



(12)

EUROPEAN PATENT APPLICATION

- (43)

Date of publication:

24.07.2019 Bulletin 2019/30

(51)

Int Cl.:

H01F 5/04 (2006.01) H01F 27/04 (2006.01)
- (21)

Application number: 18152531.2
- (22)

Date of filing: 19.01.2018

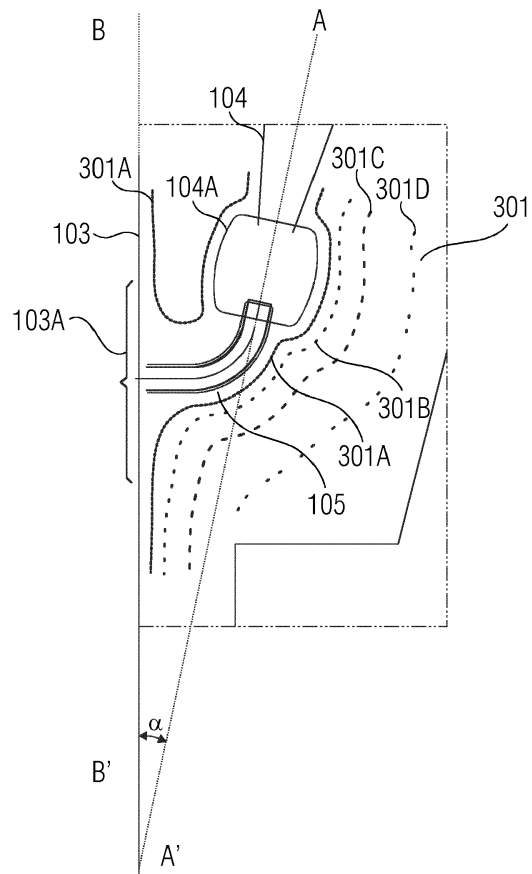
(84) Designated Contracting States: AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR Designated Extension States: BA ME Designated Validation States: MA MD TN	(71) Applicant: Siemens Aktiengesellschaft 80333 München (DE) (72) Inventor: Pandya, Manan 40081 Mumbai, Maharashtra (IN) (74) Representative: Patentanwaltskanzlei WILHELM & BECK Prinzenstraße 13 80639 München (DE)
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IMPROVED LEAD EXIT ARRANGEMENT IN AN ELECTRICAL DEVICE

(57) An electrical device (100) having a housing (101), a core (102) positioned inside the housing (101), at least one winding element (103), at least one bushing (104), and a conductor (105A), is provided. The winding element (103) partially surrounds the core (102). The bushing (104) is positioned at least partially inside the housing (101) and adjacent to the winding element (103). The conductor (105A) is positioned inside the housing (101) and connecting the winding element (103) to the bushing (104). The winding element (103) and the bushing (104) are positioned with respect to one another, so as to create an equipotential voltage field (301) there between, during operation of the electrical device (100). The conductor (105A) is positioned such that it is accommodated within the equipotential voltage field (301), thereby, experiencing low stresses and decreasing insulation (105B and 105C) required to be positioned thereon.

FIG 3B



Description

[0001] The present invention relates to an electrical device having a housing, a core, at least one winding element surrounding parts of the core, at least one bushing positioned adjacent to the winding element, and a conductor.

[0002] Such an electrical device is known to a person skilled in the art. Such a commonly known electrical device is, for example, a high voltage power transformer or a reactor.

[0003] FIG 1A illustrates a sectional view of an active part of an electrical device 100, of the state of the art, as mentioned above. The electrical device 100 comprises a tank 101 housing a core 102 positioned therein. A winding element 103 partially surrounds the core 102. A bushing 104 is positioned partially inside the tank 101 and adjacent to the winding element 103. The electrical device 100 also comprises a lead exit 105 positioned inside the tank 101. The lead exit 105 is a current carrying connection from a winding element 103 to another winding element 103, or to a tap changer, or to exit terminals, that is, bushings 104. In order to withstand operational conditions, lead exits 105 are required to be properly insulated, supported and cooled.

[0004] FIG 1B illustrates an enlarged view of a portion of the electrical device 100, marked "X" in FIG 1A showing the lead exit 105 of the state of the art. Typically, a lead exit 105 comprises a conductor 105A carrying current there within. The conductor 105A is typically covered in insulation 105B such as cellulose based insulating material. This insulation 105B is further covered by one or more insulating barriers 105C. The insulating barriers 105C are separated by oil gaps there between. The insulating barriers 105C increase dielectric strength of the oil gaps by separating them into smaller channels. Quantity of these insulating barriers 105C and distances there between, are dependent on a dielectric stress exerted on the conductor 105A and its surrounding areas, during operation of the electrical device 100. The dielectric stress is a function of parameters comprising voltage, geometry of the conductor 105A, positioning of the conductor 105A, insulating materials used, distance of the conductor 105A with respect to surrounding elements such as the tank 101, the bushing 104, the winding element 103, etc.

