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(54) **SEALING APPARATUS FOR A LIQUID-FILLED ELECTRICAL EQUIPMENT AND ASSOCIATED ASSEMBLY**

(57) The invention relates to a sealing apparatus (6) for an electrical equipment (4), the sealing apparatus (6) including:

- a breather device (16) comprising a main port (26), an input port (28) and an output port (30), and configured to allow:

• a first fluid flow from the main port to the output port if a pressure difference between the main port and the output port is higher than a predetermined overpressure threshold; and

• a second fluid flow from the input port to the main port if a pressure difference between the main port and the input port is lower than a predetermined under-pressure threshold; and

- a conservator (14) comprising an enclosure (18) including a first port (22), and a second port (24) fluidically connected to the main port, the enclosure (18) defining an internal volume (20) in fluid communication with each of the first port and the second port.

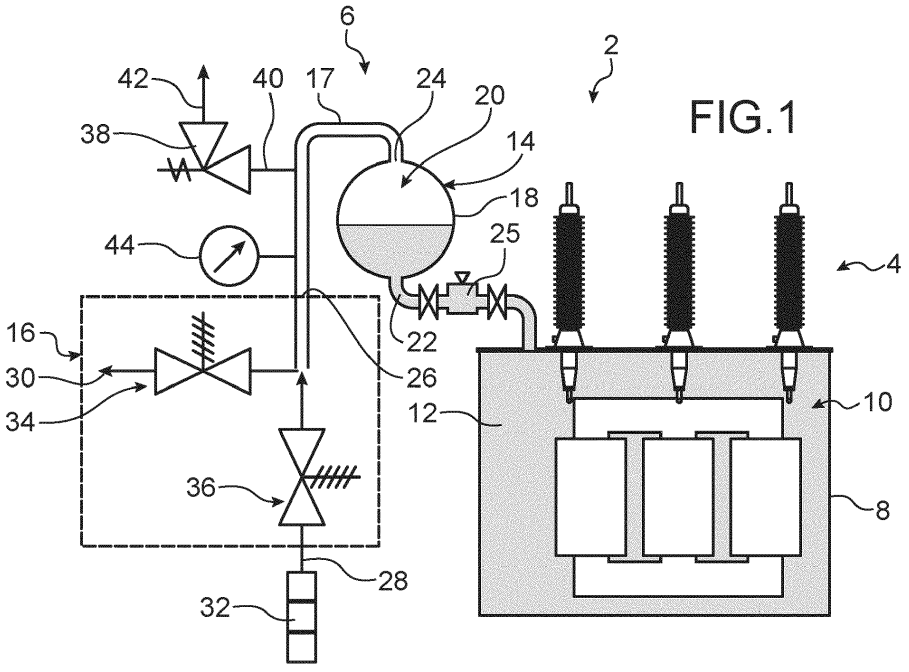

FIG.1

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Description

TECHNICAL FIELD

[0001] The invention concerns a sealing apparatus for a liquid-filled electrical equipment comprising a cavity filled with a dielectric liquid. The invention also concerns an assembly comprising a sealing apparatus and an electrical equipment.

[0002] The invention applies to the field of electric power generation and transmission, and more precisely to electric power systems.

BACKGROUND ART

[0003] In the field of electric power generation and transmission, it is known to use liquid-filled electrical equipment, such as a liquid-filled power transformer or a shunt reactor. Such an equipment comprises a casing defining a cavity, said cavity being filled with a dielectric liquid such as mineral oil or alternative insulation liquids like natural or synthetic ester.

[0004] Generally, a liquid-filled electrical equipment is provided with a conservator (also called "expansion tank") to enable expansion and contraction of the dielectric liquid due to temperature changes. Such temperature changes result, for instance, from daily and seasonal temperature variations of the environment surrounding the electrical equipment or from variations in loading.

