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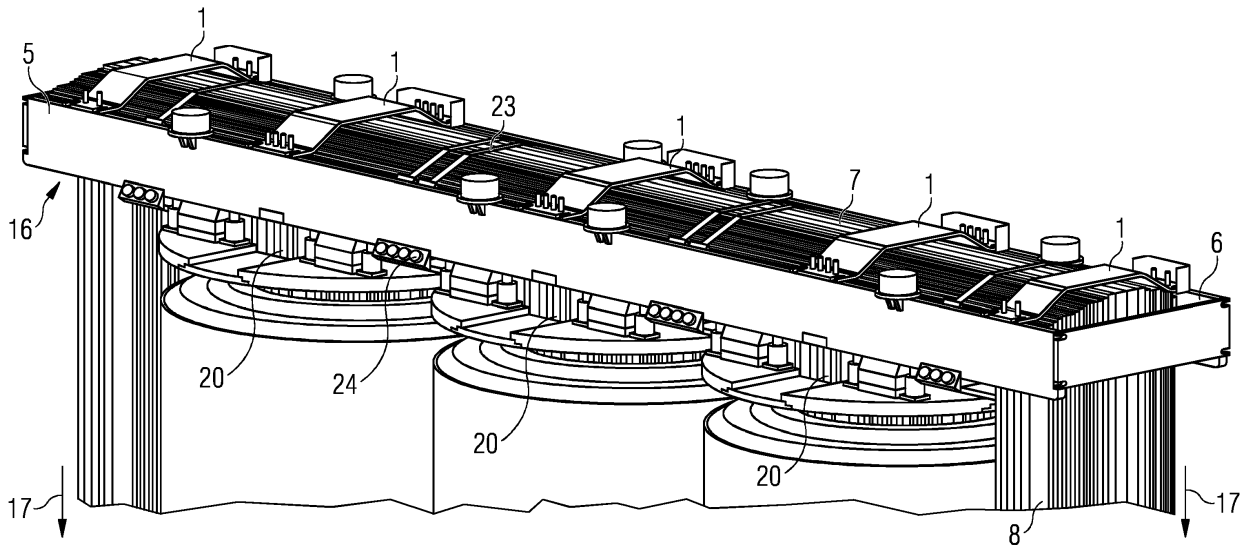
(54) **CLAMPING SYSTEM FOR AN ELECTRIC TRANSFORMER**

(57) Clamping system for a transformer, the clamping system comprising a first clamping frame (16) with a first clamping frame member (5) and a second clamping frame member (6) adapted to be arranged on opposing sides of a laminated yoke (7) of a transformer core (8) of said transformer, as well as at least one tension element, preferably at least one horizontal tie bar (19) and/or at least one tensioning bandage (23, 24), connecting the first clamping frame member (5) to the second clamping frame member (6) under tensile stress, whereas the first clamping frame member (5) and/or the second clamping frame member (6) is made of epoxy resin, preferably of epoxy resin laminate.

FIG 1



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Description

Field of the invention

[0001] The invention relates to clamping system for a transformer, the clamping system comprising a first clamping frame with a first clamping frame member and a second clamping frame member adapted to be arranged on opposing sides of a laminated yoke of a transformer core of said transformer, as well as at least one tension element, preferably at least one horizontal tie bar and/or at least one tensioning bandage, connecting the first clamping frame member to the second clamping frame member under tensile stress.

Background art

[0002] Electrical transformers and electrical power transformers in particular, usually feature a transformer core consisting of multiple laminations. Windings of a particular phase are arranged on each core column of this laminated core. In order to form a closed magnetic circuit, the ends of said core columns are connected by yokes of the laminated core; upper ends of the columns are connected to each other by an upper yoke whereas lower ends of the columns are connected to each other by a lower yoke.

[0003] In order to guarantee stability of the laminated core, the laminations are pressed together by means of a clamping system. To this end, clamping frames are employed which are attached to the upper and lower yokes of the laminated core. Respective members of these clamping frames are positioned on opposing sides of the yoke and are held together under tension, such that the respective yoke is wedged in between said clamping frame members.

