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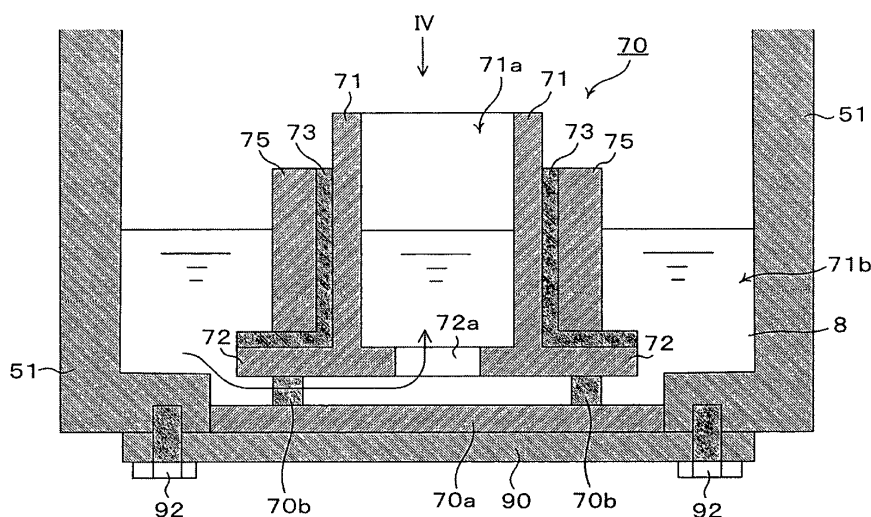
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(54) OIL DIFFUSION PUMP AND OIL VAPOR GENERATOR USED THEREFOR

(57) Provided is an oil diffusion pump equipped with an oil vapor generator capable of eliminating a problem that arises when a heater wire is used as a heating source for a hydraulic oil. The oil diffusion pump is a vacuum pump in which an oil vapor generator (70) is arranged in a casing (51) and operated to vaporize a hydraulic oil (8) and produce oil vapor, and this oil vapor is sprayed from a jet (53, 53a) to exhaust an intake air. The oil vapor generator (70) comprises a tubular case (71) (object to

be heated) extending in an upright direction, an induction coil (75) wound around the tubular member (71) via an insulating material (73), and a power supply means for applying an alternating current to the induction coil (75). The case (71) and the coil (75) are installed in the casing so as to be immersed in the hydraulic oil (8) stored in the casing (51). The power supply means is operated to apply an alternating current to the induction coil (75) to heat the case (71) itself and thus vaporize the hydraulic oil (8).

[FIG. 3]



Description

TECHNICAL FIELD

[0001] The present invention relates to an oil diffusion pump, which is connected to a vacuum container constituting a variety of vacuum devices, such as a vapor deposition device and a sputtering device, and suitably used as a vacuum pump for evacuating inside the container, and an oil vapor generator installed in the pump.

BACKGROUND ART

[0002] In a variety of vacuum devices, such as a vapor deposition device and sputtering device, an oil diffusion pump is used as a vacuum pump used in an exhaust device for evacuating inside a vacuum container constituting the devices. In oil diffusion pumps of the related art, those using an electric heater including a heater wire as a heating source for a hydraulic oil held in a boiler are known (Patent Document 1).

RELATED ART DOCUMENTS

PATENT DOCUMENT

[0003] Patent Document 1: Japanese Unexamined Patent Publication (Kokai) No. 2007-23778

SUMMARY OF THE DISCLOSED SUBJECT MATTER

[0004] Although it is advantageous that the device can be formed inexpensively when using a heater wire as a heating source for a hydraulic oil, it involves elements of causing various troubles, such as losing a heating function due to disconnection of the heater wire, arising of a current leakage due to an insulation defect of the heater wire, arising of a contact defect due to a high temperature of a terminal board, and arising of rust on a heated body. Also, since a temperature of the heater wire becomes high as red heat during operation of the oil diffusion pump, a position of attaching it has to be determined cautiously and there is also a disadvantage in an installation environment that a degree of freedom is limited in the installation position.

[0005] Furthermore, since a heater wire as a hydraulic oil heating source exhibits a large loss in heat conduction also in terms of an energy efficiency, the heating efficiency is low and energy saving may be hindered, furthermore, there are the possible disadvantages below.

- (1) slow heat rising time (taking long time at start-up)
- (2) being poor in heat response
- (3) being difficult to heat a body to be heated selectively and resulting in heating periphery of the object to be heated,

etc.

[0006] According to an aspect of the present invention, there are provided an oil vapor generator capable of eliminating disadvantages in using a heater wire as a heating source for a hydraulic oil and an oil diffusion pump comprising the oil vapor generator and capable of contributing to power saving during its operation.

[0007] An oil diffusion pump of the present invention is a vacuum pump provided with an oil vapor generator arranged in a jet provided in a casing, wherein the oil vapor generator is operated to heat a hydraulic oil to produce oil vapor and the oil vapor in the jet is sprayed from the jet for an operation of high-vacuum exhaustion of an intake air.

[0008] The oil vapor generator comprises a body to be heated, an induction coil provided near the object to be heated in an electrically insulated way, and a power supply means for applying an alternating current to the induction coil. It is configured to operate the power supply means to apply an alternating current to the induction coil so as to heat the body to be heated and, thus, vaporize the hydraulic oil.

[0009] The oil vapor generator of the present invention is used for heating a hydraulic oil in an oil diffusion pump comprising a casing and jet so as to produce oil vapor.

The oil vapor generator of the present invention comprises an object to be heated provided in the jet inside the casing such that a part or all thereof is immersed in the hydraulic oil stored in the casing in the oil diffusion pump, an induction coil provided near the object to be heated in an electrically insulated way such that a part or all thereof is immersed in the hydraulic oil stored in the casing, and a power supply means for applying an alternating current to the induction coil. By operating the power supply means, the object to be heated is heated so as to vaporize the hydraulic oil.

[0010] In both of the inventions above, a shape of the object to be heated constituting the oil vapor generator is not particularly limited and, for example, a plate shape, tubular shape or a combination of a plate shape and tubular shape, etc. may be mentioned. For example, when forming the object to be heated to be a tubular shape extending in an upright direction (FIG. 3 to FIG. 5), the induction coil may be wound around the object to be heated via an insulating material (FIG. 3 to FIG. 5). When forming the object to be heated by a plate material, such as a disk shape, the induction coil may be provided around the object to be heated (for example, on the back surface, etc.) via an insulating material. When combining, separate induction coil may be used for each and a plurality of power supply means may be used, alternatively, power may be supplied by using one system of an induction coil and a power supply means. In either case, the object to be heated and the induction coil in the present invention are installed such that a part or all thereof is immersed in the hydraulic oil stored in the casing.

