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(54) **COUPLING DEVICE AND METHOD FOR INDUCTIVELY COUPLING A LOAD TO A POWER LINE**

(57) The invention relates to a coupling device and a method for coupling a load to a power line and for inductively transferring electrical power between the power line and the load, wherein the coupling device comprises a first coupling member and a second coupling member which are arranged to be mated in a coupled position at opposite sides of a first mating plane, wherein the first coupling member and the second coupling member are arranged for holding a first transformer part and a second transformer part, respectively, which in the coupled position form a transformer core for receiving the power line, wherein the power line comprises a first insulated, electrically conductive wire and a second insulated, electrically conductive wire, wherein the coupling device is arranged for receiving a first length and a second length of each of the first wire and the second wire through the transformer core.

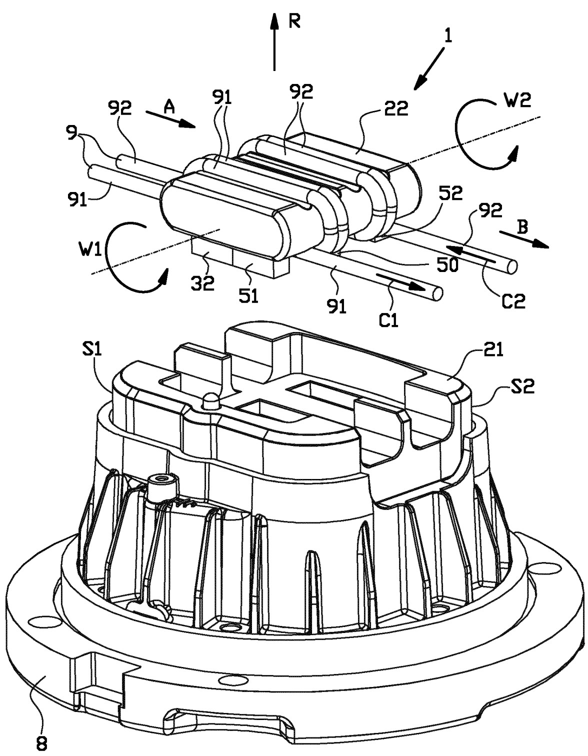

FIG. 3

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Description

BACKGROUND

[0001] The invention relates to a coupling device and a method for inductively coupling a load to a power line. The coupling device may for example be used for coupling lighting features to a main power line in various types of infrastructure, such as airfields, tunnels and/or offshore facilities.

[0002] NL 2015819 C discloses such a coupling device for inductively coupling a load to a power line. The coupling device comprises a first coupling member and a second coupling member which are arranged to be mated in a coupled position, wherein the coupling members comprise transformer parts that form a ferrite transformer core for surrounding the power line. The coupling device is arranged for receiving the power line in a longitudinal direction. The power line comprises two conductive wires and the ferrite transformer core comprises two channels that allows for passage of each of said two conductive wires through the ferrite transformer core in the direction of the power line. The known coupling device can be used to inductively clamp a power line with relative ease and transfer power to a secondary transformer circuit of a load in a one-to-one ratio.

[0003] The known coupling device is suitable to be used in systems with up to two kilowatts of power and in combination with power lines of up to two kilometers in length.

[0004] It is an object of the present invention to provide a coupling device and a method for inductively coupling a load to a power line, wherein the coupling device can be used in systems with more power or in combination with power lines of greater length.

SUMMARY OF THE INVENTION

[0005] According to a first aspect, the invention provides a coupling device for coupling a load to a power line and for inductively transferring electrical power between the power line and the load, wherein the coupling device comprises a first coupling member and a second coupling member which are arranged to be mated in a coupled position at opposite sides of a first mating plane, wherein the first coupling member and the second coupling member are arranged for holding a first transformer part and a second transformer part, respectively, which in the coupled position form a transformer core for receiving the power line, wherein the power line comprises a first insulated, electrically conductive wire and a second insulated, electrically conductive wire, wherein the coupling device is arranged for receiving a first length and a second length of each of the first wire and the second wire through the transformer core.