[0005] FIG 2 illustrates a sectional view of the state of the art electrical device 100, illustrated in FIG 1A, showing a contour plot 201 of various voltage fields created between the winding element 103 and the bushing 104 during operation of the electrical device 100. The contour plot 201 is represented without considering the lead exit 105 positioned between the winding element 103 and the bushing 104. A voltage field 201A around a mid-portion 103A of the winding element 103 and a voltage field 201B around a lower end 104A of the bushing 104, are both high voltage fields. A voltage field 201C of the contour plot 201, around the high voltage fields 201A and

201B is at a voltage lower than that of the voltage fields 201A and 201B. A voltage field 201D of the contour plot 201, represented by contour lines farther away from the contour lines representing the voltage field 201C, is at a lowest voltage compared to that of the voltage fields 201A, 201B, and 201C. Each of the contour lines of the contour plot 201 are illustrated by dotted lines, the continuity of which decreases as a function of voltage that the contour lines represent, that is, an increase in discontinuity of the contour lines of the contour plot 201 indicates a gradual decrease in the voltages of the voltage fields 201A, 201B, 201C, and 201D. Typically, a conductor 105A illustrated in FIGS 1A-1B, when placed in the voltage fields 201A, 201B, 201C, and 201D having varying voltages therein, experiences high levels of dielectric stress as opposed to a conductor 105A positioned in a voltage field having a uniform voltage. When the dielectric stress is high, higher is the quantity of insulation barriers 105C required to be mounted on the conductor 105A in order to withstand the operational conditions. Moreover, costs of the lead exits 105 typically increase with the quantity of insulation barriers 105C employed as a result of material costs, associated component costs such as oil gap spacers, etc., and associated labour costs of installing the insulation barriers 105C.

[0006] Therefore, it is an object of the present invention to provide an electrical device of the aforementioned kind that reduces costs associated with insulation barriers for lead exits without compromising operating efficiency and/or safety of operating the electrical device.

[0007] The electrical device disclosed in the present invention achieves the aforementioned object, in that the winding element and the bushing are positioned with respect to one another, so as to create an equipotential voltage field there between during operation of the electrical device.

[0008] According to the present invention, an electrical device having a housing, a core positioned inside the housing, at least one winding element, at least one bushing, and a conductor is provided. The housing, for example, refers to a tank of a high voltage transformer. The winding element partially surrounds the core. The bushing is positioned at least partially inside the housing and adjacent to the winding element. As used herein, the term "adjacent" refers to geometric proximity of the bushing with respect to the winding element.

[0009] In accordance with the present invention, the winding element and the bushing are positioned with respect to one another so as to create an equipotential voltage field there between during operation of the electrical device. As used herein, the term "operation" refers to all normal and abnormal operating conditions, for example, testing of the electrical device. Also used herein, "equipotential voltage field" refers to a region in space having a uniform potential spread across the region. For example, when a voltage measurement probe is positioned at various points along such an electric field, the voltage measured at each of the points is nearly equal.

Advantageously, the equipotential field encompasses an area surrounding the winding element, an area surrounding the bushing, and an area there between, such that the electric field has a continuous uniform potential there within. In accordance with the present invention, the winding element is positioned along a first axis and the bushing is positioned along a second axis such that the first axis and the second axis have a predefined angle of inclination there between. In a preferred embodiment, the second axis, along which the bushing is positioned, is inclined with respect to the first axis, along which the winding element is positioned. That is, the first axis is aligned vertically and the second axis is aligned at an inclination with respect to the vertical. In a preferred embodiment according to the present invention, the predefined angle of inclination between the first axis and the second axis is in a range of about 5 degrees to about 30 degrees. Advantageously, the bushing is positioned along the second axis such that a lower end of the bushing is in close proximity with a mid-portion of the winding element so as to create the equipotential field. According to the present invention, a distance between the lower end of the bushing and the mid-portion of the winding elements is in a range of about 300mm to about 800mm. According to the present invention, a voltage between the bushing and the winding element, that is, in the equipotential field, is equal to a voltage at the bushing and/or a voltage at the winding element. As used herein, the term "equal" is not to be limited to mathematical equality but extended to a range of variation of the voltage between the bushing and the winding element with respect to the voltages at the bushing and/or the winding elements. This range is about 0% to about -20%. The voltages at the bushing, at the winding element, and in the equipotential field, are based on an operational rating of the electrical device, for example, a voltage range of 200kV to 1200kV, for high voltage transformers and reactors.

[0010] The conductor is positioned inside the housing and connects the winding element to the bushing. In accordance with the present invention, the conductor provides a current carrying path between the winding element and another conductor enclosed in the bushing. Advantageously, the conductor is positioned between the bushing and the winding element such that the conductor is accommodated within the equipotential voltage field. As the conductor is accommodated within the equipotential voltage field, the conductor experiences low dielectric stress. According to an embodiment of the present invention, the conductor is entirely accommodated within the equipotential voltage field. According to another embodiment of the present invention, the conductor is near completely accommodated within the equipotential voltage field.

[0011] The conductor is configured of a developed length lesser than or equal to about 1000 mm. The conductor is configured to have a first insulating element positioned thereon. The first insulating element is con-

figured to cover the conductor surface, for example, by wrapping it, tightly winding it, etc., over the conductor. A thickness of the first insulating element lies in a range of about 0 mm to about 20 mm. The conductor is configured to have subsequent insulating barriers positioned around the first insulating element. The subsequent insulating barriers are positioned such that there is a predefined gap there between for allowing oil to be stored therein. Spacers may be employed to maintain these oil gaps in the subsequent insulating barriers. The first insulating element and the subsequent insulating barriers are configured of cellulose based materials. The first insulating element and the subsequent insulating barriers are configured based on one or more stresses that the conductor experiences in the equipotential voltage field. For example, a thickness of the first insulating element, a number of the subsequent insulating barriers, a thickness of each of the subsequent insulating barriers, gaps between the subsequent insulating barriers, etc., is configured based on the stresses.

