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(54) **AN ELECTRICAL CONNECTION TO AN ELECTRICAL CONDUCTOR ROD**

(57) The present invention relates to an electrical connection arrangement (100) for connecting to an electrical conductor rod (1), the electrical connection arrangement (100) comprises: tubular electrical conductor (102) comprising a tubular end portion (104) with an inner diameter (d1) larger than the outer diameter (d2) of the electrical conductor rod (1), the tubular end portion (104) is adapted to receive an end portion (2) of the electrical conductor rod (1) inside the inner diameter (d1) of the tubular end portion (104), the tubular end portion (104) of the tubular electrical conductor (102) comprises at least one longitudinal cut (106); a clamp (108) adapted to surround an outer diameter (d3) of the tubular end portion (104) of the tubular electrical conductor (102), the clamp (108) is configured to apply a variable force on the tubular end portion (104) to connect the tubular end portion (104) and the end portion (2) of the electrical conductor rod (1) mechanically and electrically.

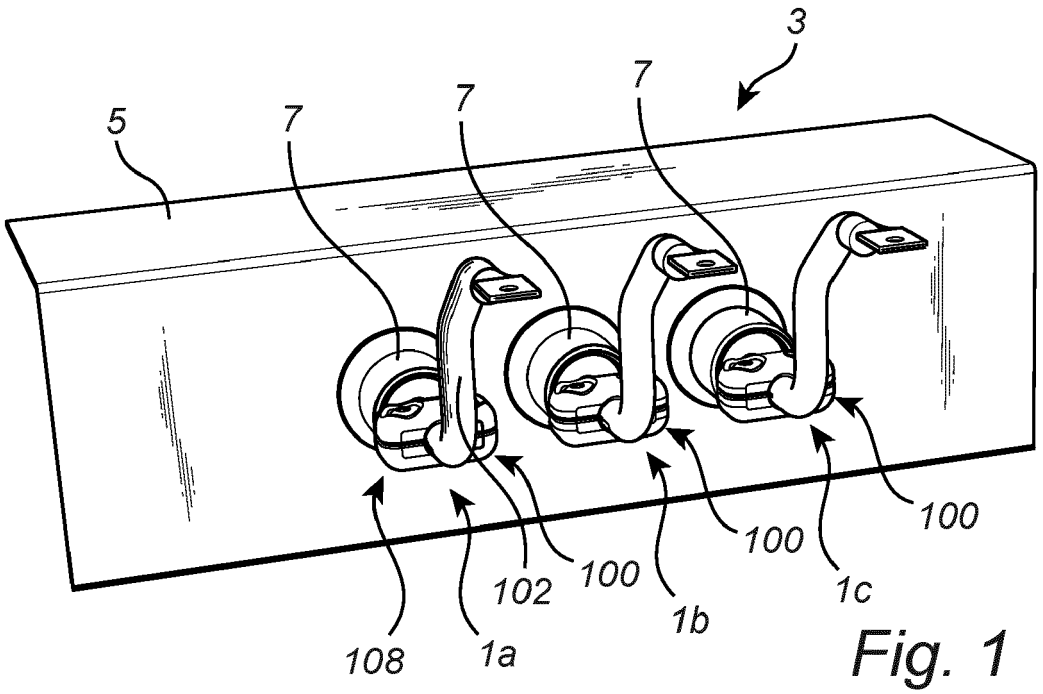

Fig. 1

EP 4 297 191 A1

Description

Field of the Invention

[0001] The present invention relates to an electrical connection arrangement for connecting to an electrical conductor rod.

Background

[0002] Electrical connections to cylindrical rod conductors of an electric bushing for medium voltage applications are subject to electrical stress. To reduce electrical stress and avoid dielectric breakdown the diameter of the connecting rod conductors should be large which also means that a relatively large amount of material is needed which consequently leads to a costly connection.

[0003] Traditionally, the connection is made by screwing a threaded massive bar into a threaded hole of the mating conductor. The electrical connection is provided through the threads themselves or through spring washer which often causes an unstable electrical connection.

[0004] Accordingly, there is room for improvement with regards to connections to electrical rod conductors, especially in medium voltage applications.

Summary

[0005] In view of the above-mentioned and other drawbacks of the prior art, it is an object of the present invention to provide an electrical connection arrangement that at least partly alleviates the deficiencies with prior art.