[0006] By receiving two lengths of each wire through the transformer core, the ratio between the primary side of the transformer core (at the power line) and the secondary side of the transformer core (at the load) can be adjusted. In particular, a ratio between the primary side and the secondary side of 2:1 can be achieved. Hence, more power can be supplied trough the power line to compensate for losses. Hence, the power line can be used for greater distances, i.e. distances exceeding two kilometers. Moreover, the power line can be used to power more demanding loads and/or the power line can be used in combination with a greater number of loads. Finally, the increased capacity of the transformer core can reduce the energy losses in the transformer.

[0007] In an embodiment thereof the transformer core comprises a first channel for receiving the first length and the second length of the first wire and a second channel for receiving the first length and the second length of the second wire. By receiving lengths of the same wire through the same channel multiple times, the aforementioned ratio can be improved.

[0008] In a further embodiment thereof the coupling device is arranged for receiving at least two or at least three windings of each of the first wire and the second wire through the first channel and the second channel, respectively. By winding the wires, it can be ensured that each length passes through the respective channel in the same direction. Hence, the current direction in the consecutive lengths of a respective wire can be in the same direction for each winding to ensure that the magnetic field generated by the current in each winding contributes to rather than counteracts the magnetic field of the previous winding.

[0009] In a preferred embodiment thereof the coupling device is arranged for receiving the windings of the first wire about a first winding axis and for receiving the windings of the second wire about a second winding axis that is coaxial to the first winding axis. Hence, the windings of both wires can be wound about the same winding axis.

[0010] In an alternative embodiment the coupling device is arranged for receiving the windings of the first wire about a first winding axis and for receiving the windings of the second wire about a second winding axis that is parallel to and spaced apart from the first winding axis. Hence, the windings can be arranged side by side about spaced apart winding axes.

[0011] In another embodiment the coupling device is arranged for leading-in the first wire and the second wire in a lead-in direction and for leading-out the first wire and the second wire in a lead-out direction in-line or substantially in-line with the lead-in direction. The coupling device can thus be coupled in-line to a continuous power line that extends from said coupling device towards a next coupling device to form an electrical infrastructure with a plurality of coupling devices.

[0012] Alternatively, the transformer core comprises a first channel and a second channel for receiving the first length of the first wire and the first length of the second wire, respectively, wherein the first channel is arranged for receiving, in addition to the first length of the first wire, a second length of the second wire, wherein the second channel is arranged for receiving, in addition to the first length of the second wire, a second length of the first wire. Typically, the current direction in the second wire is opposite to the current direction in the second wire. Hence, by switching or alternating the lengths of the respective wires between the first channel and the second channel, the current directions can be aligned within each channel. This can ensure that the magnetic fields generated by said currents contribute to rather than counteract each other.

[0013] In an embodiment thereof the coupling device is arranged for leading-in the first wire and the second wire in a lead-in direction and for leading-out the first wire and the second wire in a lead-out direction opposite to the lead-in direction. The aforementioned switching of the wires between the channels allows for the first wire to be led back into the transformer core in the lead-out direction opposite to the lead-in direction. Hence, the wires do not have to be wound and can immediately be led back into the transformer core. This can result in a more compact coupling device as no space is required to allow for the winding of the wires on the outside of the transformer core.

[0014] In an embodiment thereof the coupling device has a first side where the first wire and the second wire are led-in, wherein the coupling device is arranged for doubling the first wire and the second wire back through the transformer core at a second side of the coupling device opposite to the first side. The coupling device thus only requires minimal space on the second side for doubling back the wires.

