force inside an oil collector in order to separate an oil included in an air discharged from a compressor body (see JP 2013-36397 A). When the oil separated by the secondary separation is collected and is returned to a system, the oil is directly returned to a suction port of a main body or a tooth groove of each rotor being in the course of compression and having a pressure lower than the secondarily separated oil in many cases. However, since the returned oil includes a large amount of hot-temperature air, volume efficiency is degraded when the oil is directly returned to the suction port, and a power necessary for driving the compressor increases when the oil is directly returned to the tooth groove being in the course of compression.

SUMMARY OF THE INVENTION

[0003] The present invention is made in view of the above-described problems, and an object thereof is to provide a compressor capable of decreasing a power necessary for a driving operation and an oil supply method thereof.

[0004] According to an aspect of the present invention, there is provided a compressor including: a compressor body that includes a suction port which suctions a gas, a pair of rotors comprising a female rotor and a male rotor which are rotatably supported by a bearing and compressing the gas suctioned from the suction port in cooperation with a rotor chamber, and an discharge port which discharges the compressed gas; an oil collector that includes a primary separation unit which primarily separates an oil from the gas compressed by the compressor body and a secondary separation unit which secondarily separates an oil from the gas from which the oil is primarily separated by the primary separation unit; a primary separation oil supply line that is connected to a compression tooth groove space of the female rotor defined by an inner wall of the rotor chamber and a pair of adjacent teeth of the female rotor in a cross-section perpendicular to a rotor shaft of the compressor body, and to the oil collector, the primary separation oil supply line supplying the oil separated by the primary separation unit to the compression tooth groove space of the female rotor; an oil drain line that supplies the oil separated by the primary separation unit and used to lubricate the bearing of the rotor to a low-pressure tooth groove of the rotor without using the primary separation oil supply line; and a secondary separation oil supply line that is connected to the primary separation oil supply line, the secondary separation oil supply line supplying the oil separated by the secondary separation unit to the compression tooth groove space of the female rotor.

[0005] A fluid mixture of the oil and the gas passes through the secondary separation oil supply line. Thus, when the secondary separation oil supply line is connected to the primary separation oil supply line, the fluid mixture of the primarily separated oil and the pressurized gas is supplied to the compression tooth groove space of the female rotor. Accordingly, when the fluid mixture is released to the compression tooth groove space of the female rotor, the dispersion of the oil is promoted, and hence the deflection of the oil hardly occurs in the tooth groove of the female rotor. Accordingly, oil shortage is prevented between the inner wall of the rotor chamber and the tooth tip of the female rotor as the seal portion where particularly partial oil shortage easily occurs, and hence a back flow in which the gas in the course of compression leaks therebetween may be prevented. Thus, the power necessary for driving the rotor in order to compress the leakage gas again decreases, and hence the amount of the air discharged from the compressor body may be also increased.

[0006] Further, since the fluid mixture is released to the compression tooth groove space of the female rotor, the atomization of the oil is promoted, and hence the surface area of the oil with respect to the amount of the oil supplied to the female rotor increases. Thus, heat is easily exchanged between the oil supplied to the compressor body and the gas in the course of compression. Accordingly, since the efficiency of the cooling process using the oil is improved, the gas almost becomes an isothermal compression state, and hence the power for driving the female rotor decreases. The tooth tip width of the tooth of the female rotor is generally narrow, and the amount of the gas leaking between the tooth tip of the female rotor and the compressor body is easily affected by the existence of the oil therebetween. Further, since the volume of the tooth groove of the female rotor is larger than that of the male rotor, it is considered that the merit in which the fluid mixture is supplied to the compression tooth groove space of the female rotor is larger than that of the case where the fluid mixture is supplied to the male rotor.

[0007] The primary separation oil supply line may be further connected to a compression tooth groove space of the male rotor defined by the inner wall of the rotor chamber and a pair of adjacent teeth of the male rotor in a cross-section perpendicular to the rotor shaft of the compressor body and may supply the oil which is separated by the primary separation unit and does not include the oil passing through the secondary separation oil supply line to the compression tooth groove space of the male rotor. Alternately, the compressor may further include another primary separation oil supply line for the male rotor that is connected to a compression tooth groove space of the male rotor defined by the inner wall of the rotor chamber and a pair of adjacent teeth of the male rotor in a cross-section perpendicular to the rotor shaft of the compressor body and the oil collector and supplies the oil separated by the primary separation unit to the compression tooth groove space of the male rotor.

[0008] With the above-described configuration, the oil may be supplied to compression tooth groove space of the male rotor in addition to the compression tooth groove space of the female rotor so as to perform a lubricating operation and a cooling operation. Further, since the primarily separated oil is supplied to the compression tooth groove space of the male rotor, it is possible to ensure the amount of the oil enough for keeping the sealing performance. As a result, it is possible to prevent the back flow of the gas between the tooth tip of the male rotor and the inner wall of the rotor chamber. Thus, the power necessary for driving the rotor in order to compress the leakage gas again may be decreased, and hence the amount of the air discharged from the compressor body may be also increased.

[0009] The secondary separation oil supply line may be connected to the primary separation oil supply line connected to the compression tooth groove space of the male rotor and may also supply the oil separated by the secondary separation unit to the compression tooth groove space of the male rotor. Alternatively, the oil separated by the secondary separation unit may be supplied to the compression tooth groove space of the male rotor through the primary separation oil supply line.

[0010] Since the fluid mixture of the primarily separated oil and the secondarily separated oil including the compressed gas may be supplied to the compression tooth groove space of the male rotor in addition to the compression tooth groove space of the female rotor, the atomization of the oil is promoted when the fluid mixture is released to the compression tooth groove space of the male rotor. Accordingly, since the surface area of the oil with respect to the amount of the oil supplied to the male rotor increases, heat is easily exchanged between the oil supplied to the compressor body and the gas in the course of compression. Since the efficiency of the cooling process using the oil is improved, the gas almost becomes an isothermal compression state, and hence the power for driving the rotor decreases. Further, when the fluid mixture is released to the compression tooth groove space of the male rotor, the dispersion of the oil is promoted, and hence the deflection of the oil inside the tooth groove of the male rotor hardly occurs. Accordingly, since the sealing performance inside the compressor body is improved, the back flow in which the gas in the course of compression leaks may be prevented. Accordingly, the power necessary for driving the rotor in order to compress the leakage gas again decreases, and hence the amount of the air discharged from the compressor body may be also increased.

[0011] The compressor may further include a primary separation oil supply line that supplies oil to the bearing on the side of the discharge port, wherein the primary separation oil supply line that supplies oil to the discharge side bearing is provided with a throttle portion which decreases an oil supply amount.

[0012] Since the throttle portion is provided, the amount of the oil supplied to the bearing may be suppressed to the minimum amount necessary to lubricate the bearing. Meanwhile, even in the oil which increases in temperature after the lubrication of the bearing, there is no need to worry the suction even when the oil is returned to the suction space if the amount of the oil is extremely small. For that reason, since the throttle portion is provided, it is possible to select the suction space as a place where the oil lubricating the bearing while suppressing an increase in power necessary for a driving operation or degradation in performance may be returned.