[0011] In the present invention, a flow path for a hydraulic oil may be provided in the casing in the oil diffusion pump so as to operate the oil vapor generator to heat.

[0012] In the present invention, it may be configured to thermally isolate between the oil vapor generator provided in the casing and a bottom surface of the casing.

[0013] In the present invention, the induction coil of the oil vapor generator may be formed by a heat-resistant electric wire.

[0014] The oil vapor generator to be installed in the oil diffusion pump of the present invention uses as a hydraulic oil heating source an induction coil provided near the object to be heated via an insulating material provided therebetween (as an example, an induction coil wound around a tubular object to be heated via an insulating material provided therebetween), the object to be heated is heated by applying an alternating current to the induction coil and thus the hydraulic oil is vaporized by the heat. Also, the object to be heated and the induction coil are installed on the bottom portion of the casing so as to be immersed in the hydraulic oil stored in the casing of the oil diffusion pump.

[0015] Namely, according to the oil vapor generator installed in the oil diffusion pump of the present invention, not by heating the induction coil but by applying an alternating current to the induction coil, a magnetic flux interlinking with a predetermined direction of the object to be heated (the vertical upright direction in the case of the example above) is generated, the generated magnetic flux generates an induced current, that is, an eddy current in the object to be heated and Joule heat is produced thereby (induced heating). The generated heat heats the object to be heated itself (self-heating of the object to be heated), consequently, the hydraulic oil is heated.

[0016] Therefore, because there is no consumable member like a heater wire, the heating function is not lost due to disconnection. Also, the current is all consumed in the object to be heated as a heating body, so that an electric leakage due to an insulation defect does not arise and a contact defect of a terminal board due to a high temperature does not arise. Also, because the hydraulic oil heating source can be heated selectively, the degree of freedom in selecting an installation position of the induction coil becomes higher, which is advantageous.

[0017] Also, according to the oil vapor generator installed in the oil diffusion pump of the present invention, the object to be heated and the induction coil are installed in an arrangement such that a part or all thereof is immersed in the hydraulic oil stored in the casing in the oil diffusion pump. Therefore, even when a temperature of the induction coil becomes high due to a temperature rise of the object to be heated, a cooling effect by the hydraulic oil can be expected and abnormal heating can be prevented. Accordingly, an upper limit of the temperature of the induction coil can be suppressed lower comparing, for example, with an air cooling method for cooling the induction coil provided outside the casing.

[0018] Since the oil diffusion pump of the present invention comprises the oil vapor generator of the present invention installed in the casing, all of the current applied to the induction coil of the oil vapor generator can be

consumed by the object to be heated as a heating body. Consequently, the energy efficiency of the heating body is good and power saving can be achieved.

[0019] By providing a flow path of the hydraulic oil, which is heated by operating the oil vapor generator, inside the casing of the oil diffusion pump, it becomes unnecessary to provide a pipe for circulating the hydraulic oil as a flow path of the hydraulic oil on the atmosphere side of the bottom portion of the casing (outside the casing, which will be the same in the followings), so that the casing can be simplified.

[0020] As a result of passing through the flow path heated by the object to be heated, the hydraulic oil is expected to be preheated while passing through the flow path during hydraulic oil circulation and a preferable condition can be created for generating oil vapor.

[0021] The oil diffusion pump of the present invention comprises the oil vapor generator as a heating source inside the casing as explained above and a heating source is not provided outside the casing as in an oil diffusion pump of the related art provided with a heating source. As a result, the bottom portion of the casing can be formed substantially planar and the oil diffusion pump can be placed flatly so as to improve the convenience.

[0022] According to an example of the oil vapor generator of the present invention, since the upper end in the upright direction of the object to be heated as a heating body obtained by winding the induction coil is exposed above the oil surface of the contacting hydraulic oil, oil vapor rising from the oil surface contacts with the upper portion of the inner wall of the object to be heated exposed above the oil surface, thereby, it is heated furthermore, and sufficiently heated oil vapor can be generated in a short time. As a result, in the oil diffusion pump incorporating the oil vapor generator as above, heat rising of the hydraulic oil (that is, generation of oil vapor) in a further shorter time can be attained and, moreover, it is extremely advantageous in terms of energy efficiency.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

[FIG. 1] FIG. 1 is a schematic diagram showing a vacuum device according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a sectional schematic diagram showing an oil diffusion pump as an example used in the vacuum device in FIG. 1.

[FIG. 3] FIG. 3 is a sectional schematic diagram showing a key part of an oil vapor generator as an example used in the oil diffusion pump in FIG. 2.

[FIG. 4] FIG. 4 is a schematic plan view seeing FIG. 3 from the IV direction.

[FIG. 5] FIG. 5 is a view showing another example of a key part of an oil vapor generator corresponding to FIG. 3.

[FIG. 6] FIG. 6 is a view showing another example

of an arrangement mode of an oil vapor generator incorporated in the oil diffusion pump of the present example.

[FIG. 7] FIG. 7 is a view showing another example of an arrangement mode of an oil vapor generator incorporated in the oil diffusion pump of the present example.

DESCRIPTION OF NUMERICAL NOTATIONS

[0024]

1... vacuum device, 10... vacuum container, 21, 23 and 25 to 29... pipe, 31... main evacuation valve, 33... leak valve, 35... rough evacuation valve, 37... auxiliary valve, 39... leak valve, 50... oil diffusion pump, 51... casing, 53... jet, 53a... jet nozzle, 55... intake part, 57... exhaust part, 58... water cooling pipe, 59... oil storage, 60... rough evacuation pump, 70... oil vapor generator, 70a... pedestal, 71... case (an example of an object to be heated), 71a... inner region, 71b... outer region, 72... base, 72a... opening portion, 73... insulating material, 75... induction coil, 76... magnetic shield case, 8... hydraulic oil, 90... lower lid (flange), 92... engaging means

EXEMPLARY MODE FOR CARRYING OUT THE DISCLOSED SUBJECT MATTER

[0025] Below, an example of the present invention will be explained based on the drawings.

