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(54) **OIL FILLED POWER BUSHING WITH PRESSURE COMPENSATION BY BELLOW**

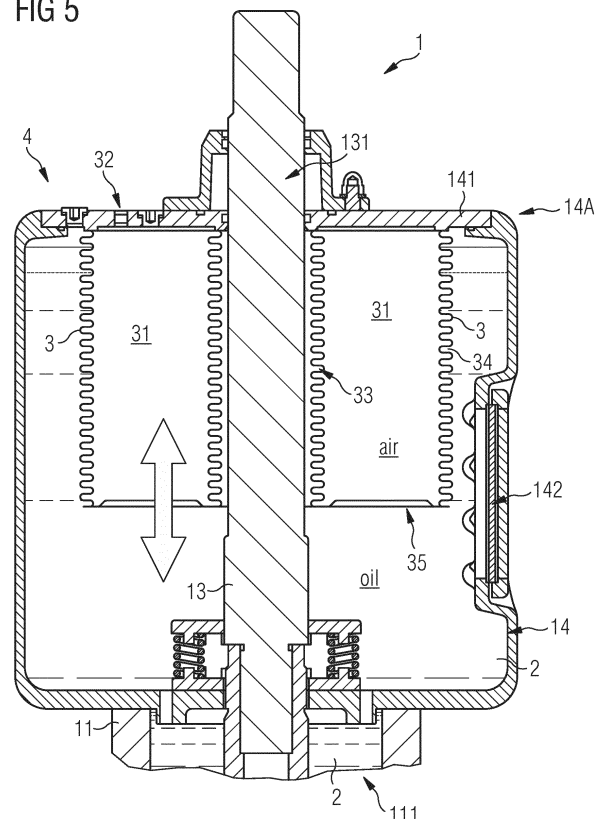
(57) Oil filled power bushing with pressure compensation by bellow.

The present invention concerns a liquid filled power bushing (1) comprising:

- an insulator (11) comprising an insulator chamber (111) for receiving an insulating liquid (2);
- an expansion chamber (14) communicating with the insulator chamber (111) for enabling an expansion or contraction of the insulating liquid (2);
- an electrical conductor (13) located within the bushing (1) and extending through the expansion chamber (14) and the insulator chamber (111);

characterized in that it further comprises a bellow (3) located inside the expansion chamber (14), the bellow (3) comprising an interior chamber (31) with variable volume, said interior chamber (31) communicating via a channel (32) with a space (4) filled with gas and located outside the expansion chamber (14) for enabling said gas to enter the interior chamber (31) in case of an expansion of the volume of the interior chamber (31) resulting from the contraction of the insulating liquid (2) and being released from said interior chamber (31) into said space in case of a contraction of the volume of the interior chamber (31) resulting from the expansion of the insulating liquid (2).

FIG 5



Description

[0001] The present invention relates generally to bushings for transformers and more particularly to insulated liquid filled power bushing.

[0002] A typical prior art bushing, presented in Figure 1, will be used hereafter for illustrating the technical problem at the origin of the present invention. Figure 1 shows an oil filled bushing 1 for a transformer or a high voltage device, said bushing 1 comprising an insulator 11 having a chamber 111 for receiving an electrical conductor 13 and insulating material 12, for instance oil and/or oil impregnated paper that surrounds the electrical conductor 13. The insulator 11 is surmounted by an oil expansion chamber 14 communicating with the chamber 111 of the insulator 11 in order to have the oil 2 filling the chamber 111 and extending upwardly into the oil expansion chamber 14. The electrical conductor 13 comprises a first extremity 131 located at the top of the bushing 1 and configured for being electrically connected to a first device and a second extremity (not shown) configured for being connected to another device, for instance a transformer. The electrical conductor 13 typically extends from the top of the bushing 1 to its bottom through the oil expansion chamber 14 and the insulator chamber 111, clamping means and gaskets ensuring the different parts of the bushing 1 being hermetically held together. According to this prior art technique, the oil expansion chamber 14 further comprises a gas cushion 15 located above the oil level in said oil expansion chamber 14. The oil filling the bushing 1 is therefore in contact with the gas cushion 15, allowing the oil 2 to expand or contract in function of variations of the temperature.