[0013] According to another aspect of the present invention, there is provided an oil supply method of a compressor including: a compressor body that includes a suction port which suctions a gas, a pair of rotors comprising a female rotor and a male rotor rotatably supported by a bearing and compressing the gas suctioned from the suction port in cooperation with a rotor chamber, and an discharge port which discharges the compressed gas; and an oil collector that includes a primary separation unit which primarily separates an oil from the gas compressed by the compressor body and a secondary separation unit which secondarily separates an oil from the gas from which the oil is primarily separated by the primary separation unit, the oil supply method of the compressor including: supplying the oil separated by the primary separation unit to the bearing of the rotor and a compression tooth groove space of the female rotor through a primary separation oil supply line connected to the compression tooth groove space of the female rotor defined by an inner wall of the rotor chamber and a pair of adjacent teeth of the female rotor in a cross-section perpendicular to a rotor shaft of the compressor body and the oil collector; supplying the oil used to lubricate the bearing to a low-pressure tooth groove of the rotor through an oil drain line connected to the compressor body without using the primary separation oil supply line; and supplying the oil separated by the secondary separation unit to the compression tooth groove space of the female rotor through a secondary separation oil supply line connected to the primary separation oil supply line.

[0014] According to the present invention, it is possible to decrease the power necessary for driving the compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1A is a schematic view illustrating a compressor according to a first embodiment of the present invention, FIG. 1B is an enlarged side view illustrating the inside of a compressor body, and FIG. 1C is a schematic view illustrating the position of an oil inflow port provided in a rotor chamber.

FIG. 2 is an enlarged side view illustrating the inside of a compressor body according to a second embodiment of the present invention.

FIG. 3 is an enlarged side view illustrating the inside of a compressor body according to a reference example of the present invention.

FIG. 4 is an enlarged side view illustrating the inside of a compressor body according to a modified example of the present invention.

FIG. 5 is an enlarged side view illustrating the inside of a compressor body according to another modified example of the present invention.

FIG. 6A is a schematic view illustrating a compressor according to a first comparative example, and FIG. 6B is an enlarged side view illustrating the inside of a compressor body.

FIG. 7A is a schematic view illustrating a compressor according to a second comparative example and FIG. 7B is an enlarged side view illustrating the inside of a compressor body.

FIG. 8 is a graph illustrating a specific power with respect to a shaft power.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Hereinafter, a first embodiment of the present invention will be described with reference to the accompanying drawings.

[0017] FIG. 1A illustrates a compressor 1 according to a first embodiment of the present invention. The compressor of the present invention is a screw type compressor 1, and is lubricated and cooled by oil flowing therein. The compressor 1 includes a compressor body 10 and an oil collector 30.

[0018] The compressor body 10 includes a rotor casing 12 which is provided in a rotor chamber 11 therein so as to accommodate a screw rotor 20 to be described later in a rotatable state. The compressor body 10 includes a suction port 13 which suctions a gas from the outside and a discharge port 14 which discharges a gas.

[0019] As illustrated in FIG. 1B, the screw rotor 20 includes a pair of rotors, that is, a female rotor 22 and a male rotor 24. A tooth groove 27a is formed between a pair of teeth 22a and 22a adjacent to each other in the circumferential direction of the female rotor 22. When taking a look at a cross-section perpendicular to a rotor shaft of the compressor body 10, a compression tooth groove space 27 of the female rotor 22 is defined between the inner wall of the rotor chamber 11 as the inner surface of the rotor casing 12 and the pair of teeth 22a and 22a adjacent to each other in the circumferential direction of the female rotor 22. When taking a look at a cross-section perpendicular to the rotor shaft of the compressor body 10, in the same way as the female rotor 22, a compression tooth groove space 28 of the male rotor 24 is defined between the inner wall of the rotor chamber 11 as the inner surface of the rotor casing 12 and a pair of teeth 24a and 24a adjacent to each other in the circumferential direction of the male rotor 24. One of both rotors 22 and 24 is connected to an electric motor (not illustrated) provided in the rotor casing 12. In each of a rotor shaft 23 which serves as the rotation center of the female rotor 22 and a rotor shaft 25 which serves as the rotation center of the male rotor 24, the suction side is supported by a suction side bearing 15 which is provided in the rotor casing 12. The discharge side of each of the rotor shafts 23 and 25 is supported by a discharge side bearing 16 which is provided in the rotor casing 12. Furthermore, FIG. 1A representatively illustrates only the female rotor 22 as the screw rotor 20.

[0020] A gas which is suctioned from the upside through the suction port 13 in a manner such that an electric motor rotates the screw rotor 20 is compressed by the rotation of the female rotor 22 and the male rotor 24, and is discharged as a high-pressure gas to the downside through the discharge port 14.

[0021] The oil collector 30 includes a hollow cylinder 31, a separation unit 34 which serves as a primary separation unit including the inner wall (the inner wall surface) of the oil collector 30, a filter 32 which serves as a secondary separation unit, and an oil reservoir 33. The discharged compression gas is introduced into the separation unit 34 of the oil collector 30 through a discharge line 35 including the discharge port 14 and the discharge passageway. At this time, a compression air is introduced in a substantially tangential direction to an annular passageway formed between the hollow cylinder 31 and the inner wall of the oil collector 30, and the oil and the gas are centrifugally separated from each other by a swirl flow generated at that time. In this way, the oil is primarily separated from the compression gas which includes an oil element flowing into the oil collector 30 through the discharge line 35. The compression gas from which the oil is primarily separated is guided to the filter 32 through the hollow cylinder 31. The filter 32 is formed as, for example, a demister, and the oil is secondarily separated from the gas when the compression gas passes through the filter. The oil reservoir 33 collects the oil which is primarily separated and falls along the inner wall surface of the oil collector 30 by the own weight. Furthermore, the compression gas from which the oil is separated twice is supplied to a compression gas supply target through a supply pipe 36 communicating with the filter 32. For example, the compression gas is supplied to a gas supply target such as a factory. The oil which is primarily separated from the gas inside the oil collector 30 is guided into the rotor casing 12 through a supply side line of an oil circulation line 40 causing the oil collector 30 and the compressor body 10 to communicate with each other.

[0022] The oil circulation line 40 includes a supply side line including a primary separation oil supply line 41, a secondary separation oil supply line 52, and a discharge side bearing oil drain line 54 and a collection side line including the discharge line 35. One end of the primary separation oil supply line 41 communicates with the oil reservoir 33, and the other end thereof is divided into three sub-oil supply lines 42, 46, and 48.