[0026] As shown in FIG. 1, a vacuum device 1 of the present example comprises a vacuum container 10. Inside the vacuum container 10, a variety of equipment necessary for forming a thin film (film formation) in general are arranged, such as a film formation source (illustration omitted) like a vapor source and sputter source, and a substrate holder for holding a substrate to be subjected to a treatment, etc. The vacuum container 10 is connected with a downstream side of a pipe 21. The vacuum container 10 is connected with a vacuum gauge (illustration omitted) to detect an atmospheric pressure (vacuum degree) inside the vacuum container 10.

[0027] The upstream side of the pipe 21 is connected to a downstream side of the intake pipe 23 via a main evacuation valve 31. The upstream side of the intake pipe 23 is connected to an intake part 55 of an oil diffusion pump 50. The middle of the pipe 21 is connected to the downstream side of a branch pipe 25. The middle of the branch pipe 25 is connected to the downstream side of a pipe 26, and a leak valve 33 is provided on the upstream side of the pipe 26.

[0028] The upstream side of the branch pipe 25 is connected to the downstream side of the pipe 27 via a rough evacuation valve 35. The upstream side of the pipe 27 is connected to a rough evacuation pump 60. The middle

of the pipe 27 is connected to the downstream side of the pipe 28. The upstream side of the pipe 28 is connected to an exhaust part 57 of the oil diffusion pump 50 via an auxiliary valve 37. A joint part of the pipe 27 and the pipe 28 is connected to the downstream side of the pipe 29, and the upstream side of the pipe 29 is provided with a leak valve 39. A vacuum gauge (illustration omitted) is connected inside the pipe 28 to detect a pressure inside the oil diffusion pump 50.

[0029] In addition to the above, the vacuum device 1 of the present example is provided with a control device (illustration omitted) for controlling an operation of the device 1. The control device provided in the present example is configured to comprise a main control circuit (illustration omitted) including a variety of processing circuits, a vacuum gauge drive circuit (illustration omitted) connected with a vacuum gauge connected inside the pipe 21, a rough evacuation pump control circuit (illustration omitted) for operating and controlling the rough evacuation pump 60 and an oil diffusion pump control circuit (illustration omitted) for operating and controlling the oil diffusion pump 50.

[0030] The main control circuit is connected to respective valves (main evacuation valve 31, leak valves 33 and 39, rough evacuation valve 35 and auxiliary valve 37), and those valves are opened/closed in accordance with a predetermined sequence of the main control circuit. The oil diffusion pump 50 is connected to a rough evacuation pump 60, and an exhaust air from the oil diffusion pump 50 through the auxiliary valve 37 is sucked by the rough evacuation pump 60 and exhausted from a not shown path.

[0031] As shown in FIG. 2, the oil diffusion pump 50 of the present example has a tubular container (casing) 51 having a closed bottom. On the bottom inside the casing 51, an oil vapor generator 70 for heating and vaporizing a hydraulic oil 8 is installed. The bottom of the casing 51 is formed to be substantially planar. The detailed explanation on the oil vapor generator 70 will be made later on. Inside the casing 51, a jet 53 is arranged where oil vapor, which is the hydraulic oil 8 (refer to FIG. 3) heated by the oil vapor generator 70, vaporized and convected upward is taken in and sprayed through a nozzle 53a to the rough evacuation direction. The upper end of the casing 51 is provided with an intake part 55 and the side surface of the casing 51 is provided with an exhaust part 57.

[0032] Next, an operation of the oil diffusion pump 50 will be explained.

[0033] When the oil vapor generator 70 is operated after opening the main evacuation valve 31, the hydraulic oil 8 is heated to around a boiling temperature to be oil vapor by the oil vapor generator 70 and fills inside the jet 53 and is sprayed from the nozzle 53a to the inner side-wall of the casing 51. An air taken in from the intake part 55 (air inside the vacuum container 10) is blown to the jet flow direction by the spray and discharged from the exhaust part 57. Thereby, evacuation inside the vacuum

container 10 is carried out. In FIG. 2, "circle (○)" schematically indicates a state of oil vapor, which is vaporized oil. Note that after spraying the oil vapor from the jet nozzle 53a, the intake part 55 is opened so that the hydraulic oil 8 does not come into the vacuum container 10.

[0034] Also, the mechanism is that the casing 51 is cooled by the water cooling pipe 58, so that the oil vapor of the hydraulic oil 8 adhered to the inner wall of the casing 51 is cooled and condensed, returns to an oil storage 59 at a lower portion of the casing 51 and reheated by the oil vapor generator 70 to circulate.

[0035] As shown in FIG. 3 and FIG. 4, the oil vapor generator 70 in the present example is installed via a plate-shaped pedestal 70a on the bottom portion inside the casing 51 of the oil diffusion pump 50 shown in FIG. 2. The pedestal 70a is supported by a lower lid (flange) 90 from the atmosphere side. A heat insulating material (illustration omitted) may be provided between the pedestal 70a and the lower lid 90. The lower lid 90 is attached to the bottom surface of the casing 51 by an engaging means 92, such as a bolt, in a detachable way, and the atmosphere-side bottom portion of the casing 51 is formed to be substantially planar.

[0036] Above the pedestal 70a (the upper direction in FIG. 3), a tubular case 71 is arranged as an example of an object to be heated. A lower end of the case 71 is supported by a base 72 having an opening portion 72a near its substantial center. The base 72 is supported by the pedestal 70a via leg portions 70b having a predetermined height, so that it is arranged to form a space of allowing the hydraulic oil 8 to flow between the pedestal 70a and itself. In this example, the space between the base 72 and the pedestal 70a formed by the leg portions 70b functions as a preheating flow path of the hydraulic oil. Also, by providing this space, it is configured to secure heat insulation between the oil vapor generator 70 arranged in the casing 51 of the oil diffusion pump 50 and the bottom surface of the casing 51.

[0037] As the case 71, a flanged case (illustration omitted) formed integrally with the base 72 having an opening portion 72a may be used, as well. Alternatively, the base 72 may be supported above the pedestal 70a via an insulating disk member (illustration omitted) of an induction coil 75, which will be explained later on.

[0038] The case 71 in the present example is formed by a material to be heated. As the material to be heated, at least any one of stainless steel, carbon steel, rolled steel for general structure specified in JIS-G3101 may be used.

[0039] As stainless steel, all kinds of SUS may be used, for example, SUS304, SUS303, SUS302, SUS316, SUS316L, SUS316J1, SUS316J1L, SUS405, SUS430, SUS434, SUS444, SUS429, SUS430F AND SUS302, etc. Carbon steel includes low carbon steel with a little carbon amount, such as soft steel materials, and high carbon steel with a large amount of carbon, such as hard steel materials. The rolled steel for general structure includes SS330, SS400, SS490 and SS540.