[0006] According to a first aspect of the invention, there is provided an electrical connection arrangement for connecting to an electrical conductor rod, the electrical connection arrangement comprises: a tubular electrical conductor comprising a tubular end portion with an inner diameter larger than the outer diameter of the electrical conductor rod, the tubular end portion is adapted to receive an end portion of the electrical conductor rod inside the inner diameter of the tubular end portion, the tubular end portion of the tubular electrical conductor comprises at least one longitudinal cut; a clamp adapted to surround the outer diameter of the tubular end portion of the tubular electrical conductor, the clamp is configured to apply a variable force on the tubular end portion to connect the tubular end portion and the end portion of the electrical conductor rod mechanically and electrically.

[0007] The present invention is at least partly based on the realization that a suitable outer diameter of the electrical conductor can be achieved without the need for a massive conductor. Further, it was realized that a massive conductor is not required from a resistance point of view of the electrical connection. Therefore, a tubular electrical conductor is provided to reduce the amount of material of the conductor without compromising the electrical resistance requirement. Further, in order to connect the tubular conductor to the electrical connection rod, a clamp is provided that is configured to apply a force on the overlapping portion between the tubular electrical conductor and the electrical conductor rod. The overlapping portion, or electrical connection area, is where the electrical conductor rod is inside tubular electrical conductor.

[0008] The cut in the tubular end portion of the tubular electrical conductor facilitates for inserting the electrical rod conductor in the tubular electrical conductor since it allows for the tubular end portion to flex a little radially outwards, and to deform when exposed to the clamp force. By applying the force on the tubular end portion, the clamp deforms the split tubular end portion and presses or forces it onto the electrical rod conductor to provide sufficient electric contact. A longitudinal cut may equally be considered a longitudinal slit or split.

[0009] In embodiments, the clamp may comprise a first clamp portion and a second clamp portion adapted to be fitted from opposite sides of the tubular end portion to jointly surround the outer diameter of the tubular end portion, wherein the first clamp portion comprises through-holes for arrangement of screws to be fitted in matching threads of the second clamp portion. This advantageously provides for varying the force applied by the clamp by the tightening of the screws. Screws provide a simple yet robust way of forcing the first clamp portion and a second clamp portion towards each other to press the split tubular end portion onto the electrical conductor rod.

[0010] In embodiments, the first clamp portion may comprise a groove or a hole for fitting of the heads of the screws below an adjacent outer surface of the first clamp portion when the screws are tightened in the threads of the second clamp portion through the through-holes of the first clamp portion. The groove or hole is advantageously a countersink for the screws. By hiding the screws in holes or groves, sparkover to adjacent electrical phases including electrical connection arrangements can be avoided or at least the risk of sparkover can be reduced.

[0011] In embodiments, the at least one longitudinal cut may reach to the inlet of the tubular end portion, the inlet is adapted to receive the electrical conductor rod. Thereby, the tubular end portion is split in one or more portions to facilitate insertion of the electrical conductor rod. The electrical connection arrangement may comprise two or more longitudinal cuts.

[0012] In embodiments, at least one longitudinal cut may be arranged so that the clamp force is directed to reduce or close a width of the at least one longitudinal cut. The clamp force may be directed substantially perpendicular to a longitudinal axis of the tubular electrical conductor.

[0013] In embodiments, a wall thickness of the tubular electrical conductor may be substantially smaller than the inner diameter of the tubular electrical conductor. A smaller wall thickness advantageously reduces the amount of material of the tubular electrical conductor. However, the wall thickness should be thick enough to

provide sufficiently low electrical resistance.

[0014] Preferably, the clamp is electrically conductive. Thus, the clamp may be made from a metal or a metal alloy.

[0015] In embodiments, edges of the outer surfaces of the clamp are rounded edges. For example, radiuses of the edges of the outer surfaces of the clamp exceed 8 mm, preferable exceed 12 mm, more preferably exceed 15 mm. Rounded edges are preferred in order to reduce electrical stress and avoid breakdown to adjacent phases or to the ground tank. The edge radiuses depend on the voltage difference level according to the relevant standard. A larger edge radius is preferred to reduce the electrical stress.

[0016] In embodiments, bend radiuses of the tubular electrical conductor may be at least 15 mm, preferably at least 20 mm, more preferably at least 30 mm. A larger bend radius reduces the risk of breakdown to adjacent electrical phases compared to a smaller bend radius.