[0023] The end of the rotor chamber oil supply line 42 as the sub-oil supply line 42 is divided into a female rotor side oil supply line 43 and a male rotor side oil supply line 44 (see FIG. 1B). The female rotor side oil supply line 43 communicates with the female rotor side compression tooth groove space 27 through an oil inflow port 17 which is provided in the rotor chamber 11 on the side of the female rotor 22. Specifically, the female rotor side oil supply line 43 is connected to the female rotor side compression tooth groove space 27 which is defined between the inner wall of the rotor chamber 11 and the pair of teeth 22a and 22a adjacent to each other in the female rotor 22 in the cross-section perpendicular to the rotor shaft of the compressor body 10 (see FIG. 1C). The oil inflow port 17 is provided at a position facing the female rotor 22 in the rotor chamber 11. The male rotor side oil supply line 44 communicates with the male rotor side compression tooth groove space 28 through an oil inflow port 18 provided in the rotor chamber 11 on the side of the male rotor 24. Specifically, the male rotor side oil supply line 44 is connected to the male rotor side compression tooth groove space 28 which is defined between the inner wall of the rotor chamber 11 and the pair of teeth 24a and 24a adjacent to each other in the male rotor 24 in the cross-section perpendicular to the rotor shaft of the compressor body 10 (see FIG. 1C). The oil inflow port 18 is provided at a position facing the male rotor 24 in the rotor chamber 11. The end of the discharge side bearing oil supply line 46 as the sub-oil supply line 46 communicates with the discharge side bearing 16. The end of the suction side bearing oil supply line 48 as the sub-oil supply line 48 communicates with the suction side bearing 15.

[0024] A throttle portion 50 which reduces the oil supply amount to the discharge side bearing 16 is provided in the middle of the discharge side bearing oil supply line 46. The throttle portion 50 is, for example, an orifice formed in an oil hole. Since the throttle portion 50 is provided, it is possible to suppress the amount of the oil necessary for lubricating the discharge side bearing 16 as minimal as possible. Similarly, the throttle portion 50 is provided in the middle of the suction side bearing oil supply line 48. Furthermore, in the first embodiment, the discharge side bearing oil supply line 46 and the suction side bearing oil supply line 48 are provided with the throttle portion 50, but the present invention is not limited thereto. For example, a configuration may be employed in which the throttle portion 50 is provided only in the discharge side bearing oil supply line 46 in which the temperature of the oil used to lubricate the bearing easily increases.

[0025] One end of the secondary separation oil supply line 52 communicates with the filter 32 of the oil collector 30, and the other end thereof communicates with the female rotor side oil supply line 43 of the primary separation oil supply line 41 in a connection state. Furthermore, a fluid mixture obtained by mixing at least a part of the oil secondarily separated by the filter 32 and a part of the gas is guided into the secondary separation oil supply line 52.

[0026] One end of the discharge side bearing oil drain line 54 communicates with the discharge side bearing 16, and the other end thereof communicates with the inside of the rotor chamber 11 through a communication port 19 which is provided at a position just after the confinement of both rotors 22 and 24.

[0027] Hereinafter, the circulation line of the oil used to lubricate the compressor 1 will be described.

[0028] The oil which is primarily separated from the compression gas discharged from the compressor body 10 and is accumulated in the oil reservoir 33 is supplied to the compressor body 10 through the primary separation oil supply line 41. The oil which is guided to the rotor chamber oil supply line 42 of the primary separation oil supply line 41 is supplied to the compression tooth groove space 27 of the female rotor 22 through the female rotor side oil supply line 43, and is supplied to the compression tooth groove space 28 of the male rotor 24 through the male rotor side oil supply line 44. The oil which is supplied from the oil inflow ports 17 and 18 into the rotor chamber 11 is used to cool the compression gas, to lubricate the rotors 22 and 24, and to seal a gap between the rotors 22 and 24.

[0029] The oil which is secondarily separated by the filter 32 from the compression gas from which the oil is primarily separated is guided to the female rotor side oil supply line 43 through the secondary separation oil supply line 52. Accordingly, a fluid mixture of the primary separation oil and the pressurized gas including the secondary separation oil is injected toward the compression tooth groove space 27 of the female rotor 22 corresponding to the position in the course of the compression of the gas of the female rotor. Furthermore, when the pressure of the compression tooth groove space 27 of the female rotor 22 is too high, the oil supply amount decreases. For this reason, it is desirable to supply the fluid mixture to the compression tooth groove space 27 having a pressure less than an intermediate pressure between a suction pressure and a discharge pressure.

[0030] As described above, when the secondary separation oil supply line 52 is connected to the female rotor side oil supply line 43 (the primary separation oil supply line 41), the fluid mixture of the oil and the gas is injected when the oil is supplied from the oil reservoir 33 to the compression tooth groove space 27 of the female rotor 22. For this reason, the dispersion of the oil released to the compression tooth groove space 27 is promoted and the deflection of the oil inside the tooth groove hardly occurs. Accordingly, oil shortage is prevented between the rotor chamber 11 and the tooth tip of the female rotor 22 as a portion in which partial oil shortage particularly easily occurs, and hence a back flow in which the gas in the course of compression leaks therebetween may be prevented. Thus, the power necessary for driving the rotors 22 and 24 in order to compress the leakage gas again decreases, and hence the amount of air discharged from the compressor body 10 may be also increased.

[0031] Further, since the fluid mixture of the oil and the pressurized gas is released to the compression tooth groove space 27 of the female rotor 22, the atomization of the oil is promoted, and hence the surface area of the oil with respect to the amount of the oil supplied to the female rotor 22 increases. Thus, heat is easily exchanged between the fluid mixture supplied to the rotor chamber 11 and the gas in the course of compression. Accordingly, since the efficiency of the cooling process using the oil is improved, the gas almost becomes an isothermal compression state, and hence the power for driving the female rotor 22 decreases. The tooth in the female rotor 22 generally has a narrow tooth tip width, and the amount of the gas leaking between the tooth tip of the female rotor 22 and the rotor chamber 11 easily affects the existence oil therebetween. Further, since the volume of the tooth groove in the female rotor 22 is larger than that of the male rotor 24, the merit in which the fluid mixture is supplied to the compression tooth groove space 27 of the female rotor 22 is larger than that of the case where the fluid mixture is supplied to the male rotor 24.

[0032] The oil which is supplied to the discharge side bearing 16 so as to lubricate and cool the discharge side bearing 16 and is guided to the discharge side bearing oil drain line 54, and is returned to the rotor chamber 11 having a low pressure just after the confinement through the communication port 19.

[0033] The present invention is not limited to the first embodiment, and may be modified into various forms. In the first embodiment, the other end of the secondary separation oil supply line 52 is connected to only the female rotor side oil supply line 43, and communicates with the compression tooth groove space 27 of the female rotor 22 through the primary separation oil supply line 41. However, the present invention is not limited thereto. For example, as an example illustrated in FIG. 2, the other end of the secondary separation oil supply line 52 may be connected to the female rotor side oil supply line 43 and the male rotor side oil supply line 44, and may communicate with the compression tooth groove space 27 of the female rotor 22 and the compression tooth groove space 28 of the male rotor 24 through the rotor chamber oil supply line 42 as the primary separation oil supply line 41 (a second embodiment).