[0005] However, if the conservator is not hermetically sealed, the electrical equipment is free breathing with the external environment. As a result, moisture and oxygen can ingress into the dielectric liquid, thereby changing its performance (for example by reducing the breakdown voltage capability or accelerating ageing due to oxidation) and affecting nominal operation of the electrical equipment. Moreover, moisture and oxygen may also be absorbed within a paper insulation system used in the electrical equipment, which may affect the performance and accelerate cellulose ageing (for example by oxidative or hydrolytic aging).

[0006] To prevent such a problem, it has been suggested to seal the conservator, from the surrounding air, with an elastic membrane (also referred to as "rubber bag", "hydro-compensator", "bladder" or "air bag") configured to expand and contract to absorb thermal expansion and contraction of the dielectric liquid.

[0007] However, such rubber bags are not satisfactory.

[0008] Indeed, these rubber bags are generally not robust and are subject to tearing, their lifetime expectancy being only about ten years. Such tears may result in dielectric liquid leakage, as well as ingress of oxygen and moisture within the electrical equipment. Since the aforementioned electrical equipment are generally designed to last at least thirty years, repair or replacement of the rubber bag is required on a regular basis, which is costly.

[0009] A purpose of the invention is to provide a sealing apparatus that is simpler and more robust and cost-efficient than such rubber bags.

SUMMARY OF THE INVENTION

[0010] To this end, the present invention is a sealing apparatus of the aforementioned type, comprising a conservator and a breather device,
the breather device comprising a main port, an input port and an output port, and being configured to allow:

- a first fluid flow from the main port to the output port if a pressure difference between the main port and the output port is higher than a predetermined over-pressure threshold; and
- a second fluid flow from the input port to the main port if a pressure difference between the main port and the input port is lower than a predetermined under-pressure threshold,

the conservator comprising an enclosure including a first port for connection to the cavity of the liquid-filled electrical equipment, and a second port, distinct from the first port, fluidically connected to the main port of the breather device, the enclosure defining an internal volume in fluid communication with each of the first port and the second port.

[0011] Indeed, using such a sealing apparatus, the need for a rubber bag similar to that used in the prior art is eliminated. As a result, the claimed sealing apparatus is simple and robust.

[0012] Such a sealing apparatus is designed so that, within a predetermined temperature range, corresponding to a predetermined nominal pressure range of the dielectric liquid in the electrical equipment, the electrical equipment is hermetically sealed. As an example, such a temperature range corresponds to the -25 °C to 100 °C range prescribed by the International Electrotechnical Commission (IEC) 60076 series standards.

[0013] Moreover, the claimed sealing apparatus has a pressure release capability, whereby breathing of the electrical equipment is allowed if a pressure within the cavity of the electrical equipment, that is to say a pressure at the main port of the breather device, is outside the nominal pressure range. This enhances safety.

[0014] The inventors have found that, using the claimed sealing apparatus, breathing of the electrical equipment can be reduced to approximately less than 10% of the breathing occurring if the liquid-filled electrical equipment were left free breathing.

[0015] Moreover, due to its simple architecture, the claimed sealing apparatus can be designed so that it can be accessed, from ground level, while the liquid-filled electrical equipment is in service, thus allowing an operator to easily perform inspections.

[0016] According to other advantageous aspects of the invention, the sealing apparatus includes one or more of the following features, taken alone or in any possible combination:

- the breather device comprises a first non-return valve and a second non-return valve, the first non-return valve being arranged between the main port and the output port and being configured to allow the first fluid flow if the pressure difference between the main port and the output port is higher than the over-pressure threshold, and the second non-return valve being arranged between the main port and the input port and being configured to allow the second fluid flow if the pressure difference between the main port and the input port is lower than the under-pressure threshold;
- the sealing apparatus further comprises a controller configured to control the breather device, preferably the overpressure threshold and/or the under-pressure threshold, based on at least one predetermined control parameter;
- the input port and the output port form a same common port;
- the breather device comprises a bidirectional valve arranged between the main port and the common port and configured:
    - to allow the first fluid flow if the pressure difference between the main port and the common port is higher than the overpressure threshold; and
    - to allow the second fluid flow if the pressure difference between the main port and the common port is lower than the under-pressure threshold;
- the sealing apparatus further comprises a safety valve including an inlet and an outlet, the inlet being fluidically connected to the second port of the conservator, in parallel to the breather device, the safety valve being configured to allow a third fluid flow from the inlet to the outlet if a pressure difference between the inlet and the outlet is higher than a predetermined safety threshold, the safety threshold being higher than or equal to the high pressure threshold;
- the sealing apparatus further comprises a gas drying part connected to the input port of the breather device and configured to at least partly remove moisture from the second fluid flow;
- the sealing apparatus further comprises a gas supply fluidically connected to the input port of the breather device;
- the conservator further comprises an elastic membrane arranged within the enclosure to provide a hermetic seal between the first port and the second port;
- the sealing apparatus further comprises a pressure gauge arranged upstream with respect to the first flow and configured to measure a pressure within the sealing apparatus, preferably the pressure at the main port.