[0017] The electrical connection arrangement is preferably adapted for medium voltage application in the voltage range of 1-52 kV, preferably 10-42 kV, more preferably one of 12 kV, 24 kV, 36 kV, 38kV, and 40.5 kV.

[0018] In embodiments, the clamp may be configured to cover the connection area between the tubular electrical conductor and the electrical rod conductor.

[0019] Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. The skilled person realizes that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention.

Brief Description of the Drawings

[0020] These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing an example embodiment of the invention, wherein:

Fig. 1 conceptually illustrates three electric phases each including an electrical connection arrangement according to embodiments of the invention;

Fig. 2 conceptually illustrates an electrical connection arrangement according to embodiments of the invention;

Fig. 3 is a first cross section of an electrical connection arrangement according to embodiments of the invention;

Fig. 4A is illustrates a tubular end portion of a tubular electrical conductor according to embodiments of the invention;

Fig. 4B is illustrates a tubular end portion of a tubular electrical conductor according to embodiments of the invention;

Fig. 4C is illustrates a tubular end portion of a tubular electrical conductor according to embodiments of the invention; and

Fig. 5 is a second cross section of an electrical connection arrangement according to embodiments of the invention.

Detailed Description of Example Embodiments

[0021] In the present detailed description, various embodiments of the present invention are herein described with reference to specific implementations. In describing embodiments, specific terminology is employed for the sake of clarity. However, the invention is not intended to be limited to the specific terminology so selected. While specific exemplary embodiments are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and configurations can be used without parting from the scope of the invention.

[0022] Fig. 1 conceptually illustrates three phases 1a-c of a power distribution unit 3. The power distribution unit 3 includes a gas filled housing 5 in which the phases 1a-c are connected to a cable that lead to power users such as a houses, building, factories, or similar units.

[0023] The power distribution unit 3 can be a circuit breaker and/or load break switch and/or switch-fuse disconnector and/or just disconnector, or a general-purpose switch.

[0024] Switchgears are used in electric power systems to control, protect, and isolate electrical equipment. In distribution nets, switchgears are located on both the high voltage and the low voltage side of power transformers.

[0025] Further, the unit 3 may be a secondary gas insulated switchgear in which the components of the unit 3 are housed in tank 5 which is typically filled with an insulating gas. The components may include various switches, fuses, and circuit breakers for the implementation at hand.

[0026] Each phase 1a-c comprises an electrical connection arrangement 100 which will be described in more detail with reference to subsequent drawings. The electrical connection arrangement 100 is connected to an electrical conductor rod 1 of an electric bushing 7 arranged between the electrical connection arrangement 100 and the housing 5.

[0027] Turning to fig. 2 showing a perspective view of an electrical connection arrangement 100 for connecting to an electrical conductor rod 1 according to embodiments of the invention. Fig. 3 is a cross-section of the electrical connection arrangement 100.

[0028] The electrical connection arrangement 100 comprises a tubular electrical conductor 102 and a clamp 108. The tubular electrical conductor 102 includes a tubular end portion 104 with an inner diameter d1 which is larger than the outer diameter d2 of the electrical conductor rod 1. This means that the electrical conductor rod 1 can fit inside the tubular end portion 104. Thus, the tubular end portion 104 is adapted to receive an end portion 2 of the electrical conductor rod 1 inside the inner

diameter d1 of the tubular end portion 104. As is better seen in figs. 4A-C, the tubular end portion 104 of the tubular electrical conductor 102 comprises at least one longitudinal cut 106. The longitudinal cut 106 may be parallel with the longitudinal axis 126 of the tubular end portion 104. However, a deviation from parallel is also acceptable.

[0029] Furthermore, the electrical connection arrangement 100 comprises a clamp 108 adapted to surround the outer diameter d3 of the tubular end portion 104 of the tubular electrical conductor 102. The clamp 108 is configured to apply a variable force on the tubular end portion 104 of the tubular electrical conductor 102 to connect the tubular end portion 104 and the end portion 2 of the electrical conductor rod 1 mechanically and electrically.