[0034] With the above-described configuration, the fluid mixture of the primary separation oil and the gas including the secondary separation oil may be supplied to not only the female rotor 22, but also the compression tooth groove space 28 of the male rotor 24. Accordingly, since the fluid mixture is released to the compression tooth groove space 28 of the male rotor 24, the atomization of the oil is promoted, and hence the surface area of the oil with respect to the amount of the oil supplied to the male rotor 24 increases. Thus, heat is easily exchanged between the oil supplied to the compressor body 10 and the gas in the course of compression. Accordingly, since the efficiency of the cooling process using the oil is improved, the gas almost becomes an isothermal compression state, and hence the power for driving the rotors 22 and 24 may be decreased. Further, the dispersion of the oil when the fluid mixture is released to the compression tooth groove space 28 of the male rotor 24 is promoted, and hence the deflection of the oil inside a tooth groove 28a of the male rotor 24 hardly occurs. Accordingly, it is possible to improve the sealing performance inside the rotor chamber 11. Thus, the power necessary for driving the rotors 22 and 24 may be decreased, and the amount of air discharged from the compressor body 10 may be increased.

[0035] However, since the fluid mixture supplied to the compression tooth groove space 27 of the female rotor 22 decreases as much as the fluid mixture supplied to the compression tooth groove space 28 of the male rotor 24, a power reduction effect due to the improvement in sealing performance becomes smaller than that of the first embodiment. The power reduction effect decrease amount is larger than the power reduction effect increase amount obtained by the improvement in cooling efficiency of the second embodiment. In a balance state, the power increases and the sealing performance decreases, and hence the performance of the compressor 1 is slightly degraded compared to the first embodiment as a whole. This is because the width of the tool tip of the female rotor 22 is narrower than that of the male rotor 24 and the tooth groove space is also large as described above. Accordingly, it is considered that the oil distribution becomes more sensitive compared to the male rotor 24.

[0036] Furthermore, in the second embodiment, the other end of the secondary separation oil supply line 52 is connected to the female rotor side oil supply line 43 and the male rotor side oil supply line 44 through the rotor chamber oil supply line 42. However, the present invention is not limited thereto, and the secondary separation oil supply line 52 may be divided into the secondary separation oil supply line 52 connected to the female rotor side oil supply line 43 and the secondary separation oil supply line 52 connected to the male rotor side oil supply line 44. In that case, the secondary separation oil supply line 52 may be a secondary separation oil supply line in which the line from one end to the other end thereof is separated or a secondary separation oil supply line in which one line is divided from the other end (see FIG. 4).

[0037] FIG. 3 illustrates a reference example in which the other end of the secondary separation oil supply line 52 is connected to only the male rotor side oil supply line 44 instead of the female rotor side oil supply line 43 (a reference example).

[0038] Referring to FIG. 8, it is understood that the specific power of the second embodiment is higher than that of the first embodiment. Thus, it is proved that energy may be saved in that the compressor of the first embodiment may compress a large amount of air by a power smaller than the compressor of the second embodiment. In the reference example, it is understood that the specific power is larger than those of the first embodiment and the second embodiment. Thus, in the compressors of the first embodiment and the second embodiment of the present invention including the primary separation oil supply line 41 which is connected to the oil collector 30 and the compression tooth groove space 27 of the female rotor 22 and supplies the oil separated by the separation unit 34 as the primary separation unit of the oil collector 30 to the compression tooth groove space 27 of the female rotor 22 and the secondary separation oil supply line 52 which supplies the oil separated by the filter 32 as the secondary separation unit to the compression tooth groove space 27 of the female rotor 22 and is connected to the primary separation oil supply line 41, it is proved that energy may be saved in that a large amount of air may be compressed by a power smaller than the compressor of the reference example.

[0039] Further, in the first embodiment, the discharge side bearing oil supply line 46 and the suction side bearing oil supply line 48 are formed by dividing the primary separation oil supply line 41. However, the present invention is not limited thereto, and the ends of the discharge side bearing oil supply line 46 and the suction side bearing oil supply line 48 may directly communicate with the oil reservoir 33. However, in any case, there is a need to supply the oil used to lubricate the bearing to the tooth groove 27a and 28a of the rotors 22 and 24 just before the compression start (just before the confinement) or the low-pressure tooth grooves of the rotors 22 and 24 as the tooth grooves 27a and 28a of the rotors 22 and 24 just after the compression start (just after the confinement) without using the primary separation oil supply line 41.

[0040] Furthermore, a method of connecting the secondary separation oil supply line 52 to the primary separation oil supply line 41 is not limited to the above-described embodiment, and may be modified into various forms.

[0041] Further, in the above-described embodiment, the end of the rotor chamber oil supply line 42 as the sub-oil supply line 42 is divided into the female rotor side oil supply line 43 and the male rotor side oil supply line 44. However, as illustrated in FIG. 5, the female rotor side oil supply line 43 and the male rotor side oil supply line 44 may be formed respectively as the separate primary separation oil supply lines. Here, in a case where the secondary separation oil supply line is connected to the female rotor side oil supply line 43 and the male rotor side oil supply line 44 as the primary separation oil supply line, the secondary separation oil supply line may be connected only to the female rotor side oil supply line 43. As a modified example, the secondary separation oil supply line may be connected to the male rotor side oil supply line 44 in addition to the female rotor side oil supply line 43.

[0042] FIG. 6A illustrates the compressor 2 of a first comparative example in which the end of the secondary separation oil supply line 52 directly communicates with the rotor chamber 11. In this drawing, the same reference numerals will be given to the same components as the compressor 1 of FIGS. 1A to 1C, and the repetitive description will not be presented.

[0043] In the first comparative example, as illustrated in FIG. 6B, the end of the rotor chamber oil supply line 42 communicates with the rotor chamber 11 through a primary separation oil inflow port 81 provided between the female rotor 22 and the male rotor 24 of the rotor chamber 11. That is, in the first comparative example, the end of the rotor chamber oil supply line 42 is connected to the compression tooth groove space as the connection portion of the compression tooth groove spaces 27 and 28 of the female and male rotors 22 and 24 defined by the inner wall of the rotor chamber 11 and the tooth 24a of the male rotor 24 and the tooth 22a of the female rotor 22 in the cross-section perpendicular to the rotor shaft of the compressor body 10. The end of the secondary separation oil supply line 52 is located on the side of the suction side bearing 15 of the rotor chamber 11 in relation to the primary separation oil inflow port 81, and directly communicates with the rotor chamber 11 through a secondary separation oil inflow port 82 provided between the female rotor 22 and the male rotor 24. The discharge side bearing oil drain line 54 communicates with the rotor chamber 11 through a communication port 83 provided between the female rotor 22 and the male rotor 24. The communication port 83 is disposed between the primary separation oil inflow port 81 and the secondary separation oil inflow port 82 in the axial direction of the screw rotor 20.