[0017] The invention also relates to an assembly comprising an electrical equipment and the sealing apparatus as defined above, the electrical equipment being a liquid-filled electrical equipment comprising a cavity filled with a dielectric liquid, the first port of the conservator of the sealing apparatus being connected to the cavity of the liquid-filled electrical equipment so that the internal volume is partially filled with dielectric liquid when a temperature of the dielectric liquid is within a predetermined nominal temperature range.

[0018] Advantageously, the assembly further comprises a Buchholz relay arranged between the first port of the conservator and the cavity of the liquid-filled electrical equipment.

[0019] The invention also relates to an assembly comprising an electrical equipment and a sealing apparatus, the electrical equipment being a blanketed-tank electrical equipment comprising a cavity, a dielectric liquid and a blanketing gas being provided in the cavity, the blanketing gas forming a gas blanket arranged on top of the dielectric liquid, the sealing apparatus comprising a breather device including a main port, an input port and an output port, and configured to allow:

- a first fluid flow from the main port to the output port if a pressure difference between the main port and the output port is higher than a predetermined over-pressure threshold; and
- a second fluid flow from the input port to the main port if a pressure difference between the main port and the input port is lower than a predetermined under-pressure threshold,

the main port of the breather device being connected to the cavity of the blanketed-tank electrical equipment so that, when a temperature of the dielectric liquid is within a predetermined nominal temperature range, the main port leads to the gas blanket, the gas blanket confining the dielectric liquid in the cavity.

[0020] According to other advantageous aspects of the invention, the assemblies defined above include one or more of the following features, taken alone or in any possible combination:

- the electrical equipment is a power transformer or shunt reactor;
- the electrical equipment comprises a pressure gauge configured to measure a pressure within the electrical equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention will be better understood with the attached figures, in which:

- figure 1 is a schematic view of an assembly comprising a liquid-filled electrical equipment provided with a first embodiment of a sealing apparatus according to the invention; and
- figure 2 is a schematic view of an assembly compris-

ing a blanketed-tank electrical equipment provided with another embodiment of a sealing apparatus according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0022] An assembly 2 comprising a liquid-filled electrical equipment 4 connected to a sealing apparatus 6 according to the invention is shown on figure 1.

[0023] As an example, the liquid-filled electrical equipment 4 is a transformer, such as a three-phase transformer, or a shunt reactor.

[0024] The liquid-filled electrical equipment 4 comprises a casing 8 defining a cavity 10, the cavity 10 being filled with a dielectric liquid 12. For instance, the dielectric liquid 12 is mineral oil.

[0025] The sealing apparatus 6 is configured to provide hermetic sealing to the cavity 10 within a predetermined nominal pressure range inside the cavity 10, corresponding to a predetermined nominal temperature range (for instance -25 °C to 100 °C), while allowing for thermal expansion and contraction of the dielectric liquid 12. The sealing apparatus 6 is also configured to allow for breathing of the liquid-filled electrical equipment 4 when the pressure within the cavity 10 is outside the nominal pressure range.

[0026] The sealing apparatus 6 comprises a conservator 14 and a breather device 16 connected to each other through a tubing 17.

[0027] The conservator 14 comprises an enclosure 18 defining an internal volume 20. The enclosure 18 further comprises a first port 22 and a second port 24, distinct from the first port 22, the internal volume 20 being in fluid communication with each of the first port 22 and the second port 24.