[0040] Among them, it is preferable to configure the case 71 with a ferromagnetic material having low electric resistance with resistivity of $10 \times 10^{-8} \Omega \text{m}$ to $20 \times 10^{-8} \Omega \text{m}$ or so, such as a soft steel material. When the case 71 is configured by a ferromagnetic material (soft steel, etc.) having low electric resistance, since electric resistance is low, an eddy current amount generated by application to the induction coil 75 becomes large, consequently, a self-heating amount by the case 71 itself becomes large and a high efficiency can be expected.

[0041] It is also preferable to configure the case 71 by an easily available general steel SS400. In that case, even if it is an object to be heated, whose temperature becomes high, a rust prevention property can be expected because it is always immersed in the hydraulic oil in a vacuum atmosphere. Other than the above, the case 71 may be formed, for example, by a mold provided with a clad member on a surface on the induction coil 75 side of a material to be heated.

[0042] In the present example, the base 72 for supporting the lower end of the case 71 may be formed by a material to be heated.

[0043] The case 71 is configured to have a circumferential wall extending in the upright direction (vertical direction). In the case 71, both of an inner region 71 and outer region 71b configure the oil storage 59 (refer to FIG. 2), where the hydraulic oil 8 is filled and stored. For example, when forming the case 71 to be 120mm height, the hydraulic oil 8 is filled such that an oil surface L level of the oil vapor generator 70 becomes 30mm or so during an operation stop. In that case, when the operation of the oil vapor generator 70 starts, the oil surface L level of the hydraulic oil 8 decreases, for example, to 10mm or so.

[0044] In the present example, it is preferable that the case 71 is formed to have a thickness in a range of 5mm to 12mm so as to realize induction heating with a low frequency alternating current (low frequency induction heating).

[0045] Note that, in the present example, the inner region 71 a of the case 71 is connected with the outer region 71b of the case 71 via the opening portion 72a of the base 72 (refer to FIG. 3).

[0046] An induction coil 75 is wound around the case 71 via an insulating material 73. Thereby, the induction coil 75 is arranged in an electrically insulated way on the outer circumference (an example of periphery) of the base 71. The insulating material 73 may be configured, for example, by a polyimide film, mica or thermal spraying material of an insulating material to the outer surface of an object to be heated, etc. having a thickness of $10 \mu\text{m}$ to $180 \mu\text{m}$ or so.

[0047] As a conducting wire composing the induction coil 75, an insulator-coated heat-resistant electric wire having small electric resistance and high heat resistance may be used. For example, an alumite electric wire, which is an aluminum wire subjected to an anodizing treatment, may be mentioned. A diameter of the conducting wire

constituting the induction coil 75 is preferably in a range of 2mm to 4mm. The number of wound layers of the induction coil 75 is preferably in a range of 7 to 14 layers.

[0048] The induction coil 75 is connected with a power supply means (illustration omitted) for providing power to the induction coil 75 and a condition of power supply by the power supply means is controlled by a control device.

[0049] In the present example, since the induction coil 75 together with the case 71 is installed in an arrangement so that a part or all thereof is immersed in the hydraulic oil 8, the induction coil 75 is not heated abnormally to be higher than a temperature of the hydraulic oil 8 and, even when the temperature of the induction coil 75 itself becomes high, a cooling effect by the hydraulic oil 8 can be expected. Furthermore, temperature rise of the induction coil 75 helps to heat the hydraulic oil 8, which contributes to the energy saving effect.

[0050] Next, an operation of the oil vapor generator 70 will be explained.

[0051] First, the power supply means is operated to apply an alternating current to the induction coil 75. A frequency of the alternating current to be applied to the induction coil 75 is not particularly limited and low frequency currents of several tens of Hz to several hundreds of Hz may be mentioned, or it may be a high frequency alternating current. The same effects can be obtained by supplying a high frequency alternating current, as well. Also, the current control method is used to control the power supply means, however, it may be a power control method. The case of applying a low frequency alternating current by using the current control method will be explained as an example below.

[0052] When operating the power supply means to apply to the induction coil 75 an alternating current with a commercial frequency of 50Hz or 60Hz, a magnetic flux interlinked with the vertical upright direction of the case 71 arises, and the flux generates an eddy current in the case 71 so as to generate Joule heat. This heat heats the case 71 itself and, thereby the hydraulic oil 8 stored in the inner region 71a in the case 71 is heated directly. An oil vapor rising from the oil surface in the case 71 is furthermore heated by contacting with a high-temperature portion at the upper portion of the case 71 exposed above the oil surface, becomes a sufficiently heated high-temperature oil vapor, convects upward inside the jet 53 and is sprayed from the nozzle 53a.

[0053] As explained above, since the casing 51 of the oil diffusion pump 50 is cooled by the water-cooling pipe 58, oil vapor of the hydraulic oil 8 adhered to the inner wall of the casing 51 is cooled to be condensed and returns to the outer region 71b of the case 71 (same as the oil storage chamber 59 in FIG. 2). In the present example, since the inner region 71 a of the case 71 is connected with the outer region 71 b of the case 71 via the opening portion 72a of the base 72 (refer to FIG. 3), the hydraulic oil 8 after condensing and returning passes through the space between the base 72 and the pedestal 70a formed

by the leg portions 70b, flows to the inner region 71a in the case 71 through the opening portion 72a of the base 72, reheated by the oil vapor generator 70, and the hydraulic oil 8 is vaporized again so as to circulate.

[0054] In the present case, when the base 72 for supporting the lower end of the case 71 is formed by a material to be heated, the base 72 portion together with the case 71 can be also used as an object to be heated. In that case, the hydraulic oil 8 cooled in the casing 51 and returned to the outer region 71 b of the case 71 can be preheated in the space between the base 72 and the pedestal 70a (namely, the flow path), so that it can contribute to an improvement of efficiency in vaporizing the hydraulic oil 8 when reheating in the inner region 71a.

[0055] When the pedestal 70a for supporting the base 72 from the back surface via the leg portions 70b is formed by a material to be heated as well as the case 71 and the base 72, it is expected that the pedestal 70a also serves as an object to be heated.