[0003] As previously described, standard oil filled power bushings usually integrate such a gas cushion (for instance N₂) in the top housing for compensating oil dilatation due to thermal changes. In operation, the solubility of the gas in the oil increases with increasing temperature. Consequently, N₂ is dissolved in the oil until the oil-gas system reaches an equilibrium corresponding to an N₂ saturation level in the oil of 100%. In case of sudden temperature drop (load reduction and/or external cooling), N₂ solubility in the oil decreases, which results in N₂ being released from the oil. A large quantity of N₂ released in a short time may generate bubbles in the insulating oil. If bubbles appear in a zone of high electrical stress, partial discharges may appear, inducing degradation of the insulation. A single occurrence is not dangerous for the bushing, but the repeated entering of gas in oil followed by its release from said oil can lead to an accelerated aging of the condenser active part, and ultimately a bushing failure.

[0004] This well-known phenomenon can occur in any liquid insulating bushing. Its occurrence is linked to many variables related not only to the bushing design, but also with operation and environmental conditions.

[0005] In addition to a potential failure in the field, this phenomenon can also be an issue for transformer man-

ufacturers when testing their product. Factory test program can include a temperature rise test, followed by electrical tests. Manufacturers may want to save time by cooling as fast as possible the transformer after temperature rise test. This can lead to bubble generation, and failure during electrical tests performed right after.

[0006] In case of bubbles generated during transformer factory tests, the usual solution is to vent the bushing in order to release pressure and avoid bubble generation. The drawback of this solution is that it requires breaking the bushing sealing system, hence compromising the integrity of the bushing's internal insulation.

[0007] Some bushing manufacturers have developed solutions to physically separate oil and gas inside the bushing. Examples of solutions are presented in Figure 2 and Figure 3 and will be briefly explained below.

[0008] Figure 2 presents a bushing embodiment disclosed in US6271470B1. It shows a liquid filled power bushing 1 including an insulator 11 having a chamber 111 for receiving an insulating liquid 2. An expansion chamber 14 communicates with the insulator chamber 111 for receiving insulating liquid 2 and gas 15. The technical problem is solved by means of a movable piston 5 slidably mounted within the expansion chamber 14 and dividing the latter into a liquid filled section 14A and a gas filled section 14B. The piston 5 is adapted to move up or down in function of an expansion or contraction of the liquid volume, while preventing the gas to communicate with said liquid, and preventing therefore the formation of bubbles within said liquid.

[0009] Figure 3 illustrates another embodiment for solving the present technical problem. It shows a schematic cross-sectional view of an Oil-Impregnated Paper (OIP) insulated transformer bushing, wherein two sealed bellows 3 are used for compensating an expansion or contraction of the oil due to thermal changes. The sealed bellows 3 are completely immersed in the insulating liquid and totally closed. The sealed bellows will contract or dilate in function of an expansion or contraction of the liquid volume, in order to avoid overpressure inside the expansion chamber. The bellows do not communicate with any space located inside or outside from the bushing. The contraction of the bellows generates additional pressure inside said bellows, which the bellows can withstand due to their material and design.

[0010] Nevertheless, the above-mentioned solutions present the following disadvantages:

- The use of a moving piston 5 sliding along the electrical conductor introduces technical risks in ensuring the tightness between insulating liquid 2 and gas 15, especially at the interfaces between piston 5 and conductor, and between piston 5 and walls of expansion chamber 14. In addition, physical contact between moving parts and fixed parts generates friction, which can damage the gaskets at the interface and reduce the life expectancy of such assembly.
- Fully sealed bellows completely immersed in the in-

insulating liquid need to be able to mechanically withstand the overpressure generated when the insulating liquid expands. Leak-tightness of the bellows has to be monitored, for instance by a pressure indicator.

[0011] An objective of the present invention is to propose a new concept for solving the technical problem related to the generation of gas bubbles in insulating oil of oil filled bushing, like OIP insulated transformer bushings, which is notably efficient during fast variations of the temperature within the bushing.

[0012] For achieving said objective, the present invention proposes notably a liquid filled power bushing comprising a bellow as disclosed by the object of the independent claim. Other advantages of the invention are presented in the dependent claims.