[0028] As shown on figure 1, after connection of the sealing apparatus 6 to the liquid-filled electrical equipment 4, the first port 22 of the conservator 14 is connected to the cavity 10 of the liquid-filled electrical equipment 4. As a result, during normal operating conditions (that is to say within the nominal temperature range), the enclosure 18 is partially filled with the dielectric liquid 12, a level of the dielectric liquid within the enclosure 18 rising and dropping with the thermal expansion and contraction of the dielectric liquid 12.

[0029] Preferably, a Buchholz relay 25 is arranged between the first port 22 and the cavity 10.

[0030] Moreover, the second port 24 is fluidically connected to the tubing 17.

[0031] The breather device 16 comprises a main port 26, an input port 28 and an output port 30.

[0032] The main port 26 is fluidically connected to the tubing 17, so that the main port 26 of the breather device 16 and the second port 24 of the conservator 14 are fluidically connected to each other.

[0033] The breather device 16 is configured to allow a first fluid flow from the main port 26 to the output port 30 if a pressure difference between the main port 26 and the output port 30 is higher than a predetermined overpressure threshold which is, for instance, equal to 200 mbar (millibar).

[0034] The breather device 16 is further configured to allow a second fluid flow from the input port 28 to the main port 26 if a pressure difference between the main port 26 and the input port 28 is lower than a predetermined under-pressure threshold which is, for instance, equal to -200 mbar.

[0035] The output port 30 is, for instance, in fluid communication with an exhaust environment, such as the atmosphere surrounding the assembly 2.

[0036] Preferably, the input port 28 is fluidically connected to a gas supply 32 of the sealing apparatus 6.

[0037] Alternatively, the input port 28 is in fluid communication with a gas reservoir, such as the atmosphere surrounding the assembly 2, preferably through a gas drying part 32 (also referred to as "dehydrating breather") connected to the input port 28 of the breather device 16 and configured to at least partly remove moisture from the second fluid flow.

[0038] For instance, the gas drying part 32 is a known silica gel dryer.

[0039] Alternatively, the input port 28 and the output port 30 form a single common port.

[0040] It results from the foregoing that communication between the cavity 10 and an environment outside the casing 8 can only occur through the breather device 16.

[0041] According to the embodiment of the invention shown on figure 1, the breather device 16 comprises a first non-return valve 34 (also referred to as "check valve" or "unidirectional valve") and a second non-return valve 36. In this case, the first non-return valve is arranged between the main port 26 and the output port 30 and is configured to allow the first fluid flow if the pressure difference between the main port 26 and the output port 30 is higher than the overpressure threshold. Moreover, the second non-return valve 36 is arranged between the main port 26 and the input port 28 and is configured to allow the second fluid flow if the pressure difference between the main port 26 and the input port 28 is lower than the under-pressure threshold.

[0042] Advantageously, the sealing apparatus 6 further comprises a controller (not shown) configured to control the breather device 16 based on at least one predetermined control parameter. More precisely, the controller is configured to control the overpressure threshold and/or the under-pressure threshold, or a delay in the occurrence of the first fluid flow and/or the second fluid flow (if the corresponding condition relating to pressure difference is met), based on said at least one control parameter.

[0043] For instance, the control parameter is a weather forecast (that is, a forecast of environmental conditions), or a load forecast.

[0044] Indeed, the overpressure threshold and/or the under-pressure threshold typically include a safety margin to avoid any damage to the electrical equipment 4.

With knowledge of the control parameter, the controller may control the breather device 16 to adjust the over-pressure threshold and/or the under-pressure threshold, or to apply a timely delay to the occurrence of the first fluid flow and/or the second fluid flow.

[0045] As an example, using such a controller, a first fluid flow can be prevented in case of overpressure in the electrical equipment 4 when it is already known that pressure might drop again very soon (because of a drop in load or in temperature, for instance).

[0046] As a result, breathing can be further reduced.