[0004] For the windings of an electric (power) transformer it is of utmost importance to maintain mechanical stability. Therefore, each winding is pressed between two pressure plates which are inserted between the upper yoke and the upper ending of the winding, and between the lower yoke and the lower end of the winding respectively. In order to maintain the required pressure on said pressure plates, the clamping frame assigned to the upper yoke is connected to the clamping frame assigned to the lower yoke via tension elements. After pressing the clamping frames assigned to the upper and lower yoke towards each other, the clamping frames are firmly attached to the tension elements such that said tension elements keep the distance between both clamping frames fixed.

[0005] Known clamping frames are made of magnetic steel grade (EN 10025 S235xx or S355xx) and therefore the members of each clamping frame form an electrically connected loop. Electromagnetic fields originating from the windings and connection thus generate eddy currents in the whole clamping frame. This may result in stray losses, the creation of hotspots within the active part of the transformer, and may also lead to gassing as well as to high stray losses. Moreover, known clamping frames significantly increase the total weight of the transformer due to the material they are made of.

Object of the invention

[0006] It is therefore an object of the invention to present a clamping frame for a clamping system, employment of which in an electric transformer leads to the above-mentioned problems being avoided. In particular, the proposed clamping frame should minimize losses and heat or gassing problems stemming from eddy currents in the transformer's clamping system, and at the same time facilitate a significant reduction in weight as compared to known clamping systems.

Description of the invention

[0007] In a clamping system for a transformer, the clamping system comprising a first clamping frame with

- a first clamping frame member and a second clamping frame member adapted to be arranged on opposing sides of a laminated yoke of a transformer core of said transformer, as well as
- at least one tension element, preferably at least one horizontal tie bar and/or at least one tensioning bandage, connecting the first clamping frame member to the second clamping frame member under tensile stress,

an object of the invention is achieved in that the first clamping frame member and/or the second clamping frame member is made of epoxy resin, preferably of epoxy resin laminate.

[0008] By employing epoxy resin (laminate), the clamping frame's weight is significantly decreased. Moreover, due to the employment of an electrically insulating material, the clamping frame no longer allows eddy currents to freely flow through it. Thus, additional elements for electric isolation, as they are employed in the prior art, become moot and any effects attributed to eddy currents prevailing in the clamping frame can be effectively minimized or avoided. At the same time, clamping frames made of epoxy resin (laminate) have structural strength and stability properties facilitating to reliably keep the laminated yoke in shape and position when pressure is exerted on the first and second clamping frame members.

[0009] According to a preferred embodiment of the invention, the epoxy resin laminate is realized as epoxy woven glass cloth.

[0010] Such a material provides the clamping frame with optimal electric isolation and structural properties (e.g. sufficient stiffness) and thereby greatly improves the overall stability of the whole clamping system and at the same time reduces stray losses in the clamping sys-

tem.

[0011] According to another preferred embodiment of the invention, the epoxy woven glass cloth is EP GC 203 or EP GC 205, as defined in the norm IEC 60893.

[0012] These materials both have

- a minimum flexural strength of 340 MPa (measured at 150°C ± 3 K after 1 hour at 150°C ± 3 K not to be less than 50% of the specified value; test method in IEC 60893-2 Subclause 5.1; nominal thickness of sheet to which test is applicable is 1,5 mm or more),
- a minimum Charpy impact strength parallel to laminations of 33 kJ/m^2 (EP GC 203) and 50 kJ/m^2 (EP GC 205) (test method in IEC 60893-2 Subclause 5.4.2; nominal thickness of sheet to which test is applicable is 5 mm or more),
- a minimum Izod impact strength parallel to laminations of 34 kJ/m^2 (EP GC 203) and 54 kJ/m^2 (EP GC 205) (test method in IEC 60893-2 Subclause 5.4.3; nominal thickness of sheet to which test is applicable is 5 mm or more),
- a minimum breakdown voltage at 90°C in oil parallel to laminations of 35 kV (test method in IEC 60893-2 Subclause 6.1; nominal thickness of sheet to which test is applicable is 3 mm or more),
- and a minimum insulation resistance after immersion in water of 5 x 10^4 MΩ (EP GC 203) and 1 x 10^4 MΩ (EP GC 205) (test method in IEC 60893-2 Subclause 6.3).

[0013] Therefore, a clamping frame made of this material is strong enough to maintain stability of the clamping system as well as of the transformer's laminated core under stress, and in addition to that provides excellent isolation in order to reduce negative effects associated with eddy currents through the clamping frame.