[0013] The power bushing according to the invention comprises notably:

- an insulator comprising a chamber for receiving an insulating liquid like oil, wherein said insulating liquid is usually located in a space between an electrical conductor and walls of the insulator forming said insulator chamber;
- an expansion chamber configured for communicating with the insulator chamber for receiving the insulating liquid and enabling an expansion or contraction of the latter within said expansion chamber. Preferentially, the expansion chamber is configured for enabling an expansion of the insulating liquid within the insulator chamber, notably upwardly, into the expansion chamber, and vice versa in case of contraction. In particular, the expansion chamber is configured for enabling a flow of the insulating liquid from the insulator chamber into the expansion chamber in case of dilatation of the insulating liquid, and a flow from the expansion chamber into the insulator chamber in case of contraction. Preferentially, said expansion chamber is further configured for having said insulating liquid free of any contact with any gas, said expansion chamber being for instance fully filled with the insulating liquid so that contact with gas is made impossible;
- the electrical conductor located, preferentially centrally, within the bushing and extending through the expansion chamber and the insulator chamber;
- a bellow comprising an interior chamber characterized by a variable volume, i.e. whose volume may change in function of forces (typically the pressure applied by the insulating liquid on the bellow) acting on the bellow. The bellow according to the invention is at least partially immersed in the insulating liquid comprised within the expansion chamber, and preferentially completely comprised within the expansion chamber (i.e. located inside the expansion chamber, completely immersed in the insulating liquid). The bellow according to the invention is further characterized in that it comprises a channel or orifice

making its interior chamber communicating with a space located outside from the bushing, typically outside from the expansion chamber, so that gas may enter said interior chamber from said space when the volume of the interior chamber increases and may be released from the interior chamber into said space when the volume of the interior chamber decreases. For instance, said channel or orifice is configured for making the interior chamber communicate with the external atmosphere, so that air at atmospheric pressure surrounding the bushing may enter said interior chamber when the volume of the interior chamber increases and may be released from the interior chamber into the external atmosphere surrounding the bushing when the volume of the interior chamber decreases. According to the present invention, the interior chamber is hermetically sealed from the insulating liquid, so that gas comprised within the interior chamber is free of contact with the insulating liquid.

[0014] Preferentially, the expansion chamber surmounts the insulator. For instance, it is mounted on a top part of the insulator, wherein a first extremity of the conductor is located, said first extremity, usually called top terminal, being configured for enabling a connection of the bushing with an external electrical circuit, while a second extremity of the electrical conductor (typically its bottom part) comprises connecting means for connecting the electrical connector to a high voltage device or a transformer.

[0015] Preferentially, the bushing according to the invention is an OIP insulated transformer bushing capable of compensating pressure variations occurring in the expansion chamber by variations of the volume of the interior chamber of the bellow. According to a preferred embodiment, the bushing comprises a single tubular-shaped bellow located inside the expansion chamber.

[0016] Preferentially, said bellow is a stainless steel bellow. In particular, the bellow is fixed to a removable closing lid of the bushing, or more precisely of the expansion chamber, wherein said lid is configured for hermetically closing the expansion chamber. In particular, said lid comprises, for each of the bellow according to the invention, a communication channel that makes the interior chamber of each of the bellow communicate with said space at the exterior of the expansion chamber. Said lid is preferentially configured for closing a top part of the expansion chamber so that removing said lid enables an easy filling of the expansion chamber with insulating liquid.

[0017] According to the present invention, the problematic of the generation of gas bubbles is therefore solved by physically separating oil from gas through the means of the bellow.

[0018] Further aspects of the present invention will be better understood through the following drawings:

- Figure 1 schematic illustration of a bushing according to prior art.
- Figure 2 side elevational view in section of an insulating liquid filled power bushing according to prior art.
- Figure 3 cross-sectional view of an OIP insulated transformer bushing according to prior art.
- Figure 4 schematic representation of a tubular-shaped bellow according to the invention.
- Figure 5 schematic representation of an insulating liquid filled power bushing according to the invention.

[0019] Figures 1-3 illustrates a prior art techniques in relation with the present invention, wherein Fig. 1 is a schematic representation of a bushing confronted to the problem of gas bubbles generation within the insulating oil, and Fig. 2 and Fig. 3 are illustrations of known techniques for solving the above-mentioned technical problem.