[0047] Each of the first non-return valve 34 and the second non-return valve 36 is, for instance, a spring-operated valve.

[0048] Advantageously, the sealing apparatus 6 further comprises a safety valve 38.

[0049] The safety valve 38 comprises an inlet 40 and an outlet 42.

[0050] The inlet 40 is fluidically connected to the second port 24 of the conservator 14, for instance to the tubing 17, in parallel to the breather device 16. Moreover, the outlet 42 is, for instance, in fluid communication with the exhaust environment.

[0051] The safety valve 38 is configured to allow a third fluid flow from the inlet 40 to the outlet 42 if a pressure difference between the inlet 40 and the outlet 42 is higher than a predetermined safety threshold, the safety threshold being higher than or equal to the high pressure threshold.

[0052] The safety valve 38 acts as a protective device that prevents unacceptable excessive overpressure which could damage the casing 8 of the liquid-filled electrical equipment 4, and which may result from a failure of the breather device 16.

[0053] Preferably, a pressure gauge 44 is also connected to the tubing 17 to provide a visual indication of the pressure within the sealing apparatus 6, preferably the pressure at the main port 26. Alternatively or additionally, a pressure gauge (not shown) is connected to the casing 8 to provide a visual indication of the pressure within the liquid-filled electrical equipment 4.

[0054] Alternatively, the breather device 16 comprises a bidirectional valve (not shown) replacing the first non-return valve 34 and the second non-return valve 36. In this case, the input port and output port are combined, forming a same common port. Nonetheless, operation of the breather device 16 remains unchanged, the bidirectional valve being arranged between the main port 26 and the common port and being configured:

- to allow the first fluid flow from the main port 26 to the common port if the pressure difference between the main port 26 and the common port is higher than the overpressure threshold; and
- to allow the second fluid flow from the common port to the main port 26 if the pressure difference between the main port 26 and common port is lower than the under-pressure threshold.

[0055] Alternatively, the conservator 14 further comprises an elastic membrane (not shown) arranged within the enclosure 18 to provide a hermetic seal between the first port 22 and the second port 24. In this case, the sealing apparatus 6 is preferably configured so that, after connection to the liquid-filled electrical equipment 4, the dielectric liquid 12 is in contact with a face of the elastic membrane that is on the side of the first port 22.

[0056] A second embodiment of an assembly 102 comprising an electrical equipment 104 connected to a sealing apparatus 106 according to the invention is shown on figure 2. In this figure, numeral references that are identical to those of figure 1 refer to the same parts.

[0057] More precisely, the electrical equipment of the assembly 102 is a blanketed-tank electrical equipment. The blanketed-tank electrical equipment 104 of figure 2 differs from the liquid-filled electrical equipment 4 of figure 1 in that its casing 8 defines a cavity 10 which is not completely filled with the dielectric liquid 12. On the contrary, a gas blanket 113 is provided in the cavity 10, on top of the dielectric liquid 12.

[0058] The gas blanket 113 is made of a blanketing gas 114, generally a dry inert gas, such as nitrogen or dry air, which advantageously acts as a buffer layer that prevents air and moisture from coming into contact with the dielectric liquid 12.

[0059] In this case, and contrary to the embodiment of figure 1, the sealing apparatus 106 does not comprise a conservator. The main port 26 of the breather device 16 is directly connected to the cavity 10 (through the tubing 17) and leads to the gas blanket 113. More precisely, the assembly 102 is configured so that, within the nominal temperature range, the dielectric liquid 12 does not flow from the blanketed-tank electrical equipment 104 in the sealing apparatus 106, but only the blanketing gas 114 does. In other words, within the nominal temperature range, the dielectric liquid 12 is confined by the gas blanket 113 in the cavity 10 of the blanketed-tank electrical equipment 104.