[0014] According to another preferred embodiment of the invention, the first clamping frame comprises at least one clamping bridge adapted to connect the first clamping frame member to the second clamping frame member such that the laminated yoke is at least partially covered by the clamping bridge.

[0015] In order to provide stability to the whole clamping system during winding pressing procedure, to absorb vertical forces produced during transportation, loading and unloading of the transformer, and to provide support to the transformer cover under vacuum load, the clamping frame comprises a clamping bridge. When external pressure is applied on the clamping frame, the clamping bridge will retain the respective yoke thereby avoiding that the yoke is lifted from its position and/or that the respective core laminations deform under pressure.

[0016] According to yet another embodiment of the invention, the clamping system comprises a further clamping frame and at least two further tension elements, preferably at least two vertical tie bars, connecting the first clamping frame to the further clamping frame of the clamping system, whereas these tension elements are received in a corresponding set of openings of the clamping bridge.

[0017] The set of openings for receiving the further tension elements for connecting the first clamping frame to the further clamping frame may be positioned in a first and second mounting portion of the clamping bridge, whereas these mounting portions facilitate the connection between the clamping bridge and the first and second clamping frame members. The openings can be realized as drilled holes. Preferably, said openings can be supported by one or more support discs or support plates. Said openings allow for a particularly simple and reliable way of receiving the further tension elements for connecting the first clamping frame member and/or the second clamping frame member to the further clamping frame. While pressure is applied to the first clamping frame (i.e. to the members of the first clamping frame), these further tension elements may be loosely inserted in the openings, thereby allowing for a variation of the distance between the first clamping frame and the further clamping frame. As soon as the desired pressure (or distance between the clamping frames) has been reached, the further tension elements may be tightly fastened to the clamping bridge, e.g. by means of threaded heads of the further tension elements and corresponding nuts.

[0018] According to another preferred embodiment of the invention, lifting protrusions of the further tension elements protrude beyond the clamping bridge, preferably beyond a surface of the clamping bridge.

[0019] During loading and unloading of the transformer, it is necessary to lift the active part of the transformer (which active part comprises the transformer core and windings). To this end, the clamping frame members normally feature special fastening eyes which are mounted on the first clamping frame member and the second clamping frame member of the first clamping frame. Usually, each member has two fastening eyes. By means of these fastening eyes, the active part of known transformers can be lifted, provided that the clamping frame members sufficiently support the fastening eyes and the weight of the active part. Since the clamping frame members according to the invention are, however, not made of steel - as in the state of the art - but of epoxy resin (laminate), such fastening eyes would not be properly supported due to the structural properties of the material. Therefore, in order to provide anchoring points for a corresponding lifting device to engage the first clamping frame, the further tension elements are provided with lifting protrusions. With these lifting protrusions, which may form the ends of each further tension element, the further tension elements protrude beyond the clamping bridge. The lifting protrusions may be realised as specifically strengthened end sections of the further tension elements, e.g. as threaded heads of the further tension el-

ements.

[0020] According to yet another preferred embodiment of the invention, the clamping bridge is made of epoxy resin, preferably of epoxy resin laminate, and the openings are lined with reinforcing members, preferably realized as glass fibre tubes.

[0021] Due to the material properties of the employed epoxy resin (laminate), the clamping bridge of this embodiment may have a tendency to delaminate, e.g. due to threaded heads of the tension elements and/or of fastening elements used to fix the clamping bridge to the clamping frame members. Under pressure the threads might eat into the inner walls of the openings of the clamping bridge. In order to prevent this, the inner walls of the openings may be reinforced by means of said reinforcing members.

Brief description of the drawings

[0022] In what follows the invention is described further with regard to an example embodiment. The drawings are, however, only exemplary and are not meant to restrict the scope of the invention as described above.

Fig. 1 shows the clamping system according to the invention

Fig. 2 shows a detail of Fig. 1

Fig. 3 shows a detail of Fig. 2

Fig. 4 shows an embodiment of a vertical tie bar

Ways of carrying out the invention

[0023] Fig. 1 shows a clamping system according to the invention. As such it comprises a first clamping frame 16 which is arranged on an upper yoke 7 of a laminated core 8 of an electric transformer, as well as a further clamping frame 17, which is, however, not depicted in Fig. 1 but only an arrow indicating its position is shown. The further clamping frame 17 is identical to the first clamping frame 16 and is arranged on a lower yoke of the same laminated core 8.