[0056] In the oil vapor generator 70 of the present example, the heating source for the hydraulic oil 8 to be used is obtained by winding the induction coil 75 around the tubular case 71 formed by a material to be heated, such as a soft steel and SS400, via an insulating material 73 provided therebetween, the case 71 is heated by applying a low frequency alternating current to the induction coil 75, and the heat vaporizes the hydraulic oil 8. Because the induction coil 75 is not heated, a disconnection problem is prevented, which means that the exhaustion function of the oil diffusion pump 50 is not lost due to a loss of the heating function caused by disconnection. Also, an electric leakage caused by an insulation defect does not arise. Furthermore, the induction coil 75 itself does not become a heating body and a contact defect of a terminal board due to a deterioration caused by a high temperature does not arise because it can be accommodated in the casing 51.

[0057] Furthermore, when the base 72 supporting the lower end of the case 71 is also formed by a material to be heated, the base 72 can be also heated by applying a low frequency alternating current to the induction coil 75 and the efficiency of vaporization can be improved.

[0058] When the pedestal 70a supporting the base 72 from lower side surface is also formed by a material to be heated, there is a possibility that the pedestal 70a can be used as an object to be heated by applying a low frequency alternating current to the induction coil 75, so that an improvement of the vaporization efficiency can be expected. In that case, by providing a heat shielding material (illustration omitted) between the pedestal 70a and the lower lid 90, the vaporization efficiency may be improved furthermore.

[0059] Since the oil vapor generator 70 of the present example is installed in the oil diffusion pump 50 of the present example, all of the current supplied to the induction coil 75 of the oil vapor generator 70 can be consumed by the case 71 (or the case 71 and the base 72). Consequently, there arise effects of improving the energy

efficiency, accelerating energy saving and contributing to a reduction of heat rising time of the hydraulic oil 8 (shortening start-up time of the oil diffusion pump 50), etc.

[0060] In the oil vapor generator 70 of the present example, a key part thereof (the case 71, insulating material 73 and induction coil 75) is installed at the bottom portion of the casing 51 in a state where the lower end is arranged above the pedestal 70a, so that the atmosphere-side bottom portion of the casing 51 can be formed to be substantially planar. As a result, the oil diffusion pump 50 able to be placed flatly can be provided and the convenience is enhanced.

[0061] The oil vapor generator 70 of the present example is configured that the upper end U in the upright direction of the case 71 as a heating body wound by the induction coil 75 is exposed above an oil surface L of the contacting hydraulic oil 8, so that oil vapor rising from the oil surface L is furthermore heated as a result of contacting with the upper portion of the case 71 exposed above the oil surface L and sufficiently heated oil vapor is generated. Consequently, in the oil diffusion pump 50 incorporating the oil vapor generator 70 of the present example, the temperature of the vapor to be sprayed from the jet 53 can be made high, which is extremely advantageous for attaining an improvement of an exhausting speed.

[0062] Note that the examples above are described to facilitate understanding of the present invention and are not to limit the present invention. Accordingly, respective elements disclosed in the above examples include all design modifications and equivalents belonging to the technical scope of the present invention.

[0063] For example, in the example above, the induction coil 75 was provided via the insulating material 73 around the single-structured case 71 formed by a soft steel material or SS400, etc. and the outer circumferential part of the induction coil 75 was exposed (refer to FIG. 3), however, it is not limited to this mode and the effects of the present example may be also obtained, for example, by forming the case 71 to have a double structure of a case inner wall and a case outer wall and configuring to have the structure of an outer region 71b / case outer wall / insulating material 73 / induction coil 75 / insulating material 73 / case inner wall / inner region 71a.

[0064] In that mode, a hydraulic oil 8 stored in the outer region 71b can be also heated together with the hydraulic oil 8 stored in the inner region 71 a, so that a drastic improvement of the heating efficiency of the hydraulic oil 8 can be expected.

[0065] The tubular object to be heated is not limited to the plate material as in the example and may be a wound porous metal body or net, through which the hydraulic oil can pass through in the configuration using a material to be heated.

[0066] In the above-explained example, the outer circumferential side of the induction coil 75 was exposed (refer to FIG. 3) but it is not limited to this mode and, for example, as the mode shown in FIG. 5, almost all of the

induction coil 75 (except for a part at a lower portion: refer to FIG. 5) may be covered with a magnetic shield case 76 formed by a different material from that of the case 71. That mode is preferable as a further improvement of the heating efficiency can be expected thereby when heating the case 71 by applying an alternating current to the induction coil 75.

[0067] In the above-explained example, the tubular case 71 was used as a material to be heated to constitute the oil vapor generator 70, however, it is not limited to this mode and a plate material (illustration omitted), such as a disk shape, may be used as a material to be heated and arranged so that a part or a whole of the plate material may be immersed in the stored hydraulic oil 8. In that case, the induction coil 75 may be provided around the plate material, for example, on the back surface of the plate material (the bottom portion side of the casing 51) via an insulating material 73. The effects of the present example can be also obtained in such a mode.

[0068] Also, one oil vapor generator 70 was provided to single oil diffusion pump 50 in the example explained above, however, it is not limited to this mode and, particularly in the case of seeking for a larger oil diffusion pump, for example as shown in FIG. 7 and FIG. 8, a plurality of oil vapor generators 70 of the present example may be provided at the bottom of the casing 51.

EXAMPLES

[0069] Next, an explanation will be made on an actual example (example) and a comparative example of the present invention.

[Example]

[0070] In the present example, an oil diffusion pump 50 (FIG. 2) explained below incorporating the oil vapor generator 70 (FIG. 3) as a heating source for a hydraulic oil was prepared and evaluated under the condition below.

(Oil Diffusion Pump 50)

[0071]

- * Diameter of Exhaust Port: 250mm
- * Exhaust Rate: 2900L/sec.
- * Ultimate Pressure in Vacuum Container: 6.7×10^{-6} Pa or lower
- * Necessary Electric Power: 0.7KW
- * Hydraulic Oil: Lion S, 1 L

(Oil Vapor Generator 70)

[0072]

- * Height of Case 71: 120mm
- * Oil Surface L Level of Hydraulic oil: 30mm (during

stop), 10mm (during operation)

[Comparative Example]

[0073] In the present example, an oil diffusion pump of the conventional configuration was prepared, wherein an electric heater using a heater wire (nichrome wire) as a heating source for hydraulic oil was arranged at the bottom of the pump, and evaluation was made under the condition below.