[0020] Figure 5 describes a preferred embodiment of a liquid filled power bushing 1 according to the invention wherein volume variations of oil 2, or any insulating liquid, comprised within the bushing 1 are compensated by volume variations of an interior chamber 31 of a bellow 3. Preferentially, the interior chamber 31 communicates with the exterior, i.e. with a space located outside the expansion chamber 14, via a channel or orifice 32, but is hermetically sealed with regard to the insulating liquid (oil 2). The bushing 1 according to the invention is typically configured for use with high voltage apparatus like a transformer.

[0021] The bushing 1 comprises notably an insulator 11 whose body is configured for defining a chamber 111 for receiving an electrical conductor 13, like a central current carrying conductor, and insulating material surrounding the electrical conductor 13, for instance oil 2 and/or oil impregnated paper. The oil expansion chamber 14 is preferentially mounted at the top of the insulator 11 and communicates with the chamber 111 of the insulator 11 via a channel or orifice in order to have the oil filling the chamber 111 also filling the interior of the expansion chamber 14, for instance by extending upwardly into the oil expansion chamber 14 until a top part 14A of the expansion chamber. In working operation, the oil 2 fills the expansion chamber 14 until said top part 14A, the expansion chamber 14 being thus free of gas that could dissolve within the oil 2. Compared to existing prior art techniques, the bushing 1 according to the invention is free of a gas cushion that would be located above the oil level in the expansion chamber 14 and in contact with said oil.

[0022] The electrical conductor 13 comprises notably a first extremity 131 located above the top part 14A of

the expansion chamber 14 and configured for electrically connecting the bushing to a first electrical connection, e.g. an electrical connection of an external electrical circuit, then extends through the expansion chamber 14 and the insulator chamber 111 and terminates with a second extremity (not shown) configured for electrically connecting the bushing to a second electrical connection, e.g. an electrical connection of a high voltage device or a transformer. The electrical conductor 13 typically extends therefore from the top of the bushing 1 to its bottom through the oil expansion chamber 14 and the insulator 12, and clamping or fixing means and sealing gaskets (not shown) are preferentially used for holding the different parts of the bushing 1 together, so that oil 2 is hermetically contained within the bushing 1.

[0023] According to the present invention, the bushing 1 further comprises preferentially a single or several bellows 3, located within the expansion chamber 14 and configured for being submerged into the oil 2 contained within said expansion chamber 14 when the bushing is in operation. In particular, once oil 2 completely fills the expansion chamber 14, it surrounds at least partially the bellow 3, for instance its lateral faces and its bottom, while the top or upper part of the bellow might be fixed to the top part 14A of the expansion chamber 14. In other words, each bellow 3 is in particular mounted inside said expansion chamber 14 so as to freely expand or contract in function of variations of the volume of the oil 2, with one part of the bellow being fixed to a wall of the expansion chamber 14 while another part, opposite to said one part, is free to move within said expansion chamber 14 in order to enable an expansion or contraction of the volume of the interior chamber 31. Indeed, the bellow is characterized by an interior chamber volume that is able to change in function of forces, like pressure, applied by the oil 2 on the bellow 3. The interior chamber 31 of the bellow 3 communicates with a space located outside of the expansion chamber 14 through a small channel or orifice 32 so that a gas may enter the interior chamber 31 from said space when the interior chamber expands and may leave the interior chamber for said space when the interior chamber contracts due to forces applied by the oil on the bellow.

[0024] According to the present invention, the upper part of the bellow is preferentially fixed to the top part 14A of the expansion chamber 14, for instance to a removable lid 141 of the expansion chamber 14, that is configured for hermetically closing the expansion chamber 14. Preferentially, said lid 141 is a plate comprising fixing means for hermetically closing the expansion chamber 14. The lower part of the bellow 3 is in particular free to move substantially vertically, i.e. substantially perpendicularly compared to a plane within which the lid lies, inside the expansion chamber depending on the pressure inside said expansion chamber 14. Preferentially, the inside of the bellow 3, i.e. its interior chamber 31, is filled with air, and communicates with the external atmosphere through the small channel or orifice 32. In partic-

ular, this channel or orifice 32 includes a filter to avoid moisture ingress inside the bellow 3. In operation, the bellow 3 will contract or expand depending on the volume required by oil 2 inside the bushing in function of thermal variations, and when oil 2 dilates due to thermal expansion, the bellow 3 will contract and the air inside the bellow 3 will be expelled through the channel or orifice 32 for instance in the surrounding environment of the bushing 1, and when oil 2 contracts due to cooling, the bellow 3 will fill with air coming through the channel or orifice 32 for instance from the surrounding environment of the bushing and expand.