[0024] The first clamping frame 16 comprises a first clamping frame member 5 arranged on one side of the yoke 7, as well as a second clamping frame member 6 arranged on an a side of the yoke 7 opposite of the first clamping frame member 5. The first clamping frame member 5 and the second clamping frame member 6 are connected to each other under tensile stress by means of one or more tension elements, which may be realized as horizontal tie bars 19 (see Fig. 2), and/or outside tensioning bandages 23, and/or winding side tensioning element 24 (see Fig. 1). Due to these tension elements, said first clamping frame 16 exerts a force on the yoke 7 pressing its laminations against each other thereby holding the yoke 7 together.

[0025] According to the invention, the first clamping frame member 5 and/or the second camping frame member 6 is/are made of epoxy resin or epoxy resin laminate. This choice of material prevents eddy currents to be induced in the clamping frame 16, thereby avoiding negative effects like power losses, gassing or hotspots. Moreover, the weight of the clamping frame 16 is significantly less than the weight of known clamping frames.

[0026] A clamping bridge 1 is mounted on both clamping frame members 5, 6 such that it partially covers the yoke 7. Since the clamping bridge 1 may be made of epoxy resin or of epoxy resin laminate, no eddy currents can be induced in the clamping bridge, which thus further contributes to the above-mentioned positive effects of the clamping system according to the invention; on the other hand the clamping bridge 1 features sufficient structural strength to fulfil its purpose, namely to retain the position of most or all of the laminations and thereby the shape of the yoke 7 when pressure is applied to the first clamping frame 16, e.g. during winding pressing. Said clamping bridge 1 comprises a first mounting portion 2 for mounting the clamping bridge 1 on the first clamping frame member 5, as well as a second mounting portion 3 for mounting the clamping bridge 1 on the second clamping frame member 6. In order to mount the clamping bridge 1 on the clamping frame members 5, 6, the clamping bridge 1 is placed on the clamping frame members 5, 6 such that the fist mounting portion 2 at least partially overlaps with the first clamping frame member 5 and that the second mounting portion 3 at least partially overlaps with the second clamping frame member 6. By means of fastening elements 14 (see Fig. 3), the first mounting portion 2 is fixed to the first clamping frame member 5 and the second mounting portion 3 is fixed to the second clamping frame member 6. In order to receive said fastening elements 14, which may be realized as screws or bolts, the first mounting portion 2 and the second mounting portion 3 have a first set of openings 12 which themselves are realized as elongated holes that are open towards the sides of the clamping bridge 1.

[0027] The clamping bridge 1 also comprises a retaining portion 4 (see Fig. 2) which is adapted to be brought into contact with the yoke 7. Said retaining portion 4 comprises a first planar section 9, which is arranged in a plane different from a plane in which the first mounting portion 2 and the second mounting portion 3 are positioned. Said first planar section 9 is connected to the first mounting portion 2 by means of a second planar section 10 protruding obliquely from the first planar section 9. The transition from the first planar section 9 to the second planar section 10, as well from the second planar section 10 to the first mounting portion 2 may be facilitated by kinked or bent sections of the retaining portion 4.

[0028] Correspondingly, said first planar section 9 is connected to the second mounting portion 3 by means of a third planar section 11 protruding obliquely from the first planar section 9. The transition from the first planar section 9 to the third planar section 11, as well from the

third planar section 11 to the second mounting portion 3 may be facilitated by kinked or bent sections of the retaining portion 4.

[0029] Due to its structure the retaining portion 4 of the clamping bridge 1 resembles the structure of the yoke 7 in good approximation. The yoke 7 is assembled out of multiple laminations having different height. As a result, a surface of the yoke 7 facing the clamping bridge 1 is uneven due to laminations having different height. The corresponding profile of the yoke 7 has a maximum height in a central region with its height falling off in outer regions of said surface. Hence, the clamping bridge 1 allows to retain the position of most or all of the laminations and thereby the entire shape of the yoke 7 when pressure is applied to the first clamping frame 16 during the procedure of winding pressing.