[0044] With the above-described configuration, in the compressor 2 of the first comparative example, the secondarily separated oil is directly returned to the low-pressure tooth grooves of the female rotor 22 and the male rotor 24 just after the compression start through the secondary separation oil inflow port 82 provided on the side of the suction side bearing 15 of the rotor chamber 11. The temperature of a large amount of gas including the oil flowing through the secondary separation oil supply line 52 becomes higher than that of the gas in the low-pressure tooth groove. Thus, when the high-temperature gas including the oil is supplied to the low-pressure tooth groove having a uniform volume, a force in which the gas in the course of compression expands serves as a pressure. Further, since a difference in pressure between the low-pressure tooth groove receiving the high-temperature gas and the upstream pressure increases, the back flow of the gas in the course of compression easily occurs. Accordingly, the power necessary for driving the compressor 2 increases and the amount of the discharge air decreases. Referring to FIG. 8, it is proved that the performance is improved by 3.6% at the specific power in the first embodiment compared to the first comparative example when the shaft power is around A (kW).

[0045] FIGS. 7A and 7B illustrates the compressor 3 of a second comparative example in which the end of the discharge side bearing oil drain line 54 communicates with the rotor chamber oil supply line 42 in a connection state in addition to the end of the secondary separation oil supply line 52. In this drawing, the same reference numerals will be given to the same components as the compressor 1 of FIGS. 1A to 1C, and the repetitive description will not be presented. In the compressor 3 of the second comparative example, the rotor chamber oil supply line 42 communicates with the rotor chamber 11 through an oil inflow port 88 provided between the female rotor 22 and the male rotor 24 of the rotor chamber 11. That is, even in the second comparative example, the end of the rotor chamber oil supply line 42 is connected to the compression tooth groove space as the connection portion of the compression tooth groove spaces 27 and 28 of the female and male rotors 22 and 24 defined by the inner wall of the rotor chamber 11 and the tooth 24a of the male rotor 24 and the tooth 22a of the female rotor 22 in the cross-section perpendicular to the rotor shaft of the compressor body 10.

[0046] In the second comparative example, since the rotor chamber oil supply line 42 becomes a high pressure state, the oil is not easily returned from the discharge side bearing oil drain line 54 to the rotor chamber oil supply line 42, and the flow of the oil used to lubricate the discharge side bearing 16 is blocked. Accordingly, there is a concern that the lifetime of the discharge side bearing 16 may be degraded. Further, the mixing loss in the discharge side bearing 16 is large. In the second comparative example, the oil may not be forcedly caused to flow to the discharge side bearing 16 by using the existing oil line. For this operation, there is a need to provide an orifice and the like between the joint point of the secondary separation oil supply line 52 and the joint point of the discharge side bearing oil drain line 54 in the rotor chamber oil supply line 42. However, in this method, the oil supply amount of the rotor chamber oil supply line 42 essentially decreases. At this time, the oil supply amount to the rotor chamber 11 decreases, the compression gas temperature increases, and the leakage amount increases. Accordingly, there is a high possibility that the power necessary for driving the compressor increases and the amount of the discharge air decreases. In this way, the second comparative example is not practical in that the power necessary for the driving operation may not be decreased, and is different from the first and second embodiments although there is similarity. The first and second embodiments are practical in that the power necessary for driving the rotors 22 and 24 may be decreased and the amount of the air discharged from the compressor body 10 may be increased.

[0047] The present invention is not limited to the above-described embodiments, and may be modified into various forms. For example, in the above-described embodiments, one end of the primary separation oil supply line 41 communicates with the oil reservoir 33, and the other end thereof is divided into three sub-oil supply lines 42, 46, and 48. However, the primary separation oil supply line may be formed as the separate primary separation oil supply lines so as to correspond to each of the sub-oil supply lines.

Claims

1. A compressor comprising:

   a compressor body that includes a suction port which suctions a gas, a pair of rotors comprising a female rotor and a male rotor which are rotatably supported by a bearing and compressing the gas suctioned from the suction port in cooperation with a rotor chamber, and an discharge port which discharges the compressed gas;
   an oil collector that includes a primary separation unit which primarily separates an oil from the gas compressed by the compressor body and a secondary separation unit which secondarily separates an oil from the gas from which the oil is primarily separated by the primary separation unit;
   a primary separation oil supply line that is connected to a compression tooth groove space of the female rotor defined by an inner wall of the rotor chamber and a pair of adjacent teeth of the female rotor in a cross-section perpendicular to a rotor shaft of the compressor body, and to the oil collector, the primary separation oil supply line supplying the oil separated by the primary separation unit to the compression tooth groove space of the female rotor;
   an oil drain line that supplies the oil separated by the primary separation unit and used to lubricate the bearing of the rotor to a low-pressure tooth groove of the rotor without using the primary separation oil supply line; and
   a secondary separation oil supply line that is connected to the primary separation oil supply line, the secondary separation oil supply line supplying the oil separated by the secondary separation unit to the compression tooth groove space of the female rotor.

2. The compressor according to claim 1,
   wherein the primary separation oil supply line is further connected to a compression tooth groove space of the male rotor defined by the inner wall of the rotor chamber and a pair of adjacent teeth of the male rotor in a cross-section perpendicular to the rotor

shaft of the compressor body and supplies the oil which is separated by the primary separation unit and does not include the oil passing through the secondary separation oil supply line to the compression tooth groove space of the male rotor.

3. The compressor according to claim 1, further comprising:

another primary separation oil supply line for the male rotor that is connected to a compression tooth groove space of the male rotor defined by the inner wall of the rotor chamber and a pair of adjacent teeth of the male rotor in a cross-section perpendicular to the rotor shaft of the compressor body and the oil collector and supplies the oil separated by the primary separation unit to the compression tooth groove space of the male rotor.

4. The compressor according to claim 2 or 3, wherein the secondary separation oil supply line is connected to the primary separation oil supply line connected to the compression tooth groove space of the male rotor and also supplies the oil separated by the secondary separation unit to the compression tooth groove space of the male rotor.

5. The compressor according to claim 2 or 3, wherein the oil separated by the secondary separation unit is supplied to the compression tooth groove space of the male rotor through the primary separation oil supply line.

6. The compressor according to any one of claims 1 to 5, further comprising:

a primary separation oil supply line that supplies an oil to the bearing on the side of the discharge port,
wherein the primary separation oil supply line that supplies an oil to the discharge side bearing is provided with a throttle portion which decreases an oil supply amount.