(Conventional Oil Diffusion Pump)

[0074]

- * Diameter of Exhaust Port: 250mm
- * Exhaust Rate: 2900L/sec.
- * Ultimate Pressure in Vacuum Container: 6.7×10^{-6} Pa or lower
- * Necessary Electric Power: 2.0KW (200V)
- * Hydraulic Oil: Lion S, 1L

[Evaluation]

[0075] An operation power was measured by using an oil diffusion pump in each example. Specifically, power supply parts to the nichrome wire (the comparative example) and induction coil (the example) were measured by a clamp ammeter, a power (start-up power, operation power) was calculated from the voltage, current and power factor, and a ratio of the example to the comparative example (comparison with conventional one) was calculated. The result was that the operation power in the example was decreased by 40% at start-up and decreased by 65% during operation from those in the conventional one, and it revealed that a significant power reduction was attained both at start-up and in operation.

[0076] Temperatures (side surface and bottom surface) were measured on the oil diffusion pumps in the respective examples. The result was 170°C on the side surface (on the atmosphere side) in the example. It was decreased by 26% comparing with that in the comparative example (230°C), and it was confirmed that a boiler inner tube was heated intensively, which can contribute to a power reduction. Also, the bottom surface temperature in the example was 120°C. It turned out that a heat loss was suppressed significantly comparing with the comparative example (red heat state), wherein a red heat heater block was exposed and at a very high temperature. It also turned out that a level of not needing to consider damages on the floor was attainable.

Claims

1. An oil diffusion pump, configured that an oil vapor generator is arranged in a jet provided in a casing, the oil vapor generator is operated to heat a hydraulic

oil to produce oil vapor, and the oil vapor in the jet is sprayed from the jet to exhaust an intake air in a high vacuum, wherein:

the oil vapor generator comprises

an object to be heated,
an induction coil arranged near the object to be heated in an electrically insulated way, and
a power supply means for applying an alternating current to the induction coil;

wherein the object to be heated and induction coil are installed in the casing such that a part or all thereof is immersed in the hydraulic oil stored in the casing; and
the power supply means is operated to heat the object to be heated and vaporize the hydraulic oil.

2. The oil diffusion pump according to claim 1, wherein the object to be heated in the oil vapor generator is tubular and extending in an upright direction, and an induction coil is wound around the tubular object to be heated via an insulating material provided therebetween.
3. The oil diffusion pump according to claim 1, wherein an object to be heated in the oil vapor generator has a plate shape, and an induction coil is arranged around the plate-shaped object to be heated via an insulating material provided therebetween
4. The oil diffusion pump according to any one of claims 1 to 3, wherein a flow path for a hydraulic oil is provided in the casing.
5. The oil diffusion pump according to any one of claims 1 to 4, wherein a heating source is not provided on an atmosphere-side bottom portion of the casing.
6. The oil diffusion pump according to any one of claims 1 to 5, configured to thermally insulate between the oil vapor generator arranged in the casing and a bottom surface of the casing.
7. The oil diffusion pump according to any one of claims 1 to 6, wherein the induction coil is formed by a heat-resistant electric wire covered with an insulator.
8. A vacuum device comprising an exhaust device for evacuating inside a vacuum container, wherein the oil diffusion pump according to any one of claims 1 to 7 is used as the exhaust device.
9. An oil vapor generator for heating a hydraulic oil to produce oil vapor in an oil diffusion pump comprising

a casing and a jet, installed and used in the casing in the oil diffusion pump, comprising:

an object to be heated provided in the jet such that a part or all thereof is immersed in the hydraulic oil stored in the casing, 5
an induction coil provided near the object to be heated in an electrically insulated way such that a part or all thereof is immersed in the hydraulic oil stored in the casing, and 10
a power supply means for applying an alternating current to the induction coil; and

configured to heat the object to be heated by operating the power supply means and thus vaporize the hydraulic oil. 15