[0015] In an embodiment thereof the coupling device comprises a third coupling member, wherein the second coupling member and the third coupling member are arranged to be mated in a coupled position at opposite sides of a second mating plane parallel to and spaced apart from the first mating plane, wherein the third coupling member is arranged for holding a third transformer part which in the coupled position forms an extension of the transformer core, wherein the coupling device is arranged for receiving a third length and a fourth length of each of the first wire and the second wire through the extension of the transformer core. By having the third coupling member, the transformer core can be extended to receive more lengths of the wires. Hence, the aforementioned ratio can be improved further to for example at least 3:1 or 4:1.

[0016] In an embodiment thereof the second transformer part is arranged in abutment with both the first transformer part and the third transformer part in the coupled position. Hence, the second transformer part can form a continuous transformer core together with the first transformer part and the second transformer part.

[0017] In a further embodiment thereof the extension of the transformer core comprises a third channel and a fourth channel for receiving the third length of the first wire and the third length of the second wire, respectively, wherein the third channel is arranged for receiving, in addition to the third length of the first wire, the fourth length of the second wire, wherein the fourth channel is arranged for receiving, in addition to the third length of the second wire, the fourth length of the first wire. Again, because of the opposite current directions in the wires, switching or alternating the lengths of the respective wires between the third channel and the fourth channel can align the current direction within each channel. This can ensure that the magnetic fields generated by said currents contribute to rather than counteract each other.

[0018] In an embodiment thereof the first channel and the third channel are stacked in a stacking direction perpendicular to the first mating plane and wherein the second channel and the fourth channel are stacked in the same stacking direction, wherein the second transformer part is discontinuous in the stacking direction between the first channel and the third channel and between the second channel and the fourth channel. In this manner, it can be prevented that the second transformer part interferes with the magnetic fields generated in the transformer core and its extension. Essentially, the first channel and the third channel can form a single channel and the second channel and the fourth channel can form a single channel.

[0019] In a further embodiment the coupling device is arranged for receiving the first wire and the second wire extending in the lead-out direction from the transformer core in the lead-in direction into the extension of the transformer core at the first side of the coupling device. Hence, the wires can be directly led back into the coupling device from the transformer core into the extension of said transformer core.

[0020] In a preferred embodiment thereof the coupling device is arranged for doubling the first wire and the second wire back through the extension of the transformer core at the second side of the coupling device. The coupling device thus only requires minimal space on the first side for doubling back the wires.

[0021] In another embodiment of the invention one of the first transformer part and the second transformer part is an "E"-type transformer part comprising three legs that extend perpendicular or substantially perpendicular to the first mating plane, wherein the other of the first transformer part and the second transformer part is arranged for abutting all legs of the "E"-type transformer part.

[0022] In an optional embodiment thereof the three legs comprise a fixed center leg and two removable outer legs which are removable from in between the first transformer part and the second transformer part in a direction parallel to the first mating plane and away from the center leg. By removing said outer legs, the windings can be arranged more easily on or around said removed outer legs.

[0023] In general, it is preferred that the transformer core comprises or consist of ferrite. Ferrite is optimally permeable to magnetic fields.

[0024] According to a second aspect, the invention provides an electrical infrastructure comprising a coupling device according to any one of the aforementioned embodiments and a power line, wherein the power line comprises a first insulated, electrically conductive wire and a second insulated, electrically conductive wire. The electrical infrastructure thus obtained includes the previously discussed coupling device and thus has the same technical advantages as said coupling device and its embodiments.

[0025] According to a third aspect, the invention provides an electrical infrastructure comprising a coupling device according to the aforementioned embodiment in which the wires are doubled-back and a power line, wherein the power line comprises a first insulated, electrically conductive wire and a second insulated, electrically conductive wire, wherein the first wire and the second wire are crossed at the second side to double back the first wire through the second channel and to double back the second wire through the first channel. The electrical infrastructure thus obtained includes the previously discussed coupling device and thus has the same technical advantages as said coupling device and its embodiments.