7. An oil supply method of a compressor including: a compressor body that includes a suction port which suctions a gas, a pair of rotors comprising a female rotor and a male rotor rotatably supported by a bearing and compressing the gas suctioned from the suction port in cooperation with a rotor chamber, and an discharge port which discharges the compressed gas; and an oil collector that includes a primary separation unit which primarily separates an oil from the gas compressed by the compressor body and a secondary separation unit which secondarily separates an oil from the gas from which the oil is primarily separated by the primary separation unit, the oil supply method of the compressor comprising:

supplying the oil separated by the primary separation unit to the bearing of the rotor and a compression tooth groove space of the female rotor through a primary separation oil supply line connected to the compression tooth groove space of the female rotor defined by an inner wall of the rotor chamber and a pair of adjacent teeth of the female rotor in a cross-section perpendicular to a rotor shaft of the compressor body and the oil collector;
supplying the oil used to lubricate the bearing to a low-pressure tooth groove of the rotor through an oil drain line connected to the compressor body without using the primary separation oil supply line; and
supplying the oil separated by the secondary separation unit to the compression tooth groove space of the female rotor through a secondary separation oil supply line connected to the primary separation oil supply line.

FIG.1A

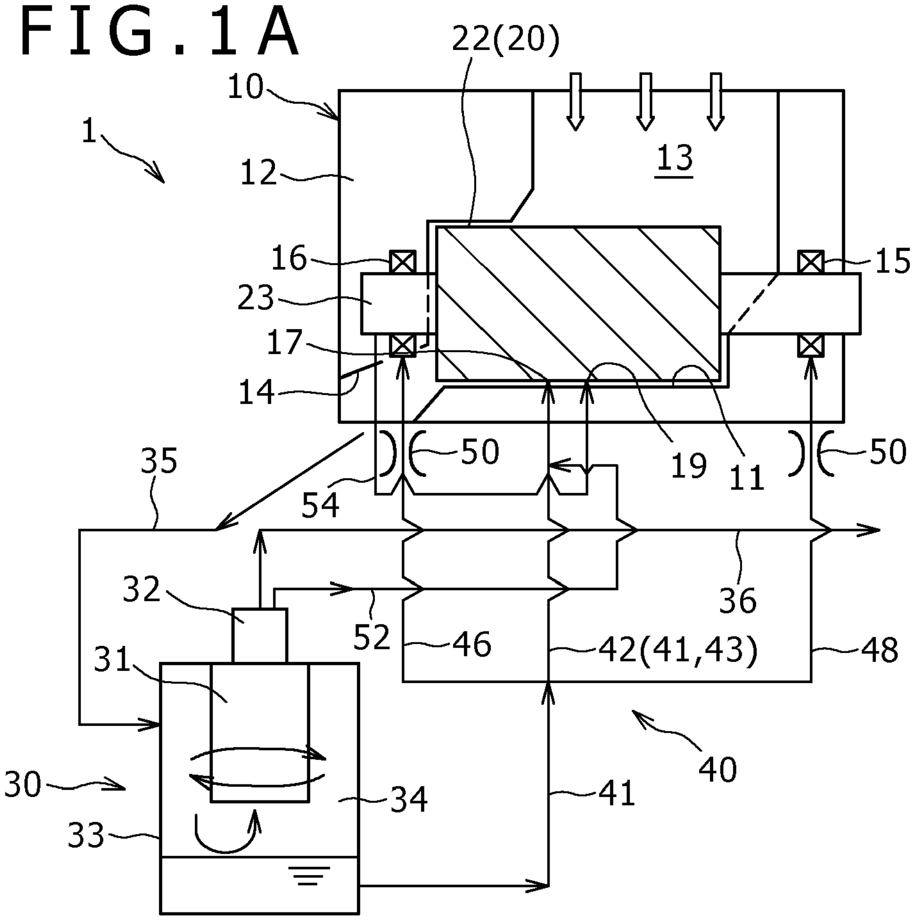


FIG.1B

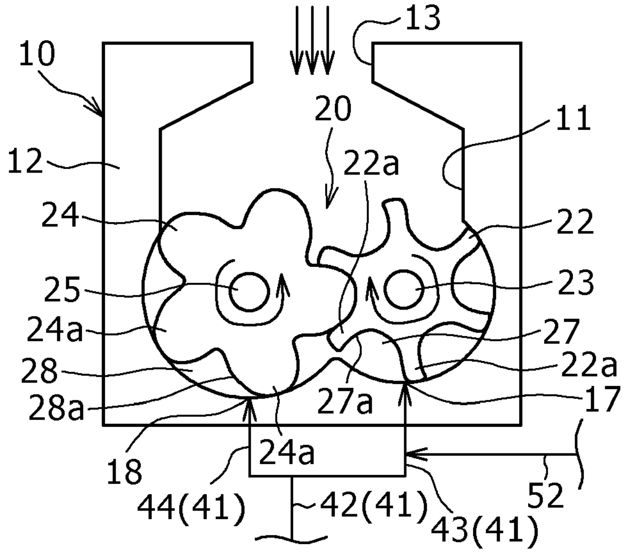


FIG.1C

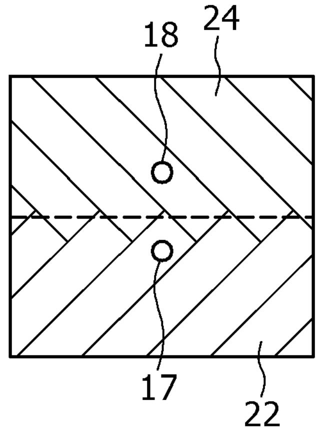
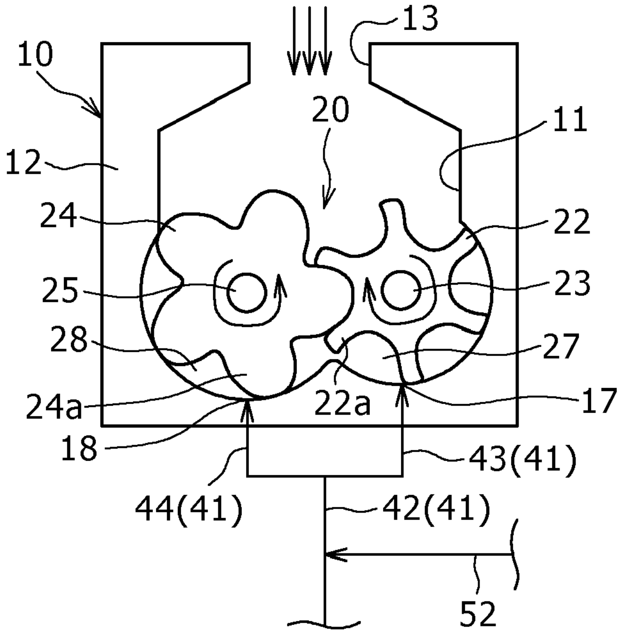