[0030] During winding pressing an external force is exerted on the first clamping frame 16 which conveys said external pressure to windings of the transformer arranged on core columns between the upper yoke 7 and the lower yoke. During this procedure the first clamping frame 16 and the further clamping frame 17, which is attributed to the lower yoke, are loosely connected such that their distance may still be varied. To this end, further tension elements, which can be realized as vertical tie bars 20, are foreseen which can be tightly fixed to the further clamping frame 17 but at first are inserted only loosely into a corresponding set of openings, i.e. the second set of openings 13, of the first clamping frame 16. In the embodiment shown, said second set of openings 13 is arranged in the clamping bridge 1, in particular in the first mounting portion 2 and the second mounting portion 3 of the clamping bridge 1. The openings of said se cond set of openings 13 are realized as bore holes which in Fig. 2 and 3 are covered by support plates 21 aiding with the stability of the mounting portions 2, 3 when the vertical tie bars 20 are tightly fixed to the clamping bridge 1. However, the positions of the second set of openings 13 may directly and unambiguously be deferred from the position of the upper ends of the vertical tie bars 20 serving as tension elements 15 for connecting the first clamping frame 16 to the further clamping frame 17.

[0031] As soon as the desired pressure on the windings has been reached, the vertical tie bars 20 are tightly fixed to the first clamping frame 16 by means of threaded nuts 22 tightened against the support plates 21. Thereby, the relative positions of the first clamping frame 16 and the second clamping frame 17 are fixed and the distance between the clamping frames 16, 17 cannot be varied any longer. Thus, the pressure on the windings is maintained without the external pressure having to be exerted any longer on the first clamping frame 16.

[0032] Since the clamping frame members 5, 6 are not made of steel - as in the state of the art - but of epoxy resin (laminate), fastening eyes, which would normally be attached to the clamping frame members 5,6 and which would be used to lift the active part of the transformer, would not be properly supported due to the structural properties of the employed material. Therefore, in order to provide anchoring points for a corresponding lifting device to engage the first clamping frame 16, the vertical tie bars 20 are provided with lifting protrusions 15. With these lifting protrusions 15, which may form the ends of each vertical tie bar 20, the vertical tie bars 20 protrude beyond the clamping bridge 1. The lifting protrusions 15 may be realised as specifically strengthened end sections of the further tension elements, e.g. as threaded heads of the vertical tie bars 20.

[0033] Fig. 4 shows an embodiment of the vertical tie bar 20. It comprises several, here four, tie plates 25, each of which terminates at one end in a corresponding lifting protrusion 15. The lifting protrusion 15 is realized as threaded projections for securing a nut and for connecting the vertical tie bar 20 with a lifting beam or a lifting structure of the lifting device. Starting from the circular cross section at the lifting protrusion 15 the tie plate 25 changes to a rectangular cross section, e.g. 50x10 flats. At the other end of the vertical tie bar 20 a single weld on pad 26 connects the individual tie plates 25 to each other.

[0034] The structure of the vertical tie bar 20 shown in Fig. 4 is particularly chosen to accommodate the number of tie plates 25 (which is based on the winding clamping force and short circuit force) within a core circle to have an optimum filling of the core in a given core circle diameter. The number of tie plates 25 will change based on stresses arising in these plates during pressing, lifting and special operating conditions like short circuit situation for each transformer. Therefore, the number of projections at the top of each vertical tie bar 20 will be based on size of the transformer and the prevailing forces.

[0035] In order to avoid delamination of the clamping bridge 1, the inner walls of the first set of openings 12 and/or of the second set of openings 13 are lined with reinforcing members 18 which are preferably realized as glass fibre tubes.

Reference signs

[0036]

1	clamping bridge
2	first mounting portion
3	second mounting portion
4	retaining portion
5	first clamping frame member
6	second clamping frame member
7	yoke
8	core
9	first planar section
10	second planar section
11	third planar section
12	first set of openings
13	second set of openings
14	fastening elements
15	lifting protrusions

16 first clamping frame
17 further clamping frame
18 reinforcing members
19 horizontal tie bar
20 vertical tie bar
21 support plate
22 threaded nut
23 outside tensioning bandage
24 winding side tensioning bandage
25 tie plate
26 weld on pad

Claims

1. Clamping system for a transformer, the clamping system comprising a first clamping frame (16) with

   - a first clamping frame member (5) and a second clamping frame member (6) adapted to be arranged on opposing sides of a laminated yoke (7) of a transformer core (8) of said transformer, as well as
   - at least one tension element, preferably at least one horizontal tie bar (19) and/or at least one tensioning bandage (23, 24), connecting the first clamping frame member (5) to the second clamping frame member (6) under tensile stress,

   characterized in that the first clamping frame member (5) and/or the second clamping frame member (6) is made of epoxy resin, preferably of epoxy resin laminate.