Claims

1. A sealing apparatus (6) for a liquid-filled electrical equipment (4) comprising a cavity (10) filled with a dielectric liquid (12), the sealing apparatus (6) comprising a conservator (14) and a breather device (16), the breather device (16) comprising a main port (26), an input port (28) and an output port (30), and being configured to allow:

    - a first fluid flow from the main port (26) to the output port (30) if a pressure difference between the main port (26) and the output port (30) is higher than a predetermined overpressure threshold; and
    - a second fluid flow from the input port (28) to the main port (26) if a pressure difference be-

tween the main port (26) and the input port (28) is lower than a predetermined under-pressure threshold,

the conservator (14) comprising an enclosure (18) including a first port (22) for connection to the cavity (10) of the liquid-filled electrical equipment (4), and a second port (24), distinct from the first port (22), fluidically connected to the main port (26) of the breather device (16), the enclosure (18) defining an internal volume (20) in fluid communication with each of the first port (22) and the second port (24).

2. The sealing apparatus (6) according to claim 1, wherein the breather device (16) comprises a first non-return valve (34) and a second non-return valve (36),
the first non-return valve (34) being arranged between the main port (26) and the output port (30) and being configured to allow the first fluid flow if the pressure difference between the main port (26) and the output port (30) is higher than the overpressure threshold; and
the second non-return valve (36) being arranged between the main port (26) and the input port (28) and being configured to allow the second fluid flow if the pressure difference between the main port (26) and the input port (28) is lower than the under-pressure threshold.

3. The sealing apparatus (6) according to claim 1 or 2, comprises a controller configured to control the breather device (16), preferably the overpressure threshold and/or the under-pressure threshold, based on at least one predetermined control parameter.

4. The sealing apparatus (6) according to any one of claim 1 to 3, wherein the input port and the output port form a same common port.

5. The sealing apparatus (6) according to claim 4, wherein the breather device (16) comprises a bidirectional valve arranged between the main port (26) and the common port and configured:

- to allow the first fluid flow if the pressure difference between the main port (26) and the common port is higher than the overpressure threshold; and
- to allow the second fluid flow if the pressure difference between the main port (26) and the common port is lower than the under-pressure threshold.

6. The sealing apparatus (6) according to any one of claims 1 to 5, further comprising a safety valve (38) including an inlet (40) and an outlet (42), the inlet (40) being fluidically connected to the second port (24) of the conservator (14), in parallel to the breather device (16), the safety valve (38) being configured to allow a third fluid flow from the inlet (40) to the outlet (42) if a pressure difference between the inlet (40) and the outlet (42) is higher than a predetermined safety threshold, the safety threshold being higher than or equal to the high pressure threshold.

7. The sealing apparatus (6) according to any one of claims 1 to 6, further comprising a gas drying part (32) connected to the input port (28) of the breather device (16) and configured to at least partly remove moisture from the second fluid flow.

8. The sealing apparatus (6) according to any one of claims 1 to 6, further comprising a gas supply fluidically connected to the input port (28) of the breather device (16).

9. The sealing apparatus (6) according to any one of claims 1 to 8, wherein the conservator (14) further comprises an elastic membrane arranged within the enclosure (18) to provide a hermetic seal between the first port (22) and the second port (24).

10. The sealing apparatus (6) according to any one of claims 1 to 9, further comprising a pressure gauge (44) arranged upstream with respect to the first flow and configured to measure a pressure within the sealing apparatus (6), preferably the pressure at the main port (26).

11. An assembly comprising an electrical equipment (4) and the sealing apparatus (6) according to any one of claims 1 to 10,
the electrical equipment being a liquid-filled electrical equipment (4) comprising a cavity (10) filled with a dielectric liquid (12),
the first port (22) of the conservator (14) of the sealing apparatus (6) being connected to the cavity (10) of the liquid-filled electrical equipment (4) so that the internal volume (20) is partially filled with dielectric liquid (12) when a temperature of the dielectric liquid (12) is within a predetermined nominal temperature range.

12. The assembly according to claim 11, further comprising a Buchholz relay (25) arranged between the first port (22) of the conservator (14) and the cavity (10) of the liquid-filled electrical equipment (4).