[0012] The stresses comprise, for example, dielectric stress. According to a preferred embodiment, the stresses and thereby the number of subsequent insulating barriers is a function of the variation of the voltage between the bushing and the winding element with respect to the voltages at the bushing and the winding element. For example, when the voltage variation is more than about 20%, the stresses increase, thereby increasing the number of subsequent insulating barriers. When the dielectric stress is below a design threshold, for example, 4.5kV/mm, the number of subsequent insulating barriers required is 0. Advantageously, a number, of the subsequent insulating barriers, is in a range of about 0 to 2.

[0013] In accordance with this invention, also disclosed is a method for assembling the aforementioned electrical device comprising a housing, a core, at least one winding element, at least one bushing, and a conductor. The method comprises positioning the bushing along a first axis and the winding element along a second axis such that the first axis and the second axis have a predefined angle of inclination there between and so as to create an equipotential voltage field there between, during operation of the electrical device. The method comprises positioning the conductor between the bushing and the winding element such that the conductor is accommodated within the equipotential voltage field. The method comprises, determining one or more stresses exerted on the conductor in the equipotential voltage field and configuring a first insulating element to be positioned on the conductor, and subsequent insulating barriers to be positioned on the first insulating element, based on the stresses.

[0014] The above-mentioned and other features of the invention will now be addressed with reference to the accompanying drawings of the present invention. The illustrated embodiments are intended to illustrate, but not limit the invention.

[0015] The present invention is further described here-

inafter with reference to illustrated embodiments shown in the accompanying drawings, in which:

- FIG 1A illustrates a sectional view of an active part of an electrical device of the state of the art.
- FIG 1B illustrates an enlarged view of a portion of the electrical device, marked "X" in FIG 1A showing a lead exit of the state of the art.
- FIG 2 illustrates a sectional view of the state of the art electrical device illustrated in FIG 1A showing electric fields created between the winding element and the bushing during operation of the electrical device.
- FIG 3A illustrates an active part of a transformer as an embodiment of an electrical device, according to the present invention, having a housing, a core, at least one winding element, at least one bushing, and a conductor.
- FIG 3B illustrates an enlarged view of a portion of the electrical device, marked "Y" in FIG 3A showing an equipotential voltage field created between the winding element and the bushing and accommodating a conductor therewithin, according to the present invention.
- FIG 3C illustrates an enlarged view of a lead exit of an electrical device shown in FIG 3A, according to the present invention.
- FIG 4 illustrates a process flowchart of an exemplary method of assembling the electrical device shown in FIG 3A, in accordance with an embodiment of the present invention.

[0016] Various embodiments are described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for the purpose of explanation, numerous specific details are set forth in order to provide thorough understanding of one or more embodiments. It may be evident that such embodiments may be practiced without these specific details.

[0017] FIG 3A illustrates an active part of a transformer as an embodiment of an electrical device 100, according to the present invention. The active part of the electrical device 100 comprises a housing 101, a core 102, at least one winding element 103, at least one bushing 104, and a lead exit 105 providing a current carrying path between the winding element 103 and the bushing 104. FIG 3B illustrates an enlarged view of a portion of the electrical device 100, marked "Y" in FIG 3A showing an equipotential voltage field 301 created between the winding element 103 and the bushing 104 and accommodating a conductor 105A therewithin, according to the present in-

vention. As shown in FIG 3B, the equipotential field 301 is represented by contour lines 301A, 301B, 301C, and 301D each representing a different voltage in the equipotential voltage field. The contour line 301A represents a uniform equipotential voltage field of the highest voltage compared to that represented by the contour line 301D. The equipotential field 301 is created by arranging the bushing 104 and the winding element 103 in close proximity with one another. As shown in FIG 3B, the bushing is aligned along the axis A-A' and the winding element is aligned along the axis B-B', such that the axes A-A' and B-B' converge at a predefined angle of inclination α , such that, there is an equipotential field 301 created between a mid-portion 103A of the winding element 103 and a lower end 104A of the bushing 104, while maintaining clearances there between as per standard design practices. The lead exit 105 is positioned such that it is entirely accommodated in the equipotential voltage field 301.

[0018] FIG 3C illustrates an enlarged view of a lead exit 105 of an electrical device 100 shown in FIG 3A, according to the present invention. The lead exit 105 that is entirely positioned within the equipotential field 301 shown in FIG 3B, experiences negligible dielectric stress due to which insulation requirements of the lead exit 105 decrease substantially, thereby eliminating need of subsequent insulating barriers 105C, shown in FIG 1B. As shown in FIG 3C, the lead exit 105 comprises a conductor 105A having a first insulating element 105B of a thickness approximately less than 20mm. This insulation in the lead exit 105 is sufficient to maintain the dielectric stresses on an outermost surface of the lead exit 105, within a design limit, for example, of 4.5kV/mm.