[0025] According to the preferred embodiment shown in Fig. 5, the bellow 3 is substantially cylindrical and fixed to the top part 14A of the expansion chamber 14. Nevertheless, other embodiments might be envisaged, wherein the bellow may have another shape, like a spherical shape, and might be connected to another part of the bushing in order to have its interior chamber 31 communicate with the exterior, i.e. the surrounding environment. In particular, a preferred embodiment of the bellow 3 is illustrated in Fig. 4. According to said preferred embodiment, the bellow 3 is a tubular-shaped bellow, i.e. has a shape of a hollow cylinder characterized by an internal wall 33, an external wall 34, a bottom plate 35 and a lid 36. The space between the internal wall 33, the external wall 34, the bottom plate 35 and the lid 36 forms said interior chamber 31 hermetically sealed from the insulating liquid (e.g. oil 2). The internal wall 33 is configured for surrounding the electrical conductor 13, forming therefore a cavity or hollow part of the cylinder, which is preferentially cylindrical, and is in other words configured for receiving or housing the electrical conductor 13 which extends according to the length of the cylinder. The geometrical shape of the bottom plate is preferentially an annular disc. The length L of the cylinder is variable in function of the pressure in the expansion chamber, so that the bellow can contract or extend. The lid 36 comprises fixing means 361 to enable fixing said lid 36 to the removable lid 141 of the expansion chamber 14 or is preferentially said removable lid 141 of the expansion chamber 14. In that case, the lid 36 of the bellow 3 is directly fixable to a wall or body of the expansion chamber in order to hermetically close the latter. Said lid 36 further comprises said channel or orifice 32 making the interior chamber 31 of the bellow communicate with the exterior as previously described.

[0026] Advantageously, the contraction and expansion of the bellow within the expansion chamber eliminates the generation of gas bubbles within the oil 2, preventing therefore an accelerated aging of the bushing in case of use in cycling load conditions (solar power plants, wind farms...), and also preventing losing time during factory acceptance test of transformers. Additionally, the presented design enables the bushing to "breathe", the latter remaining at a pressure close to atmospheric pressure due to its communication through the channel or orifice 32 with the surrounding environment of the bush-

ing, which further prevents any risk of overpressure inside the bushing that could cause one or more of the bushing sealing gaskets to leak or fail (especially in case of temporary overload conditions).

[0027] Compared to prior art techniques solving the technical problem related to the generation of gas bubbles in insulating oil, the present invention provides also the following advantages: it reduces the manufacturing costs of the power bushing due to the use of simple elements like the claimed bellow which communicates via a channel with a space like the external atmosphere. Indeed, on one hand the manufacturing costs of such a bellow are for instance lower compared to bellows designed for being totally immersed within the insulating liquid, and on the other hand, the bellow according to the invention enables a direct access to information regarding the insulating liquid level within the expansion chamber by checking the position of the extremity of the bellow that is designed for freely moving within the insulating liquid (hereafter called the freely hanging part, which is for instance the bottom part of the bellow, while the other extremity of the bellow, e.g. the top part, is fixed and cannot move - see Fig. 5 for instance) during its expansion or contraction. This further reduces the overall manufacturing costs of the bushing, since in order to check the level of the insulating liquid, the expansion chamber 14 according to the invention may simply comprise a window 142 enabling a direct visualization of the position of the freely hanging part of the bellow. Said window 142 comprises for instance an indicator indicating a position of the freely hanging part that corresponds to a critical level of the insulating liquid and which may require an intervention of an operator. Such a simple and direct verification of the insulating liquid level is not possible with all prior art techniques. For instance, the solutions based on sealed bellows totally immersed within the insulating liquid, require a complex system for determining the contraction of the bellow and/or the pressure within the insulating chamber, said complex system increasing therefore the manufacturing costs of the power bushing. Therefore and in conclusion, the present invention has many different advantages over existing solutions, which make the power bushing according to the invention a very attractive product.