13. An assembly comprising an electrical equipment (104) and a sealing apparatus (106),
the electrical equipment (104) being a blanketed-tank electrical equipment (104) comprising a cavity (10), a dielectric liquid (12) and a blanketing gas (114) being provided in the cavity (10), the blanketing

gas (114) forming a gas blanket (113) arranged on top of the dielectric liquid (12),
the sealing apparatus (106) comprising a breather device (16) including a main port (26), an input port (28) and an output port (30), and configured to allow:

- a first fluid flow from the main port (26) to the output port (30) if a pressure difference between the main port (26) and the output port (30) is higher than a predetermined overpressure threshold; and
- a second fluid flow from the input port (28) to the main port (26) if a pressure difference between the main port (26) and the input port (28) is lower than a predetermined under-pressure threshold,

the main port (26) of the breather device (16) being connected to the cavity (10) of the blanketed-tank electrical equipment (104) so that, when a temperature of the dielectric liquid (12) is within a predetermined nominal temperature range, the main port (26) leads to the gas blanket (113), the gas blanket (113) confining the dielectric liquid (12) in the cavity (10).

14. The assembly according to any one of claims 9 to 13, wherein the electrical equipment (4; 104) is a power transformer or shunt reactor.

15. The assembly according to any one of claims 9 to 14, wherein the electrical equipment (4; 104) comprises a pressure gauge configured to measure a pressure within the electrical equipment (4; 104).

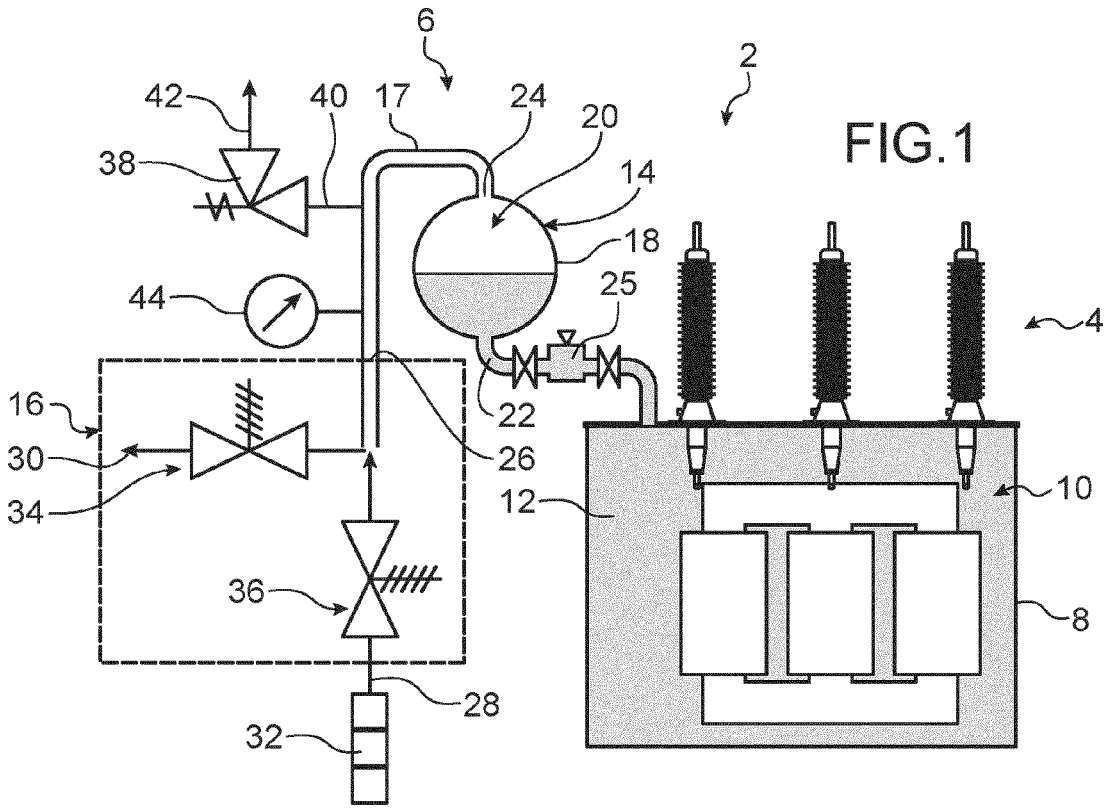
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FIG.1