[0019] FIG 4 illustrates a process flowchart 400 of an exemplary method of assembling the electrical device 100 shown in FIG 3A, in accordance with an embodiment of the present invention. The electrical device 100 comprises a housing 101, a core 102, at least one winding element 103, at least one bushing 104, and a lead exit 105 as shown in FIG 3A. At step 401, the method comprises positioning the bushing 104, along a first axis A-A', and the winding element 103, along a second axis B-B', such that, a lower end 104A of the bushing 104 is positioned proximal to a mid-portion 103A of the winding element 103. This positioning is such that the first axis A-A' and the second axis B-B' have a predefined angle of inclination α there between so as to create an equipotential voltage field 301 there between, as shown in FIG 3B, during operation of the electrical device 100.

[0020] At step 402, the method comprises positioning the lead exit 105 comprising a conductor 105A, between the bushing 104 and the winding element 103 such that the conductor 105A is accommodated within the equipotential voltage field 301. At step 403, the method comprises determining one or more stresses exerted on the conductor 105A positioned in the equipotential voltage field 301. For example, using electrostatic field calculations, dielectric stresses exerted on the conductor 105A

are measured. At step 404, the method comprises configuring a first insulating element 105B to be positioned on the conductor 105A, and subsequent insulating barriers 105C to be positioned around the first insulating element 105B, based on the one or more stresses. For example, the method comprises comparing the dielectric stress with its design limit of 4.5kV/mm. If the dielectric stress is less than 4.5kV/mm then the first insulating element 105B of a thickness less than 20mm is configured and there is no requirement to position any subsequent insulating barriers 105C. Thus, due to creation of equipotential voltage field 301, in electrical devices 100 such as transformers and reactors, rated at about 400kV to about 1200kV, the subsequent insulating barriers 105C required range from about 0 to 2, with a thickness of the first insulating element ranging from about 0mm to about 20mm.

[0021] The foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention disclosed herein. While the invention has been described with reference to various embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Further, although the invention has been described herein with reference to particular means, materials, and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims. Those skilled in the art, having the benefit of the teachings of this specification, may affect numerous modifications thereto and changes may be made without departing from the scope and spirit of the invention in its aspects.

List of reference numerals

[0022]

100 electrical device

101 housing/tank

102 core

103 winding element

103A mid-portion of the winding element

104 bushing

104A lower end of the bushing

105 lead exit

105A conductor

105B first insulating element

105C subsequent insulating elements

201 contour plot

201A, 201B, 201C, 201D voltage fields

301 equipotential voltage field

301A, 301B, 301C, 301D contour lines (representing a different voltage in the equipotential voltage field)

15 Claims

1. An electrical device (100) having

- a housing (101);
- a core (102) positioned inside the housing (101);
- at least one winding element (103) partially surrounding the core (102);
- at least one bushing (104) positioned at least partially inside the housing (101), and adjacent to the winding element (103);
- a conductor (105A) positioned inside the housing (101), and connecting the winding element (103) to the bushing (104); **characterized in that:**
- the winding element (103) and the bushing (104) are positioned with respect to one another, so as to create an equipotential voltage field (301) there between during operation of the electrical device (100).

2. The electrical device (100) according to claim 1, wherein the conductor (105A) is positioned between the bushing (104) and the winding element (103) such that the conductor (105A) is accommodated within the equipotential voltage field (301).

3. The electrical device (100) according to any one of the claims 1 and 2, wherein the bushing (104) is positioned along a first axis A-A' and the winding element (103) is positioned along a second axis B-B', and wherein the first axis A-A' and the second axis B-B' have a predefined angle of inclination α there between, and wherein the predefined angle of inclination α is in a range of about 5 degrees to about 30 degrees.

4. The electrical device (100) according to any one of the claims 1, 2, and 3, wherein a distance between the bushing (104) and the winding element (103) is in a range of 300mm to 800mm and a voltage between the bushing (104) and the winding element (103) is equal to one or more of a voltage at the

bushing (104) and a voltage at the winding element (103).

5. The electrical device (100) according to any one of the claims 1 and 2, wherein the conductor (105A) is configured of a developed length lesser than about 1000 mm. 5

6. The electrical device (100) according to any one of the claims 1, 2 and 5, wherein the conductor (105A) is configured to have a first insulating element (105B) positioned thereon, and wherein a thickness of the first insulating element (105B) lies in a range of about 0 mm to about 20 mm. 10

7. The electrical device (100) according to the claim 6, wherein the conductor (105A) is configured to have subsequent insulating barriers (105C) positioned around the first insulating element (105B). 15

8. The electrical device (100) according to the claim 7, wherein the first insulating element (105B) and the subsequent insulating barriers (105C), are configured based on one or more stresses experienced by the conductor (105A) in the equipotential voltage field (301), and wherein a number of the subsequent insulating barriers (105C) is in a range of 0 to 2. 20

9. A method for assembling an electrical device (100) of claims 1-7 having a housing (101), a core (102), at least one winding element (103), at least one bushing (104), and a conductor (105A) of the electrical device (100), the method comprising: 25
 - positioning the bushing (104) along a first axis A-A' and the winding element (103) along a second axis B-B' such that the first axis A-A' and the second axis B-B' have a predefined angle of inclination α there between, and so as to create an equipotential voltage field (301) there between, during operation of the electrical device (100); and 30
 - positioning the conductor (105A) between the bushing (104) and the winding element (103) such that the conductor (105A) is accommodated within the equipotential voltage field (301). 35

10. The method according to claim 9, further comprising 40
 - determining one or more stresses exerted on the conductor (105A) positioned in the equipotential voltage field (301); 45
 - configuring a first insulating element (105B) to be positioned on the conductor (105A), and subsequent insulating barriers (105C) to be positioned around the first insulating element (105B), based on the one or more stresses. 50