Claims

1. Liquid filled power bushing (1) comprising:

- an insulator (11) comprising an insulator chamber (111) for receiving an insulating liquid (2);
- an expansion chamber (14) communicating with the insulator chamber (111) for enabling an expansion or contraction of the insulating liquid (2);
- an electrical conductor (13) located within the bushing (1) and extending through the expan-

sion chamber (14) and the insulator chamber (111);

characterized in that it further comprises a bellow (3) located inside the expansion chamber (14), the bellow (3) comprising an interior chamber (31) with variable volume, said interior chamber (31) communicating via a channel (32) with a space (4) filled with gas and located outside the expansion chamber (14) for enabling said gas to enter the interior chamber (31) in case of an expansion of the volume of the interior chamber (31) resulting from the contraction of the insulating liquid (2) and being released from said interior chamber (31) into said space in case of a contraction of the volume of the interior chamber (31) resulting from the expansion of the insulating liquid (2).

2. Liquid filled power bushing (1) according to claim 1, wherein the bellow is partially immersed in the insulating liquid (2).
3. Liquid filled power bushing (1) according to claim 1 or 2, wherein the space (4) is the external atmosphere surrounding the liquid filled power bushing (1).
4. Liquid filled power bushing (1) according to one of the claims 1 to 3, wherein the expansion chamber (14) is configured for surmounting the insulator (11).
5. Liquid filled power bushing (1) according to one of the claims 1 to 4, wherein the channel (32) comprises a moisture filter.
6. Liquid filled power bushing (1) according to one of the claims 1 to 5, wherein the bellow (3) is fixed to a removable closing lid (141) of the expansion chamber (14).
7. Liquid filled power bushing (1) according to claim 6, wherein the removable closing lid (141) comprises said channel (32).
8. Liquid filled power bushing (1) according to one of the claims 1-7, wherein it comprises a single bellow which is a tubular-shaped bellow.