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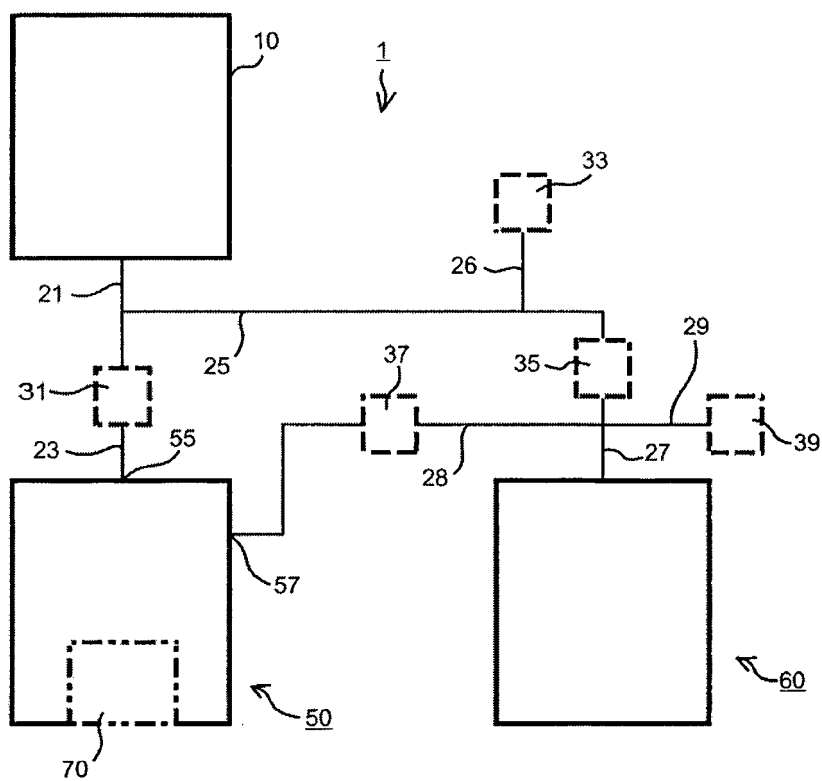
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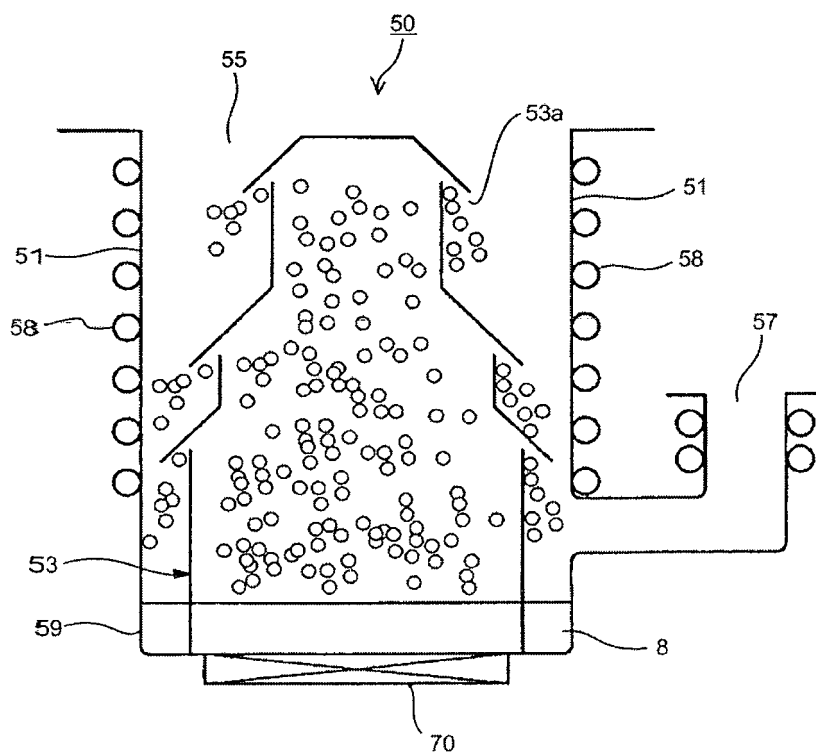
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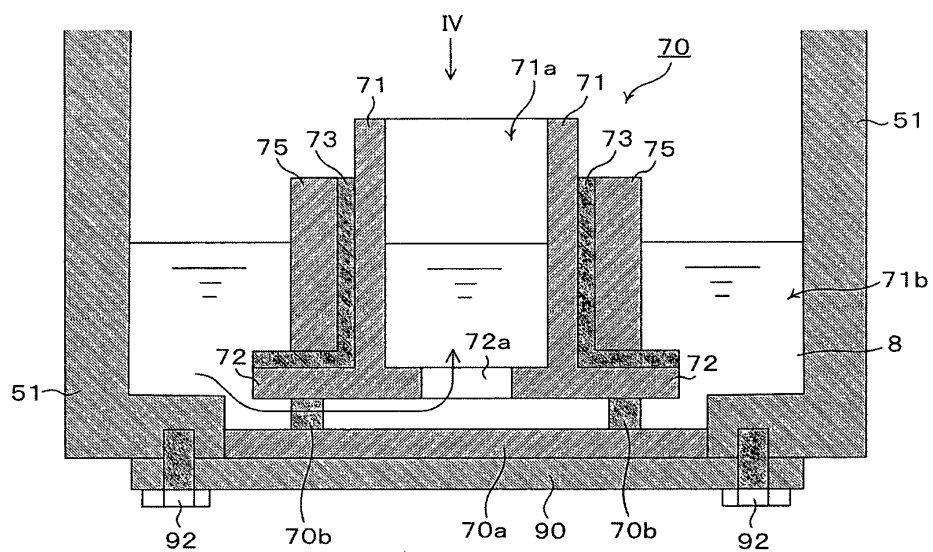
[FIG. 1]



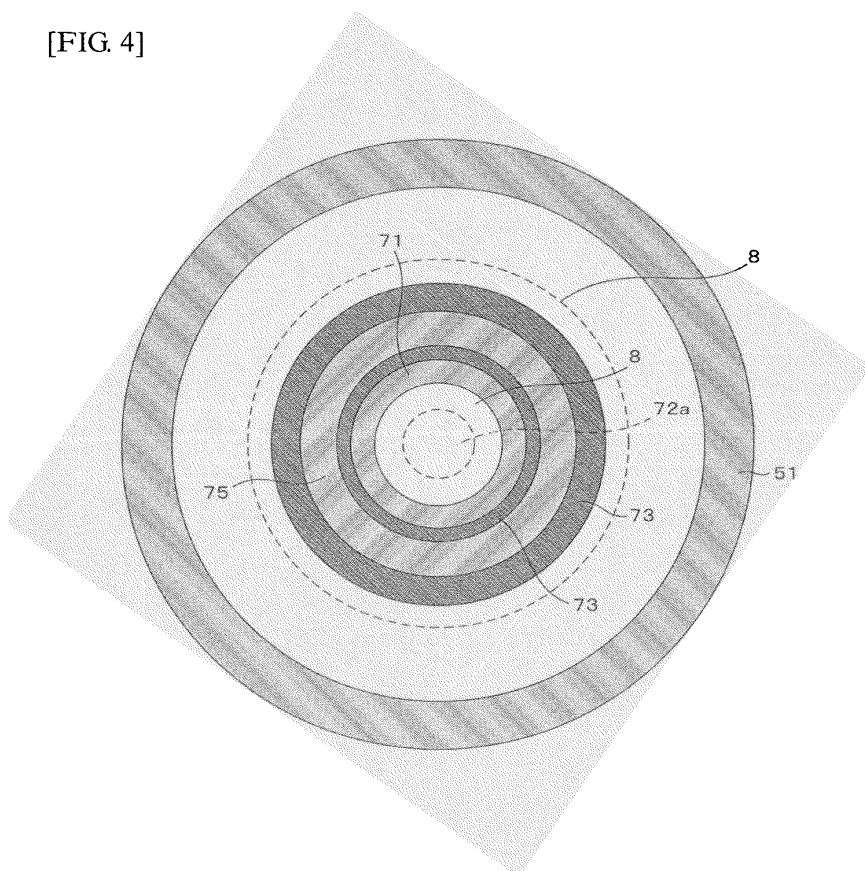
[FIG. 2]



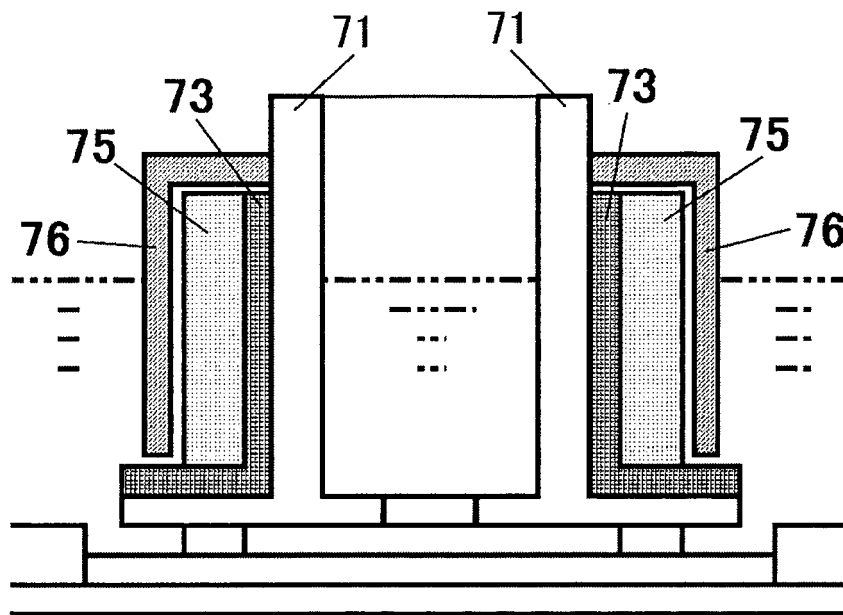
[FIG. 3]