[0030] The clamp 108 is thus adapted to apply a force on the tubular end portion 104 to press the tubular end portion 104 onto the outer surface of the end portion 2 of the electrical conductor rod 1. The clamp 108 is configured as an electric field controller meaning that by varying the clamping force the resistance of the electrical connection between the tubular electrical conductor 102 and the electrical conductor rod 1 is varied. Thus, the clamp 108 provides for improved electrical connection. Further, the clamp 108 provides for hiding the electrical connection area 107 between the tubular electrical conductor 102 and the electrical conductor rod 1 to increase the dielectric withstand voltage level of the connection. Hiding the electrical connection area in the conductive clamp 108 reduces local electric stresses or it hides the high electric stress points. The electrical connection area 107 is where the tubular electrical conductor 102 and the electrical conductor rod 1 make contact.

[0031] Figs. 4A-C illustrates the tubular end portion 104 of example tubular electrical conductors 102.

[0032] The tubular end portion 104 may comprise a single longitudinal cut 106 as illustrated in fig. 4A, or multiple longitudinal cuts 106, here exemplified in fig. 4B by two longitudinal cuts 106, and in fig. 4C by four longitudinal cuts 106. Preferable, the number of cuts 106 is in the range of 2 to 20, preferably 2 to 4 cuts. The number of cuts depend on the difference between the outer diameter of the electrical conductor rod 1 and the inner diameter d1 of the tubular end portion 104 to allow for fitting of the electrical conductor rod 1 in the tubular end portion 104 with sufficient tolerance. In addition, the material of the tubular electrical conductor 102, material thickness t, and the clamping force also affect the number of preferred slits of cuts 106. The cuts may be symmetrically arranged around the circumference of the tubular end portion 104.

[0033] A typical difference between inner diameter d1 of tubular end portion 104 and outer diameter d2 of the electrical conductor rod 1 is in the range of 0,5mm to 2,5mm, preferable 1,5mm. Further, the outer diameter d3 tubular electrical conductor 102 is typically in the range of 15 mm to 32 mm, or preferably in the range of 18 mm-22 mm. Preferably, the wall or material thickness t of the tubular electrical conductor 102 is substantially smaller than the inner diameter d1 of the tubular electrical conductor 102. A typical diameter d2 of the electrical conductor rod 1 is in the range of 12 mm to 30 mm, where a preferable diameter is about 15 mm. A typical wall thickness t is in the range of 1-4 mm.

[0034] Further, to allow for the clamp 108 to deform the tubular end portion 104 and to facilitate the fitting of the electrical conductor rod 1 in the tubular end portion 104, it is preferred if the longitudinal cut 106 reaches to the inlet 122 of the tubular end portion 104. The inlet 122 is adapted to receive the electrical conductor rod 1. In other words, the tubular end portion 104, where the clamp 104 is arranged for applying the clamp force, is split by the longitudinal cuts 106.

[0035] Turning again to fig. 3, the clamp force as provided by the clamp 108 is directed substantially perpendicular to a longitudinal axis 126 of the tubular electrical conductor 102. This causes a deformation of the tubular end portion 104 which reduces the outer diameter d3 of the tubular end portion 104. For longitudinal cuts 106 arranged off-center from the longitudinal axis 126 relative the clamp force, the clamp force is directed to reduce or close a width w of the at least one longitudinal cut 106.

[0036] In order to reduce the risk of discharge between the phases 1a-1c or between a live phase and the housing 5in fig 1, the bend radiuses of the tubular electrical conductor 102 are at least 15 mm, preferably at least 20 mm, more preferably at least 30 mm, such as about 40 mm.

[0037] Turning now to fig. 5 illustrating another cross-section of the electrical connection arrangement 100, the clamp 108 comprises a first clamp portion 110a and a second clamp portion 110b adapted to be fitted from opposite sides of the tubular end portion 104. In this way, the clamp portions 110a-b jointly surround the outer diameter d3 of the tubular end portion 104.

[0038] The first clamp portion 110a comprises through-holes 112a,b for arrangement of screws 114 to be fitted in matching threads 115 of the second clamp portion 110b. By tightening the screws in the threads 115, the first clamp portion 110a and the second clamp portion 110b are pressed together to thereby apply a clamping force to the tubular end portion 104 arranged in-between the first clamp portion 110a and the second clamp portion 110b. The first clamp portion 110a and the second clamp portion 110b jointly form a circular receiving space 119 where the tubular end portion 104 and the end portion 2 of the electrical conductor rod 1 is received.