FIG 1A

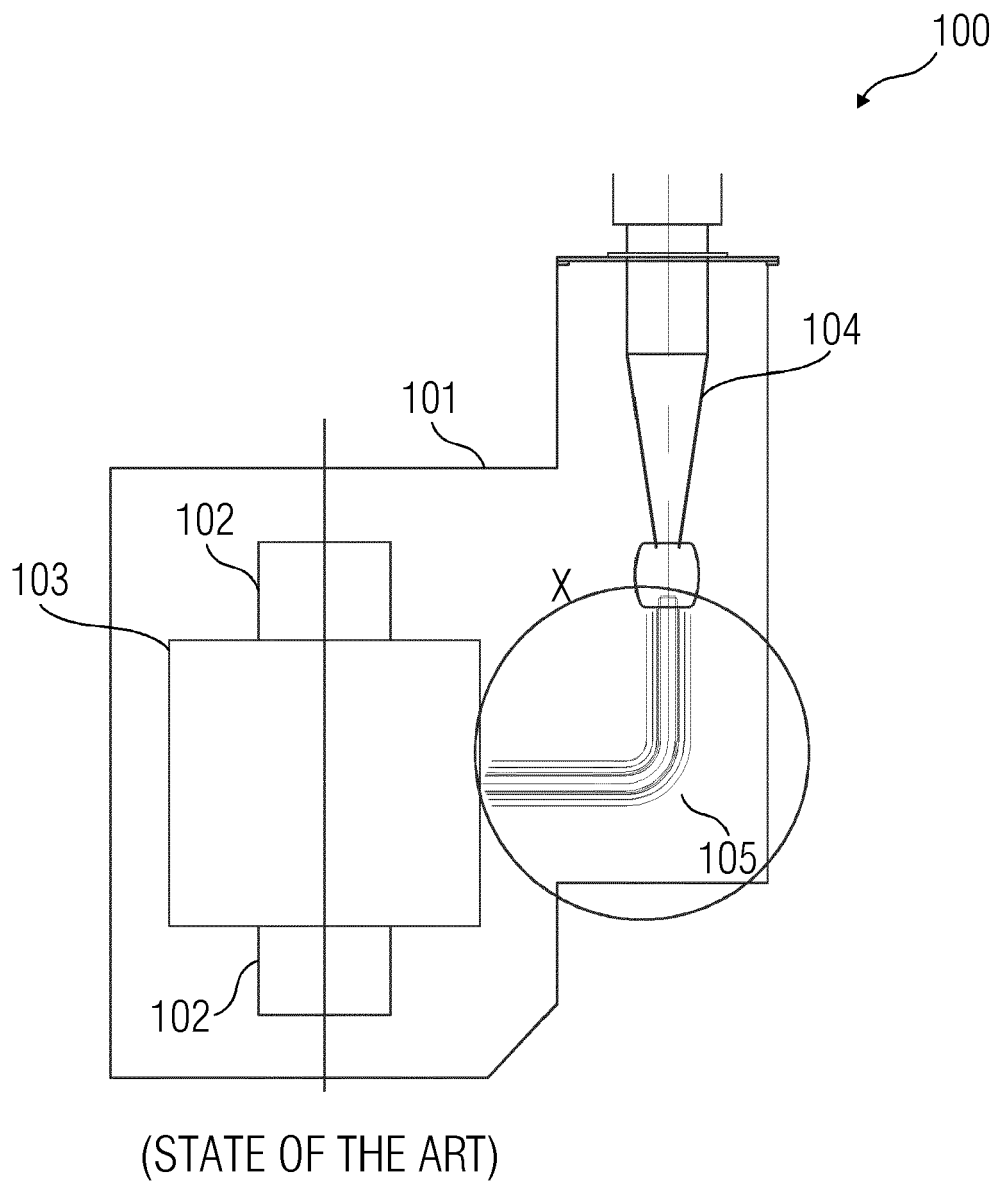
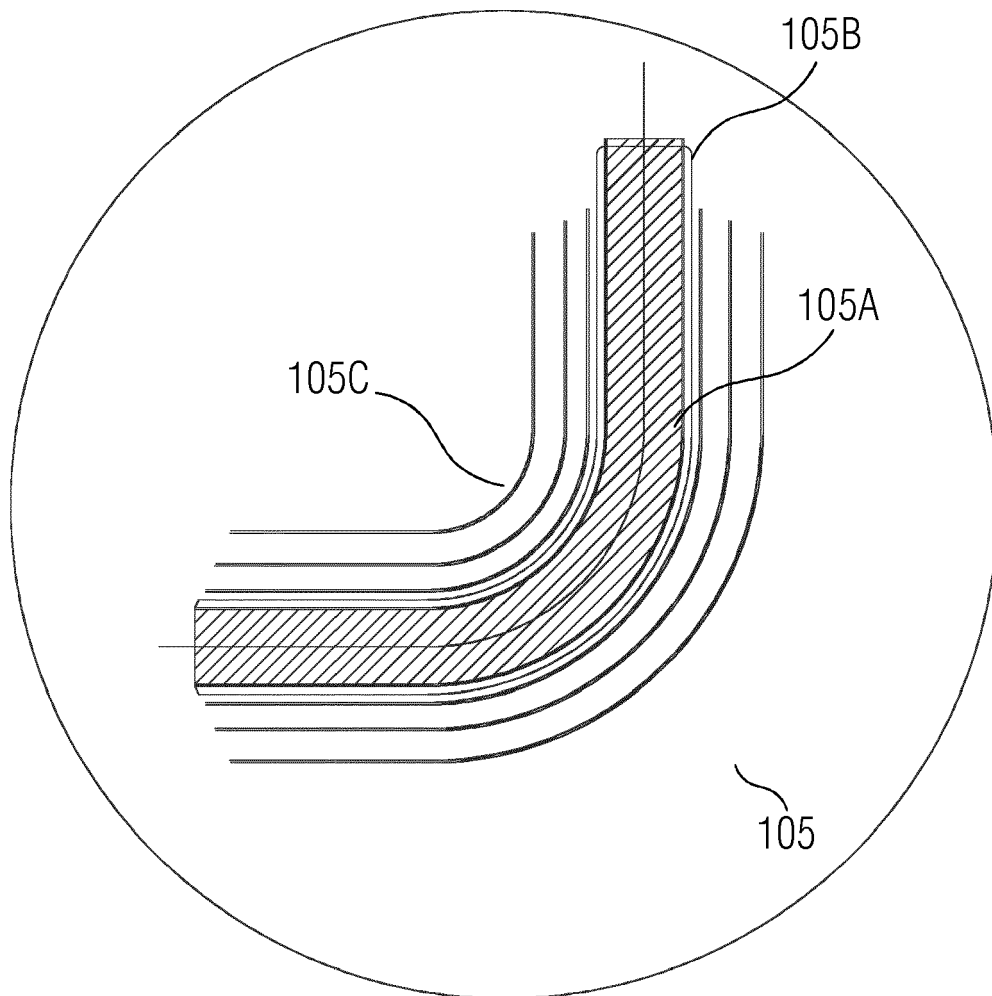