2. The clamping system according to claim 1, **characterized in that** the epoxy resin laminate is realized as epoxy woven glass cloth.

3. The clamping system according to claim 2, **characterized in that** the epoxy woven glass cloth is EP GC 203 or EP GC 205, as defined in the norm IEC 60893.

4. The clamping system according to any of the claims 1 to 3, **characterized in that** the first clamping frame (16) comprises at least one clamping bridge (1) adapted to connect the first clamping frame member (5) to the second clamping frame member (6) such that the laminated yoke (7) is at least partially covered by the clamping bridge (1).

5. The clamping system according to claim 4, **characterized in that** it comprises at least two further tension elements, preferably at least two vertical tie bars (20), connecting the first clamping frame (16) to a further clamping frame (17) of the clamping system, whereas these tension elements are received in a corresponding set of openings (13) of the clamping bridge (1).

6. The clamping system according to claim 5, **characterized in that** lifting protrusions (15) of the further tension elements protrude beyond the clamping bridge (1).

7. The clamping system according to claims 5 or 6, **characterized in that** the clamping bridge (1) is made of epoxy resin, preferably of epoxy resin laminate, and the openings (13) are lined with reinforcing members (18), preferably realized as glass fibre tubes.

FIG 1

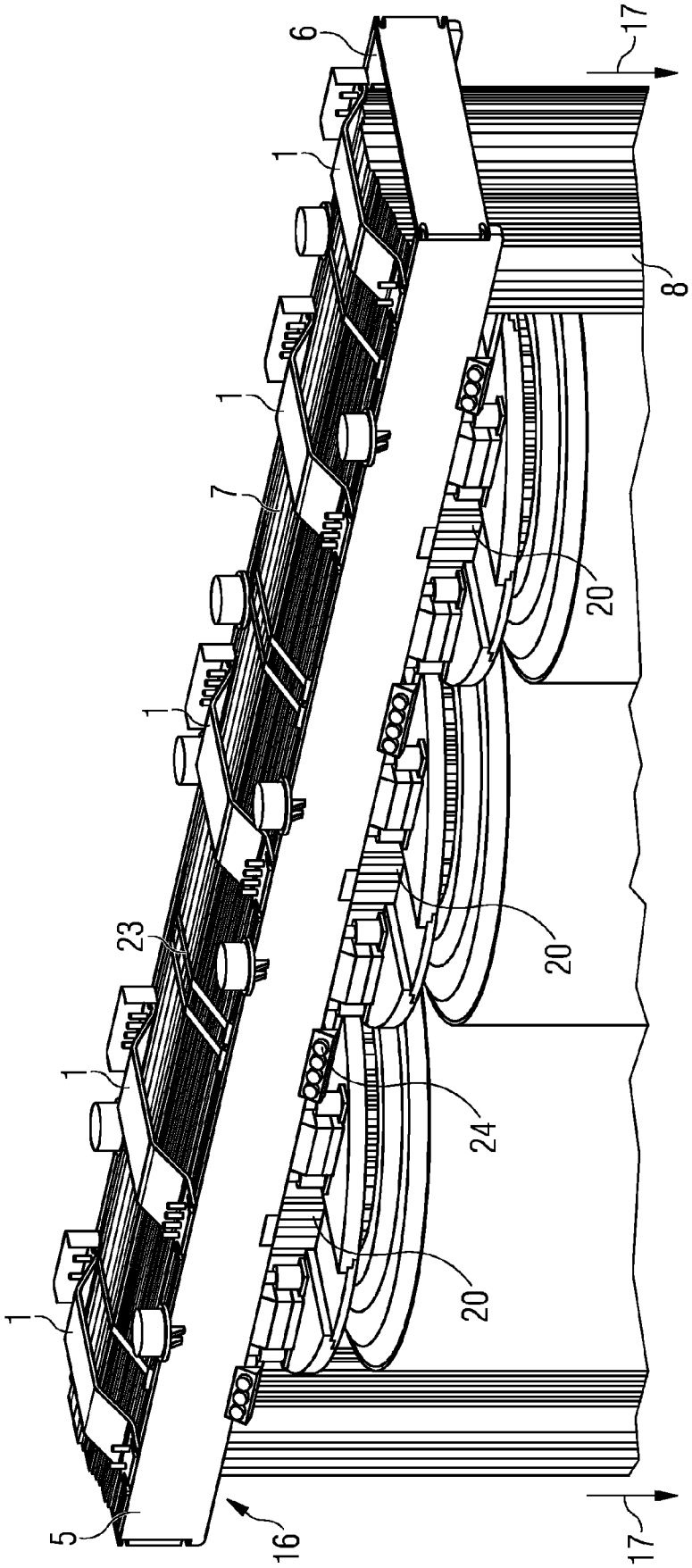


FIG 2

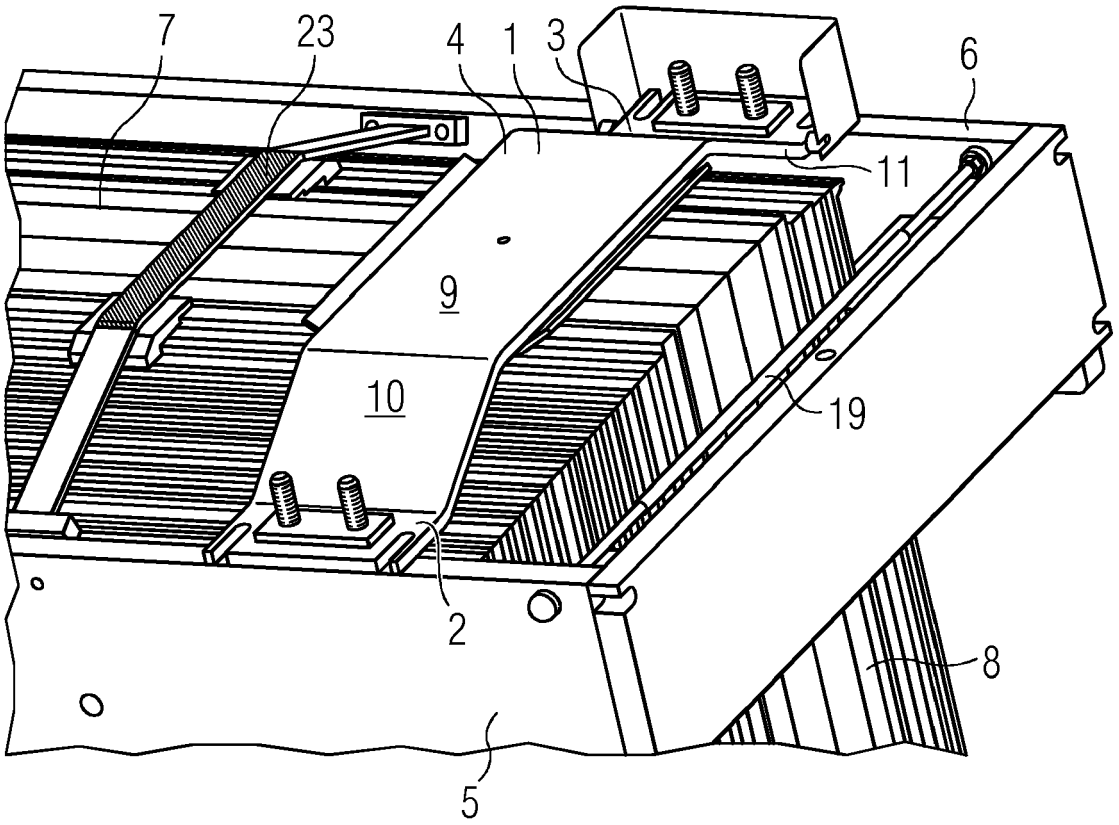


FIG 3

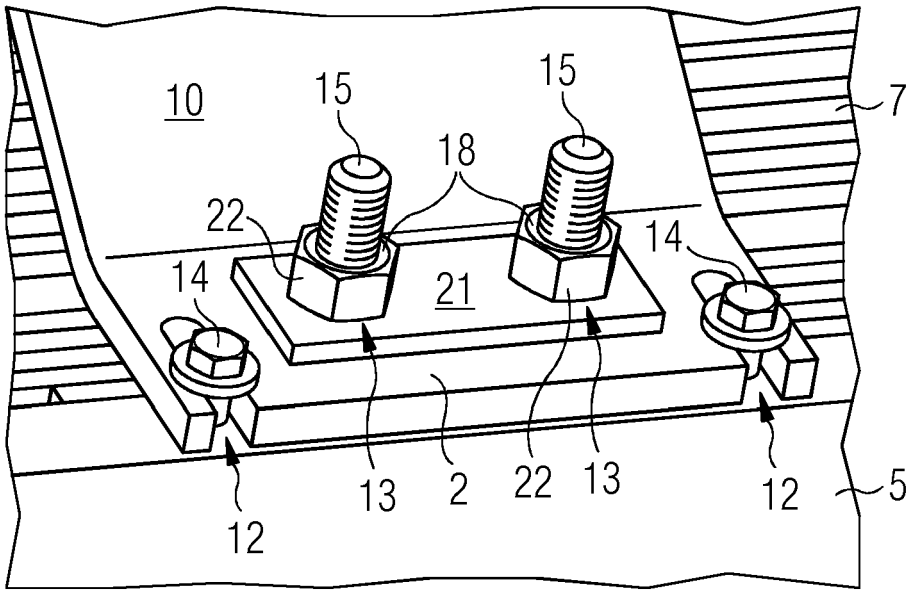
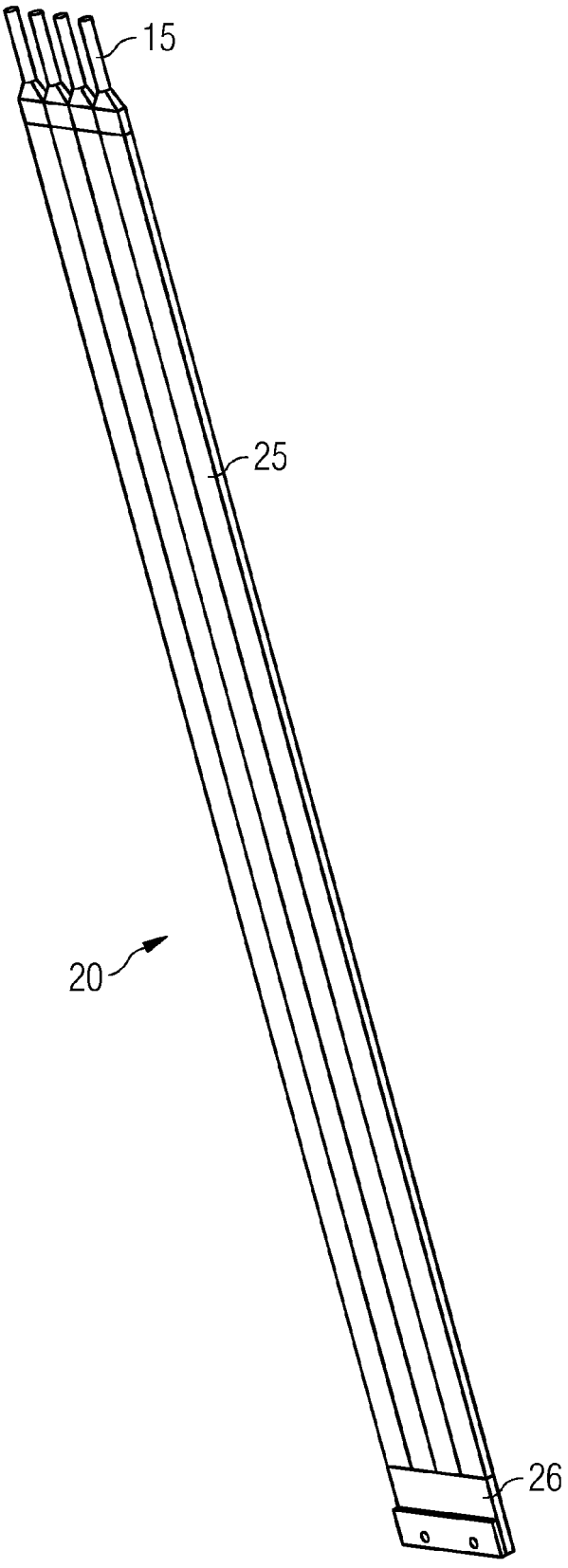


FIG 4



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EUROPEAN SEARCH REPORT

Application Number
EP 18 21 1824

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	13 June 2019	Gols, Jan

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