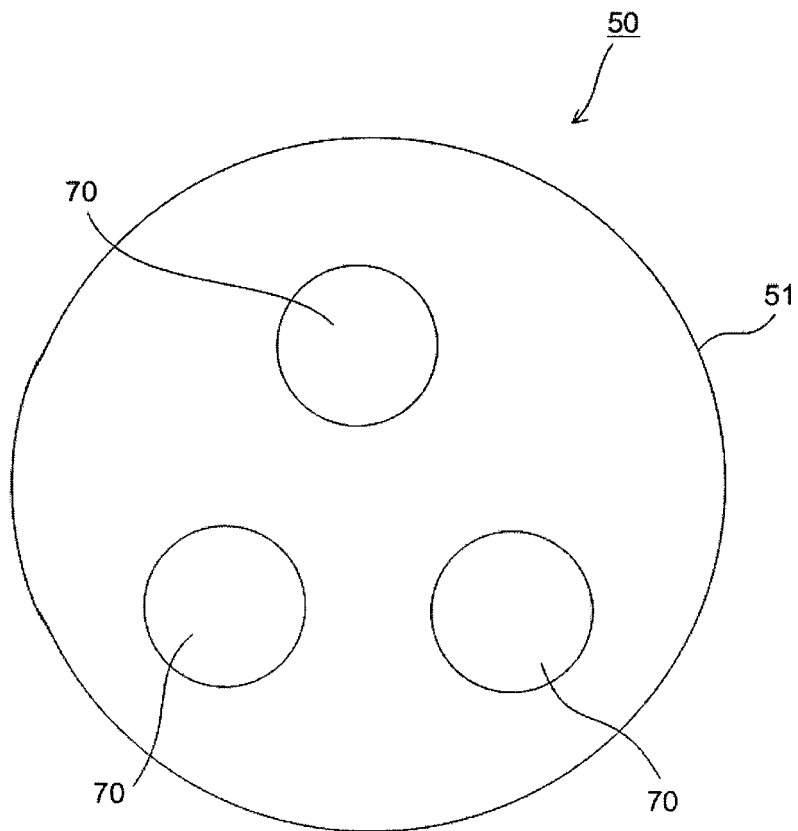
[FIG. 4]



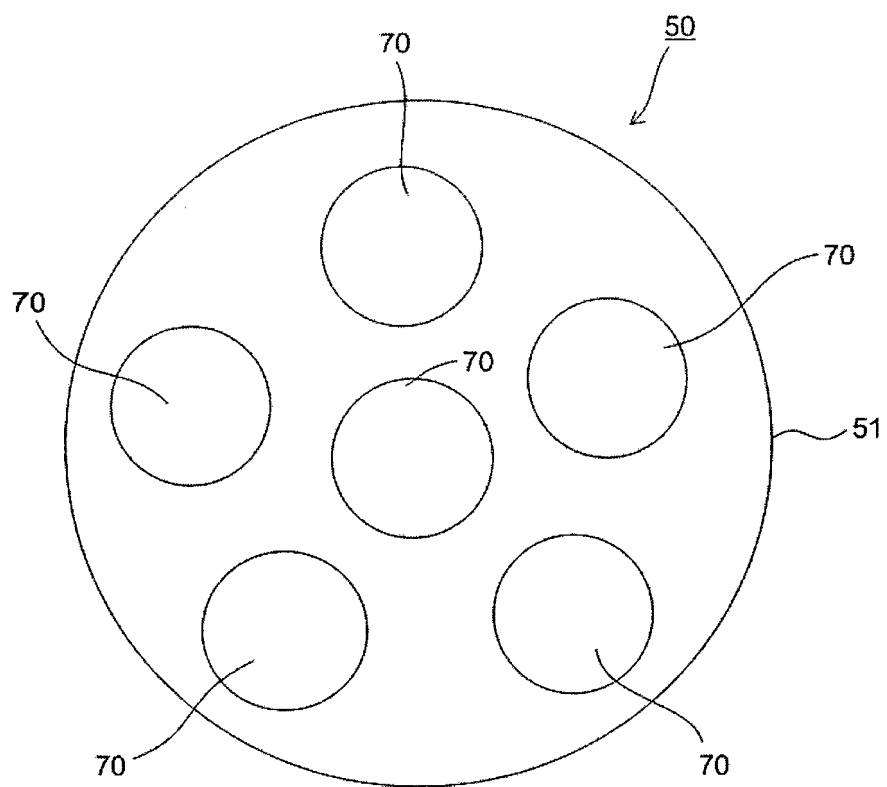
[FIG. 5]



[FIG. 6]



[FIG. 7]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/066723

A. CLASSIFICATION OF SUBJECT MATTER

F04F9/00(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)

F04F9/00, H05B6/10

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 1996-2014

Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

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.
A	JP 2011-255250 A (Shincron Co., Ltd.), 22 December 2011 (22.12.2011), entire text; all drawings (Family: none)	1-9
A	EP 601242 A1 (BROADHURST, John H.), 15 June 1994 (15.06.1994), column 5, lines 9 to 51; fig. 1 & US 5137429 A	1-9
A	JP 2007-152651 A (Tokuden Co., Ltd.), 21 June 2007 (21.06.2007), paragraphs [0009] to [0015]; fig. 1, 2 (Family: none)	1-9

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

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Date of the actual completion of the international search

18 August, 2014 (18.08.14)

Date of mailing of the international search report

26 August, 2014 (26.08.14)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/066723

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-11561 A (Tokuden Co., Ltd.), 13 January 2005 (13.01.2005), paragraphs [0011] to [0015]; fig. 1, 2 (Family: none)	1-9
A	US 4566861 A (Arthur A.LANDFORS), 28 January 1986 (28.01.1986), entire text; all drawings (Family: none)	1-9

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007023778 A [0003]