[0039] The first clamp portion 110a comprises a groove or a hole, or a counter sink 116 for fitting of the heads 118 of the screws 114 below an adjacent outer surface 120 of the first clamp portion 110a when the screws 114 are tightened in the threads 115 of the second clamp portion 110b through the through-holes 112a,b of the first clamp portion 110a. Thus, the screw heads 118 are hidden in the counter sink 116 so that high electric stress

points are avoided or at least reduced.

[0040] The clamp 108 is electrically conductive and is made from a conductive material, typically a steel alloy, an aluminum alloy, or a Zink alloy

[0041] Furthermore, the edges of the outer surfaces 130 of the clamp 108 are rounded edges 130 to reduce the electrical stress and unwanted discharge. In fig. 2, 3, and 5 some example edges are denoted 130.

[0042] With the rounded edges of the clamp 108 and large bend radius of the tubular electrical conductor 102, the phases 1a-c can be arranged closer to each other, thereby reducing the space required for the phases.

[0043] The radii of edges 130 of the outer surfaces of the clamp exceed 8 mm, preferable exceed 12 mm, more preferably exceed 15 mm, such as for example 20mm.

[0044] In the exemplified embodiments, two screws 114 are shown fitted through a respective trough hole 112a,b of the first clamp portion 110a and tightened in threads 115 of the second clamp portion 110b. However, the number of screws may vary depending on the specific implementation at hand. The dimensions of the screws are preferable in the range of M8 to M12.

[0045] Although the electrical connection arrangement 100 shown herein can be applied to various implementations, the electrical connection arrangement 100 is most advantageously adapted for medium voltage application. The voltage range for such medium voltage applications is in the voltage range of 1-52 kV, or more preferably in the range of 10-42 kV. Some example mediums voltages that are especially suitable include any one of 12 kV, 24 kV, 36 kV, 38 kV, and 40.5 kV.

[0046] Even though the invention has been described with reference to specific exemplifying embodiments thereof, many different alterations, modifications and the like will become apparent for those skilled in the art.

[0047] Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Claims

1. An electrical connection arrangement (100) for connecting to an electrical conductor rod (1), the electrical connection arrangement (100) comprises:

   a tubular electrical conductor (102) comprising a tubular end portion (104) with an inner diameter (d1) larger than the outer diameter (d2) of the electrical conductor rod (1), the tubular end portion (104) is adapted to receive an end portion (2) of the electrical conductor rod (1) inside the inner diameter (d1) of the tubular end portion (104), the tubular end portion (104) of the tubular electrical conductor (102) comprises at least one longitudinal cut (106);

   a clamp (108) adapted to surround an outer diameter (d3) of the tubular end portion (104) of the tubular electrical conductor (102), the clamp (108) is configured to apply a variable force on the tubular end portion (104) to connect the tubular end portion (104) and the end portion (2) of the electrical conductor rod (1) mechanically and electrically.

2. The electrical connection arrangement according to claim 1, wherein the clamp (108) comprises a first clamp portion (110a) and a second clamp portion (110b) adapted to be fitted from opposite sides of the tubular end portion (104) to jointly surround the outer diameter (*d3* of the tubular end portion (104), wherein the first clamp portion (110a) comprises through-holes (112a,b) for arrangement of screws (114) to be fitted in matching threads (115) of the second clamp portion (110b).

3. The electrical connection arrangement (100) according to claim 2, wherein the first clamp portion (110a) comprises a groove (116) or a hole for fitting of the heads (118) of the screws (114) below an adjacent outer surface (120) of the first clamp portion (110a) when the screws (114) are tightened in the threads (115) of the second clamp portion (110b) through the through-holes (112a,b) of the first clamp portion (110a).

4. The electrical connection arrangement (100) according to claim 3, wherein the groove or hole is a countersink (116) for the screws.

5. The electrical connection arrangement (100) according to any one of the preceding claims, wherein the at least one longitudinal cut (106) reaches to the inlet (122) of the tubular end portion (104) adapted to receive the electrical conductor rod (1).

6. The electrical connection arrangement (100) according to claim 5, comprising two or more longitudinal cuts.

7. The electrical connection arrangement (100) according to any one of the preceding claims, wherein at least one longitudinal cut (106) is arranged so that the clamp force is directed to reduce or close a width (w) of the at least one longitudinal cut (106).

8. The electrical connection arrangement (100) according to any one of the preceding claims, wherein the clamp force is directed substantially perpendicular

to a longitudinal axis (126) of the tubular electrical conductor (102).