FIG. 2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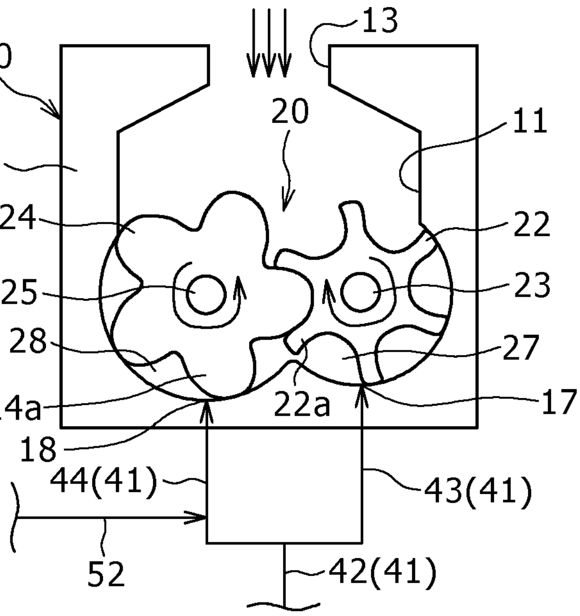
43(41)
44(41)
42(41)
52

FIG. 3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42(41)

FIG.4

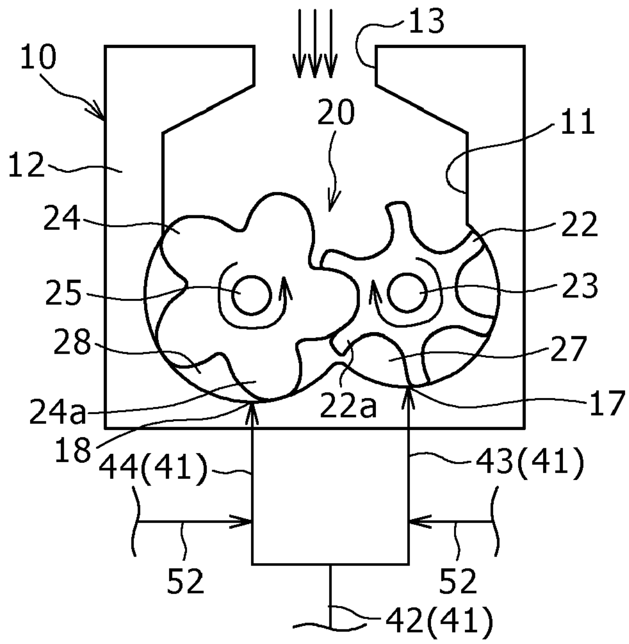
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FIG.5

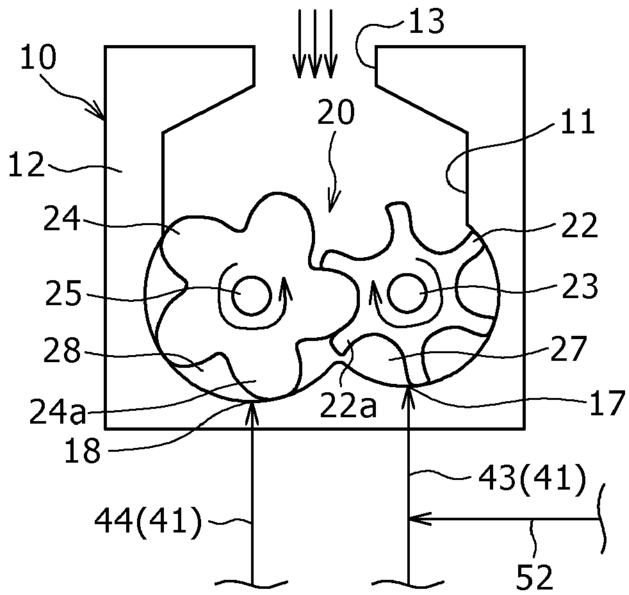
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FIG.6A

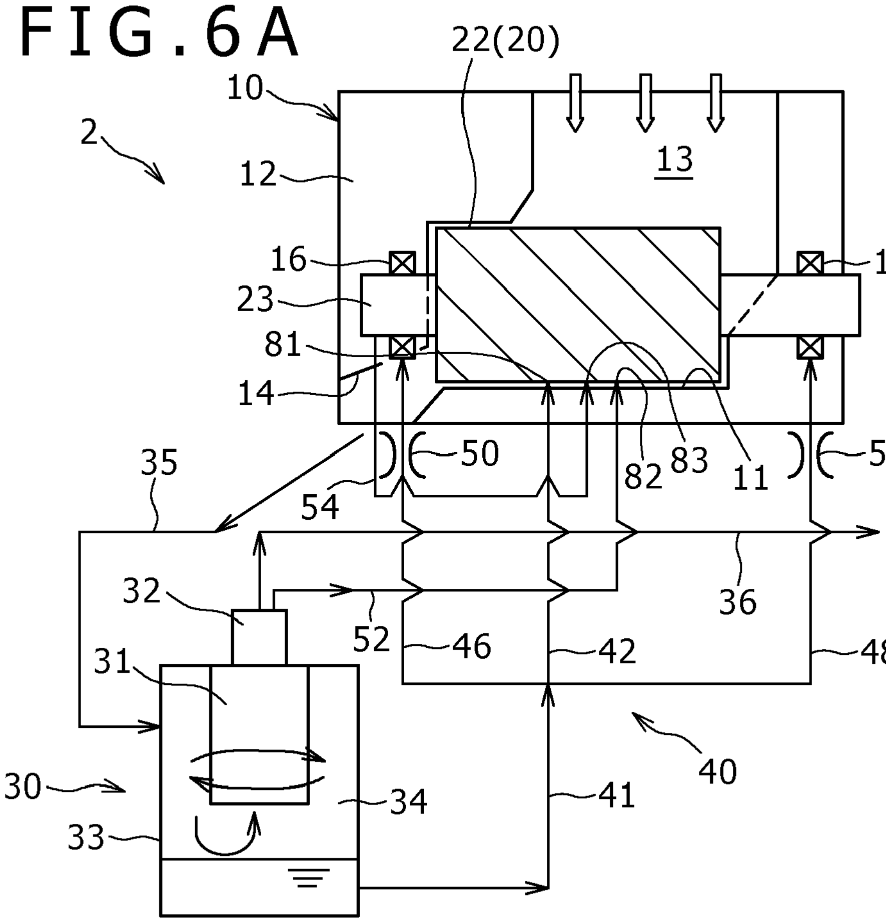
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FIG.6B

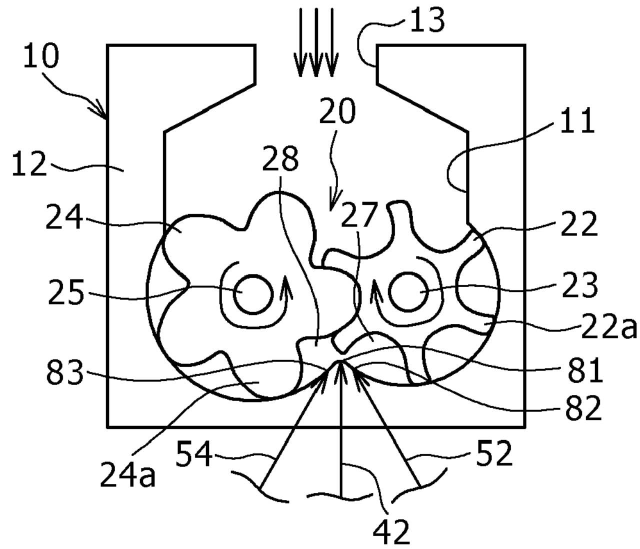
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FIG.7A