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FIG 1

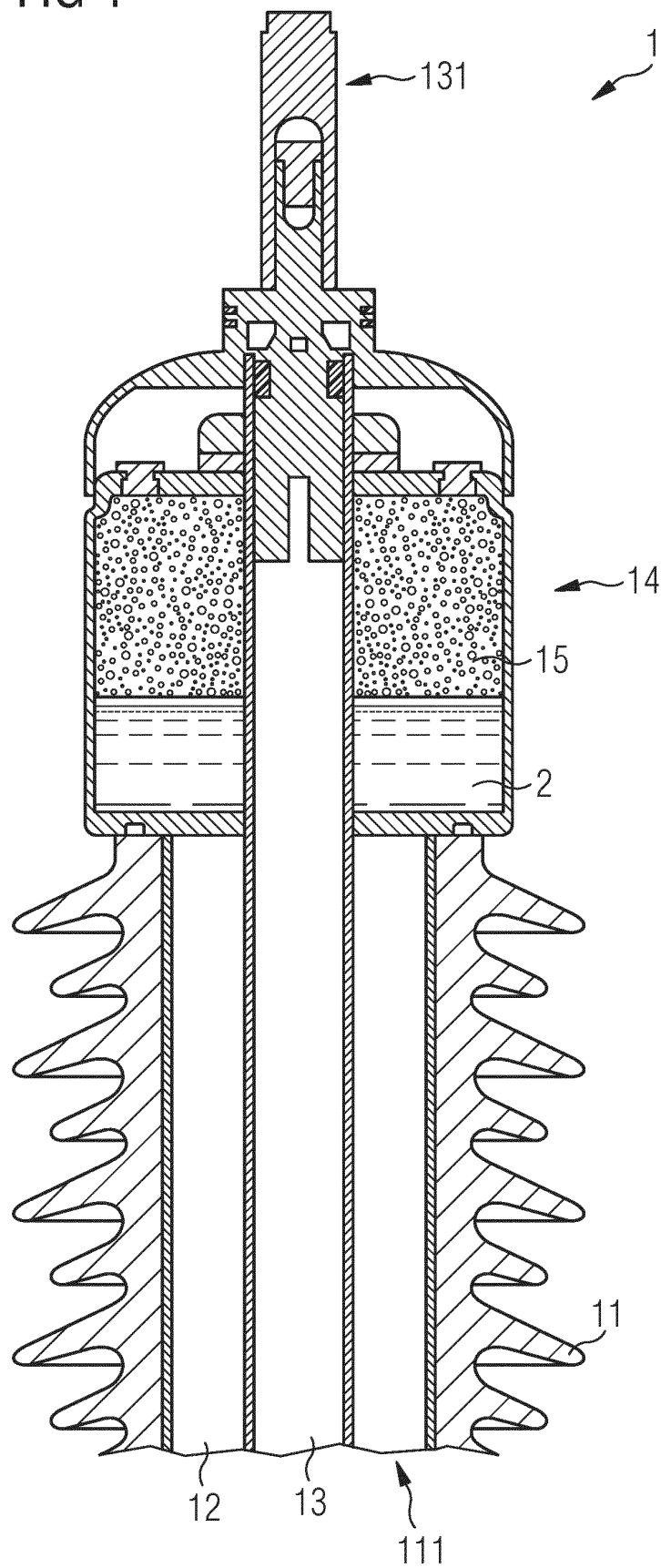


FIG 2

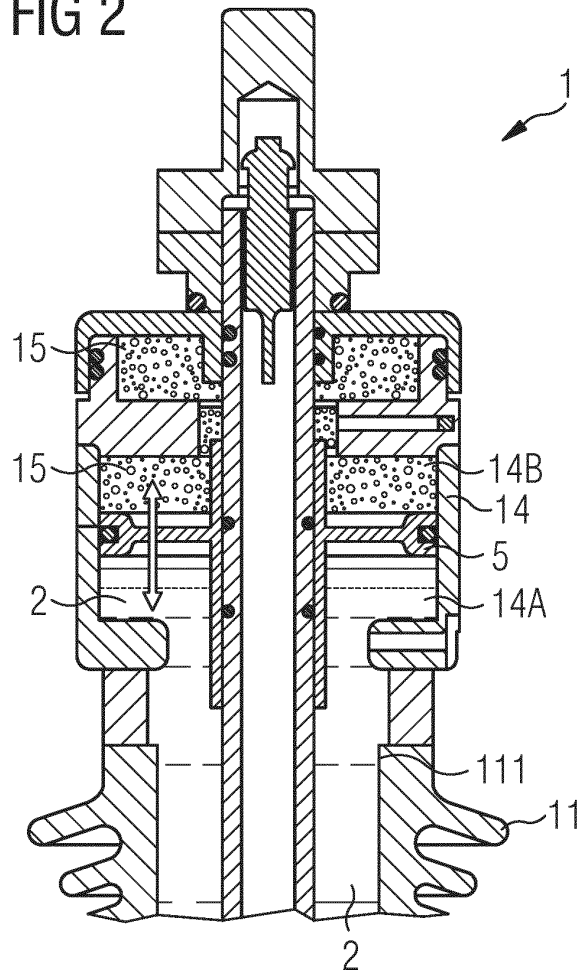


FIG 3

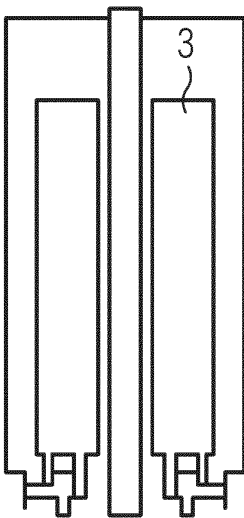


FIG 4

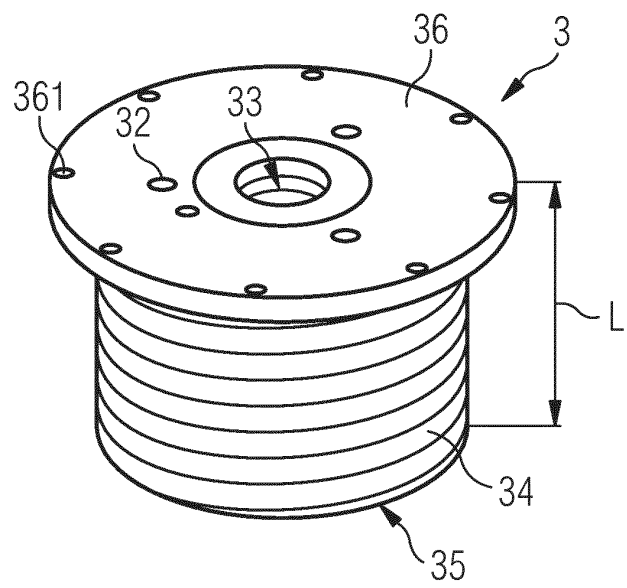
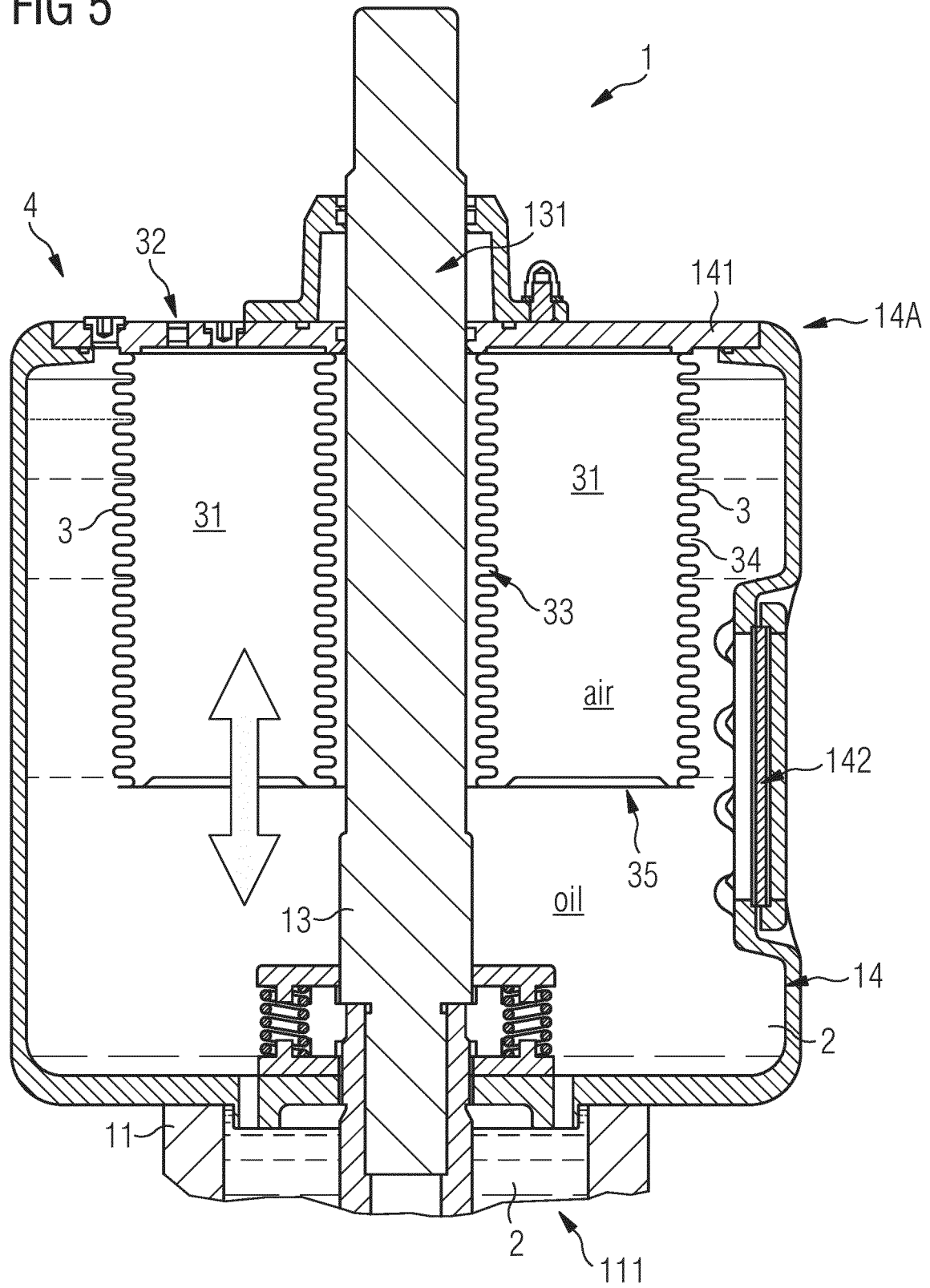


FIG 5





EUROPEAN SEARCH REPORT

Application Number
EP 17 18 8182

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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 17 18 8182

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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