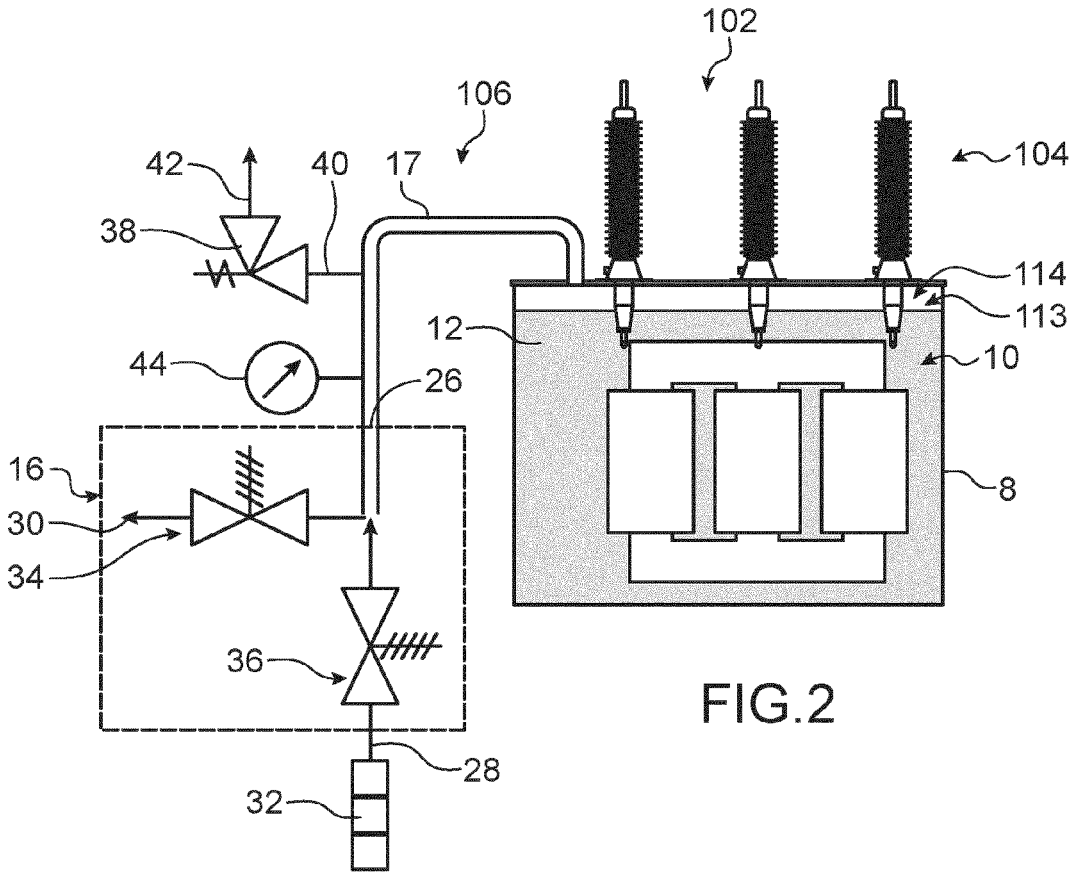
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FIG.2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 0998

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 5 946 171 A (MAGNIER PHILIPPE [FR]) 31 August 1999 (1999-08-31) * abstract * * column 2, line 26 - column 3, line 17; figure 1 *	1-15	INV. H01F27/12 H01F27/14 H01F27/08 H01F27/10
A	EP 3 404 678 A1 (GENERAL ELECTRIC TECHNOLOGY GMBH [CH]) 21 November 2018 (2018-11-21) * abstract * * paragraphs [0021] - [0026]; figure 1 *	1-15	
A	US 1 883 830 A (ST PALLEY ZOLTAN O) 18 October 1932 (1932-10-18) * abstract * * page 1, left-hand column, line 44 - page 2, left-hand column, line 29; figure 1 *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	28 May 2020	Winkelman, André

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 16 0998

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82