FIG 1B



(STATE OF THE ART)

FIG 2

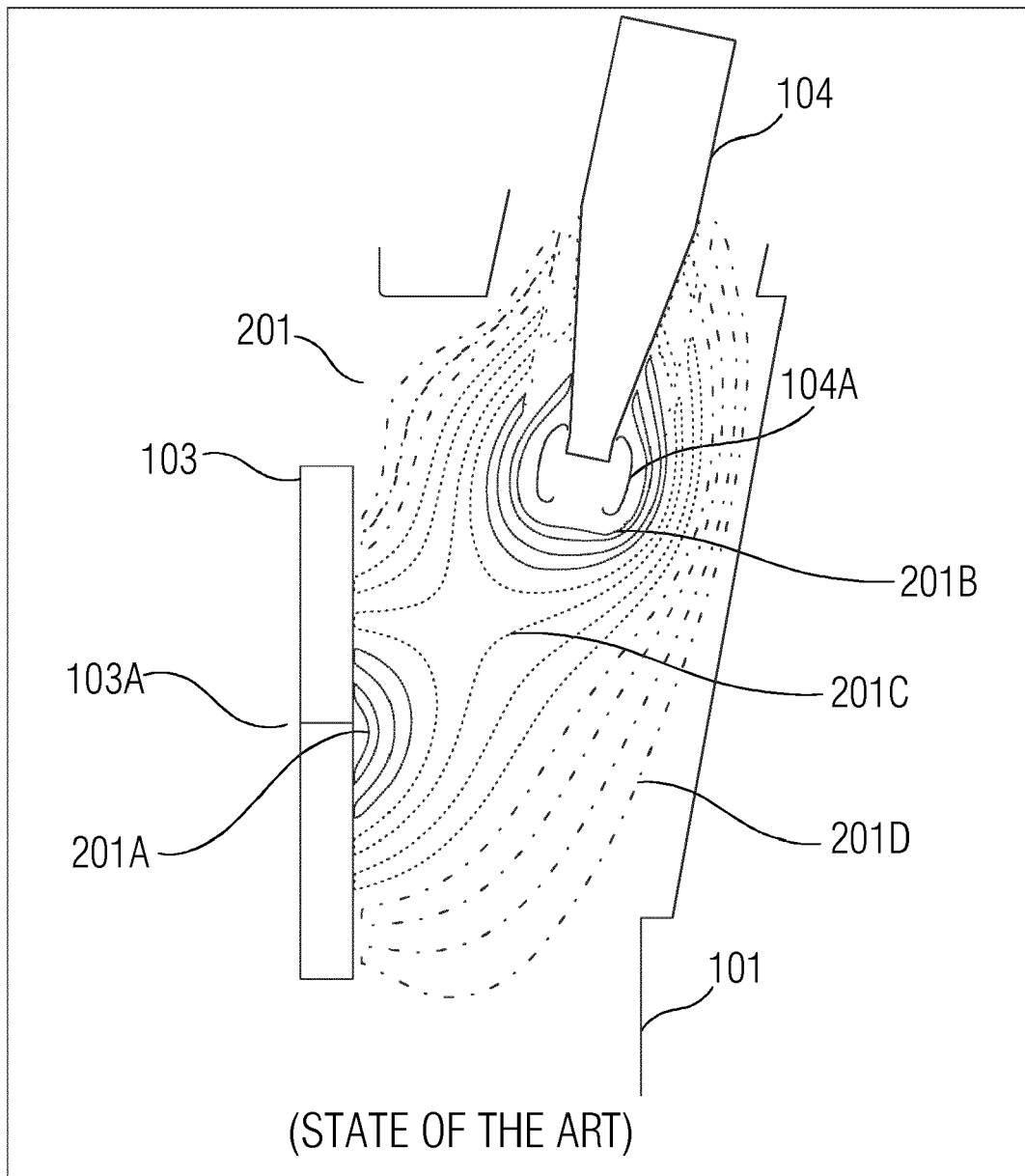


FIG 3A

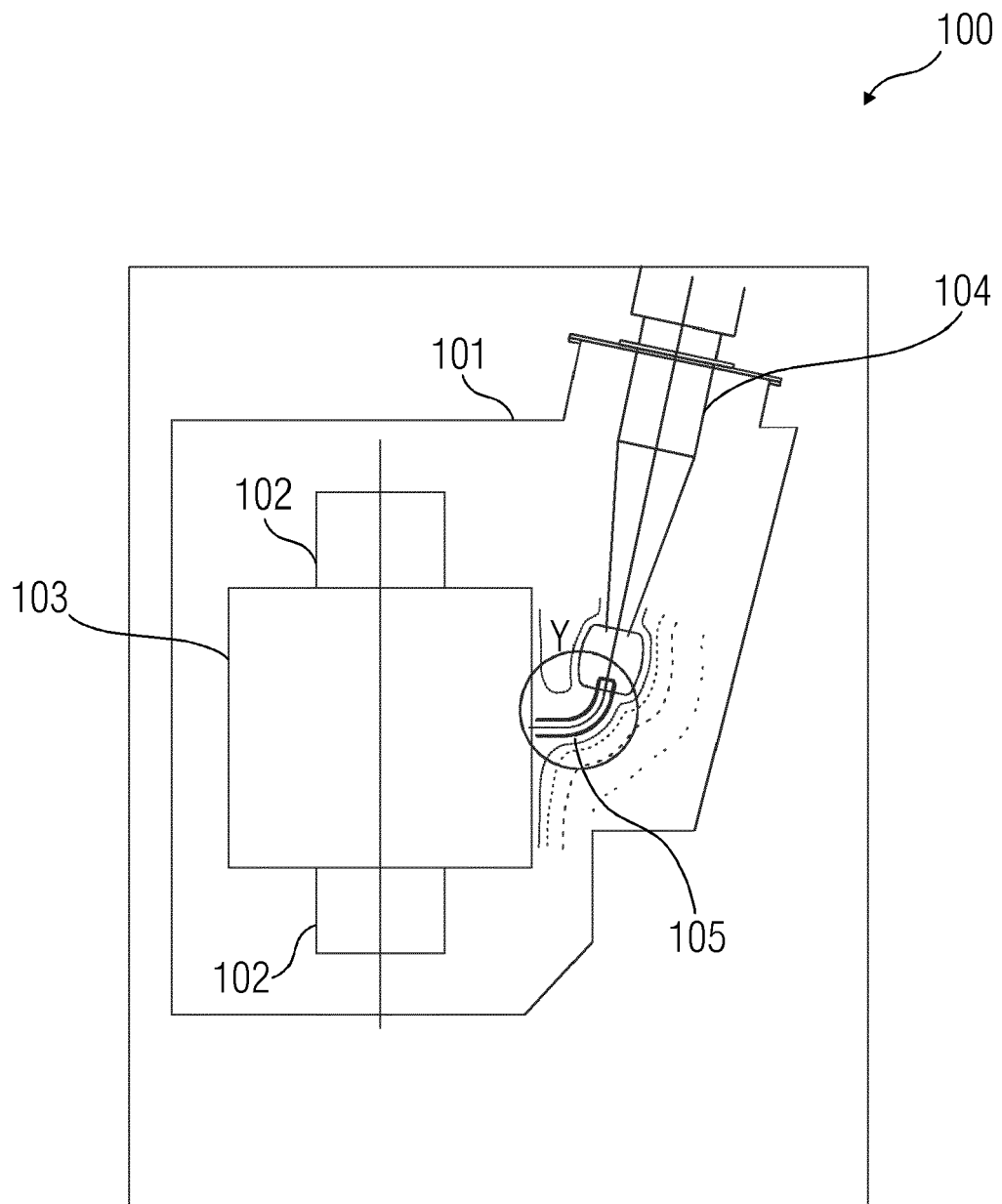


FIG 3B

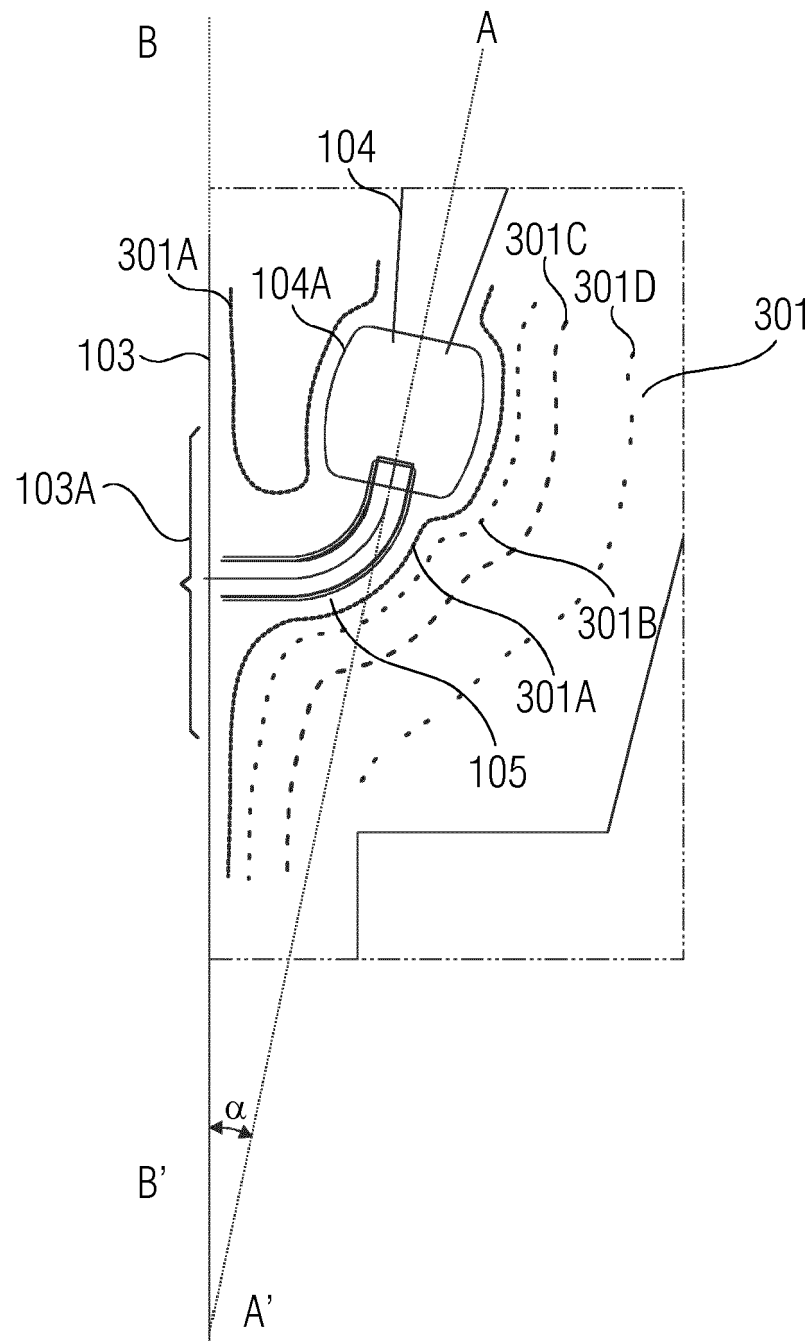


FIG 3C