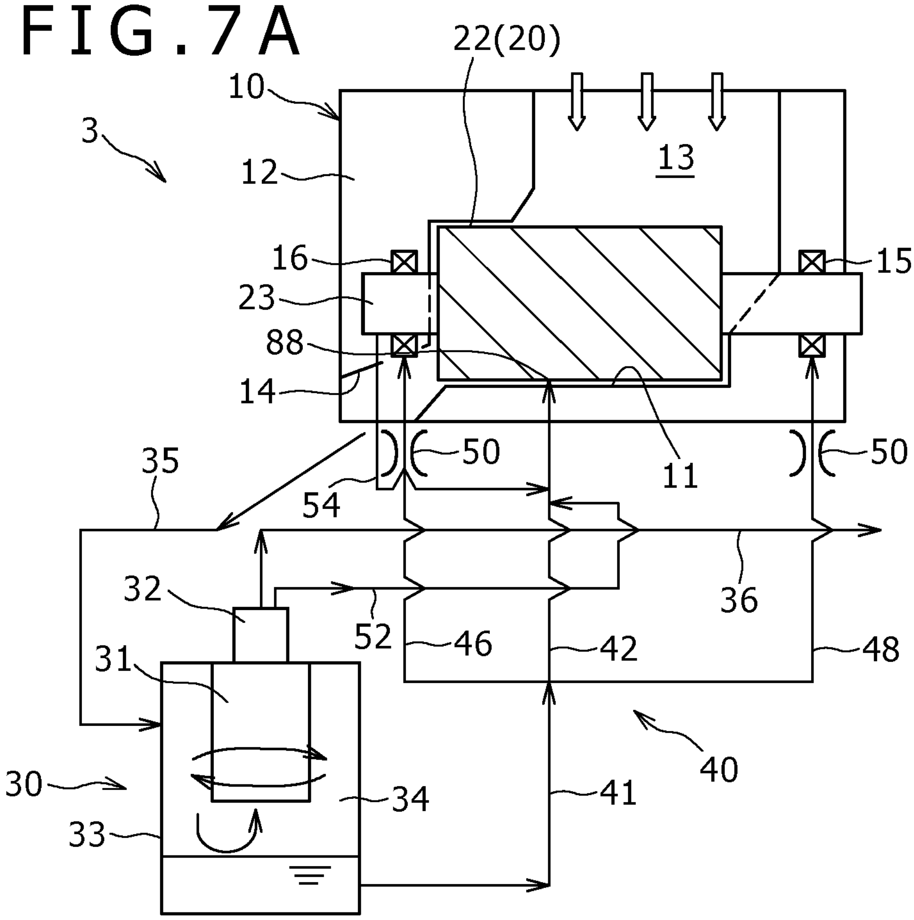
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FIG.7B

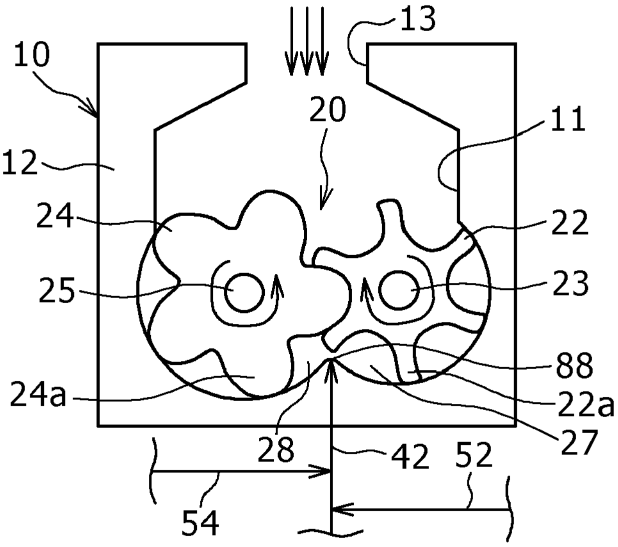
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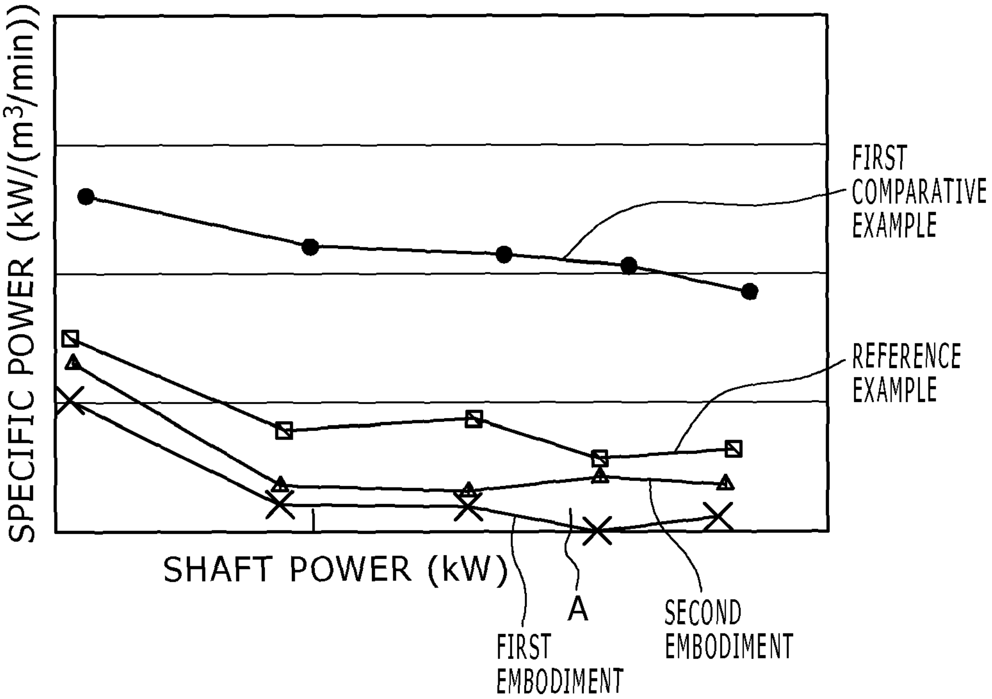
FIG. 8


SPECIFIC POWER (kW/(m3/min))
SHAFT POWER (kW)
FIRST COMPARATIVE EXAMPLE
REFERENCE EXAMPLE
A
FIRST EMBODIMENT
SECOND EMBODIMENT

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EUROPEAN SEARCH REPORT

Application Number
EP 14 18 1227

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	5 March 2015	Descoubes, Pierre

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05-03-2015

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