9. The electrical connection arrangement (100) according to any one of the preceding claims, wherein a wall thickness (t) of the tubular electrical conductor (102) is substantially smaller than the inner diameter (d1) of the tubular electrical conductor (102).

10. The electrical connection arrangement (100) according to any one of the preceding claims, wherein the clamp (108) is electrically conductive.

11. The electrical connection arrangement (100) according to any one of the preceding claims, wherein edges of the outer surfaces (130) of the clamp (108) are rounded edges (130).

12. The electrical connection arrangement (100) according to claim 9, wherein radii of the edges (130) of the outer surfaces of the clamp exceed 8 mm, preferable exceed 12 mm, more preferably exceed 15 mm.

13. The electrical connection arrangement (100) according to any one of the preceding claims, wherein bend radiuses of the tubular electrical conductor (102) are at least 15 mm, preferably at least 20 mm, more preferably at least 30 mm.

14. The electrical connection arrangement (100) according to any one of the preceding claims, the electrical connection arrangement (100) is adapted for medium voltage application in the voltage range of 1-52 kV, preferably 10-42 kV, more preferably 12 kV, 24 kV, 36 kV, 38 kV, and 40.5 kV.

15. The electrical connection arrangement (100) according to any one of the preceding claims, wherein the clamp is configured to cover the connection area between the tubular electrical conductor (102) and the electrical rod conductor (1).