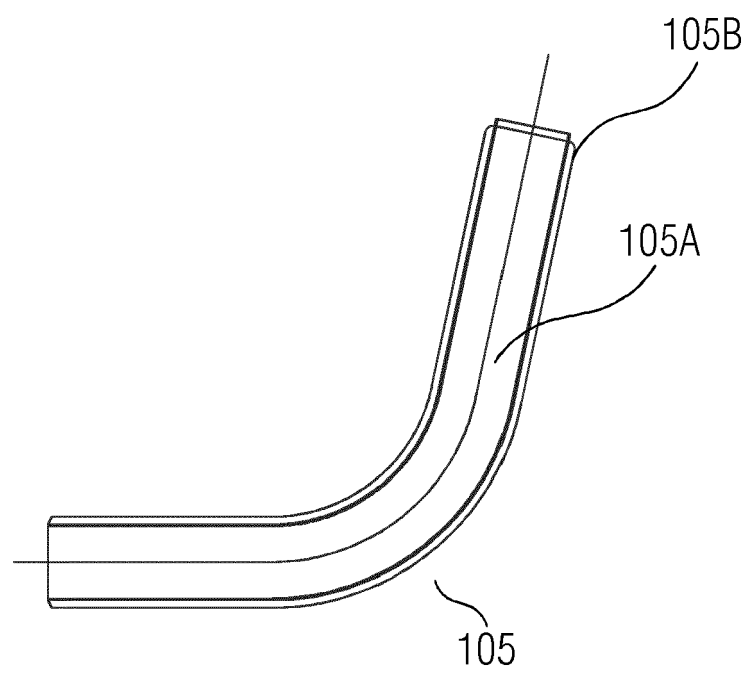
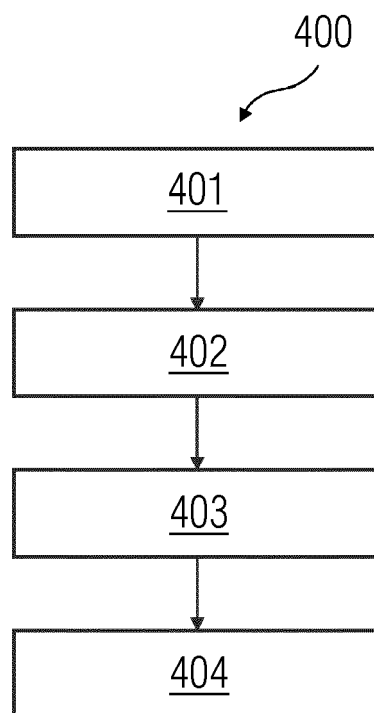


FIG 4





EUROPEAN SEARCH REPORT

Application Number
EP 18 15 2531

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Place of search Munich		Date of completion of the search 9 July 2018	Examiner Reder, Michael
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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