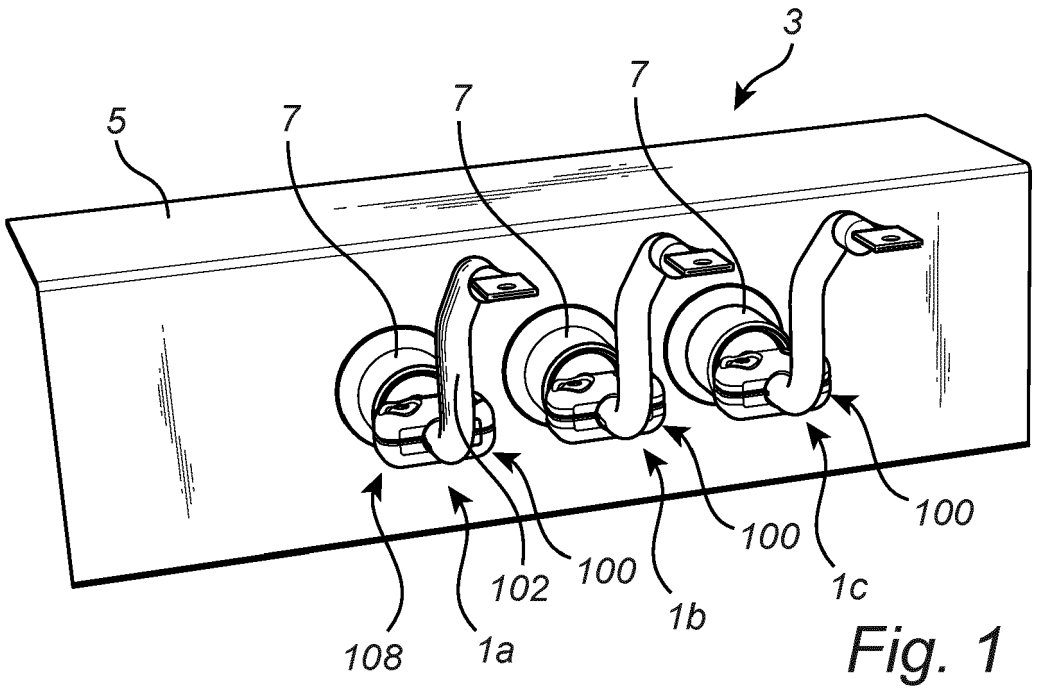

Fig. 1

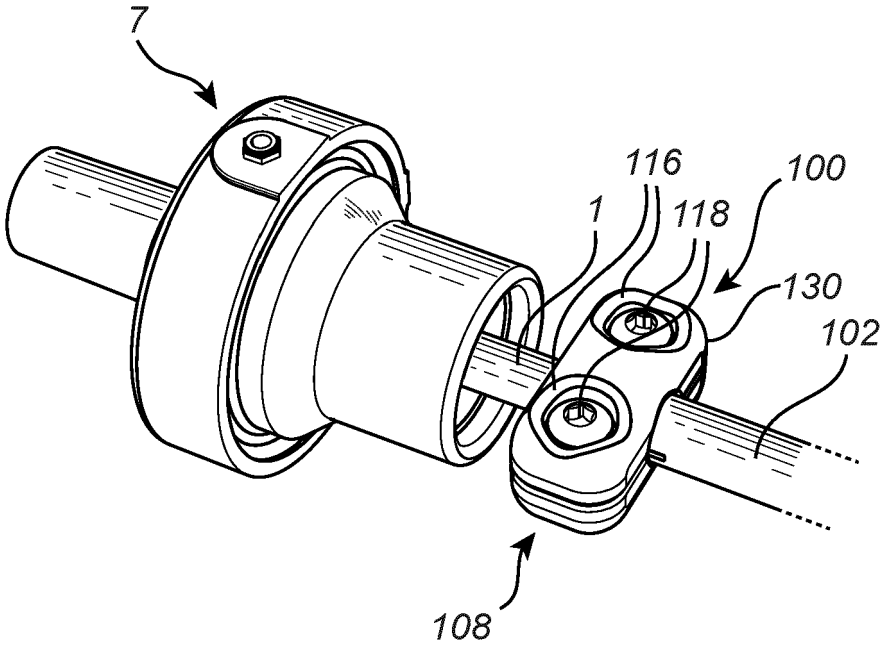

Fig. 2

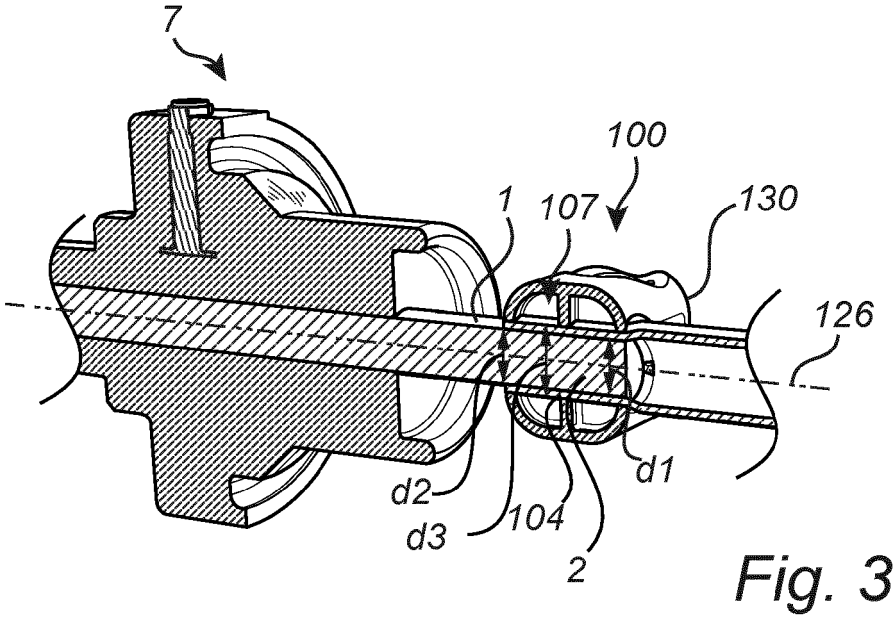

Fig. 3

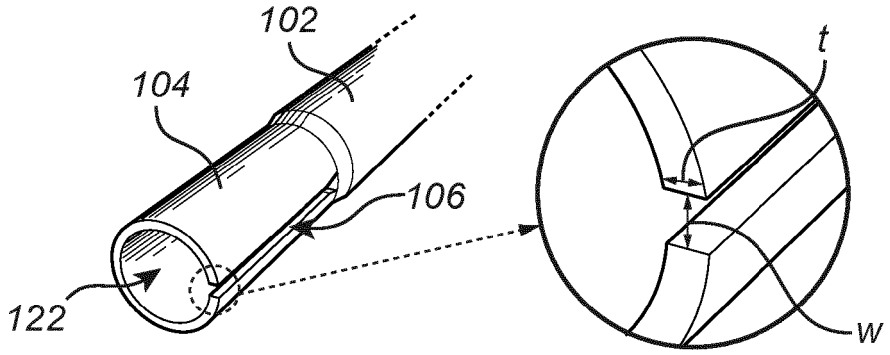

Fig. 4A

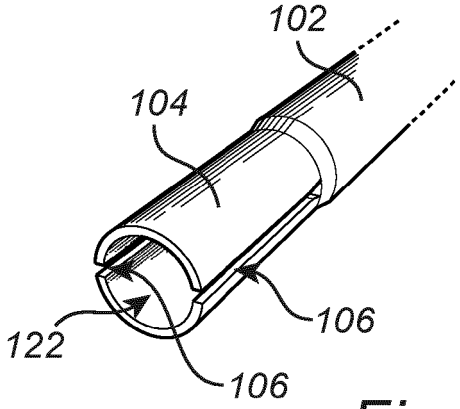

Fig. 4B

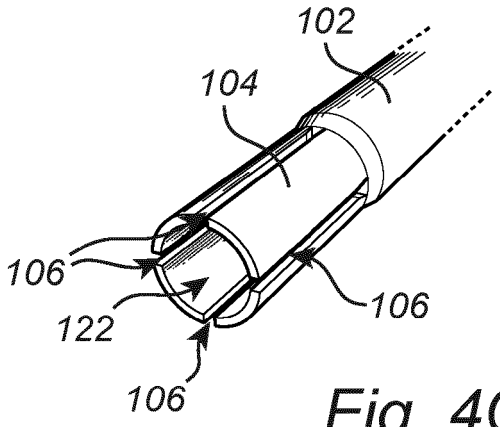

Fig. 4C

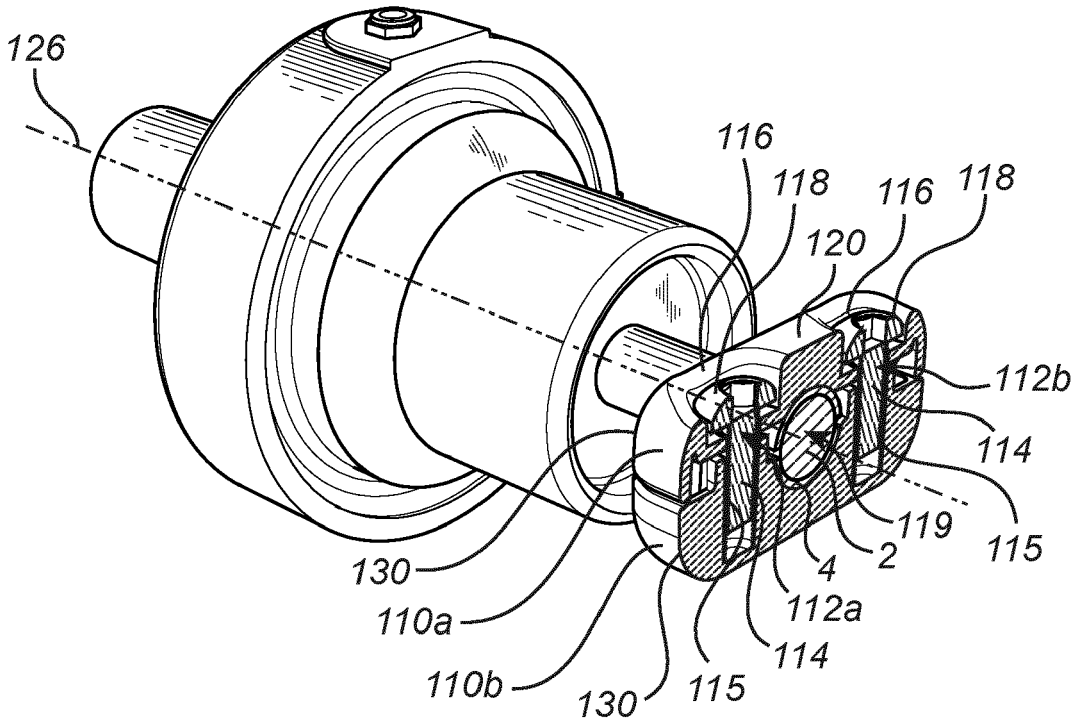
126
116
118
116
118
120
112b
114
119
115
2
4
130
110a
112a
114
110b
130
115

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 22 18 0383

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 3 701 929 A (TAGUCHI KAZUO ET AL) 31 October 1972 (1972-10-31) * figures 1-6 * * columns 1-4 *	1-15	INV. H01R4/46 H01R4/60
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TECHNICAL FIELDS SEARCHED (IPC)

H01R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	23 November 2022	Kandyla, Maria

CATEGORY OF CITED DOCUMENTS

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