[0026] According to a fourth aspect, the invention provides a method for coupling a load to a power line and for inductively transferring electrical power between the power line and the load using a coupling device according to any one of the aforementioned embodiments, wherein the method comprises the steps of:

- providing the first coupling member and the second coupling member in a decoupled position;
- positioning the first length of the first wire and the first length of the second wire in relation to one of the first transformer part and the second transformer part;
- positioning the second length of the first wire and the second length of the second wire in relation to one of the first transformer part and the second transformer part; and
- coupling the first coupling member and the second coupling member in the coupled position to form the transformer core around the power line, wherein the previously positioned first length and second length of each of the first wire and the second wire extend through the transformer core.

[0027] The method relates to the steps of obtaining the previously discussed coupling device in a coupled position around the power line and thus has the same technical advantages as said coupling device and its embodiments.

[0028] In a preferred embodiment of the method the transformer core comprises a first channel and a second channel, wherein the method comprises the steps of:

- positioning the first length and the second length of the first wire in the first channel; and
- positioning the first length and the second length of the second wire in the second channel.

[0029] In a further embodiment thereof the method comprises the step of winding the first wire and the second wire through the first channel and the second channel, respectively, over at least two or at least three windings.

[0030] In another embodiment the method comprises the steps of:

- leading-in the first wire and the second wire in an lead-in direction; and
- leading-out the first wire and the second wire in a lead-out direction in-line or substantially in-line with the lead-in direction.

[0031] Alternatively, the transformer core comprises a first channel and a second channel, wherein the method comprises the steps of:

- positioning the first length of the first wire in the first channel;
- positioning the first length of the second wire in the second channel;
- positioning the second length of the first wire in the second channel; and
- positioning the second length of the second wire in the first channel.

[0032] In an embodiment thereof the method comprises the steps of:

- leading-in the first wire and the second wire in an lead-in direction; and
- leading-out the first wire and the second wire in a lead-out direction opposite to the lead-in direction.

[0033] In a further embodiment thereof the coupling device has a first side where the first wire and the second wire are led-in, wherein the method comprises the step of doubling the first wire and the second wire back through the transformer core at a second side of the coupling device opposite to the first side.

[0034] In a further embodiment thereof the coupling device comprises a third coupling member, wherein the second coupling member and the third coupling member are arranged to be mated in a coupled position at opposite sides of a second mating plane parallel to and spaced apart from the first mating plane, wherein the third coupling member is arranged for holding a third transformer part which in the coupled position forms an extension of the transformer core, wherein the method further comprises the steps of:

- providing the second coupling member and the third coupling member in a decoupled position;
- positioning the third length of the first wire and the third length of the second wire in relation to one of

the second transformer part and the third transformer part;
- positioning the fourth length of the first wire and the fourth length of the second wire in relation to one of the second transformer part and the third transformer part; and
- coupling the second coupling member and the third coupling member in the coupled position to form the extension of the transformer core around the power line, wherein the previously positioned third length and fourth length of each of the first wire and the second wire extend through the extension of the transformer core.

[0035] In a further embodiment thereof the extension of the transformer core comprises a third channel and a fourth channel, wherein the method comprises the steps of:

- positioning the third length of the first wire in the third channel;
- positioning the third length of the second wire in the fourth channel;
- positioning the fourth length of the first wire in the fourth channel; and
- positioning the fourth length of the second wire in the third channel.

[0036] In a further embodiment thereof the method further comprises the steps of:

- positioning the first wire and the second wire such that they extend in the lead-out direction from the transformer core; and
- directing the first wire and the second wire extending in the lead-out direction from the transformer core in the lead-in direction into the extension of the transformer core at the first side of the coupling device.

[0037] In another embodiment thereof the method further comprises the steps of doubling the first wire and the second wire back through the extension of the transformer core at the second side of the coupling device.

[0038] Preferably, the method further comprises the step of forming an electrical infrastructure using one or more of the coupling device coupled to the power line.

[0039] In an embodiment thereof the method further comprises the step of crossing the first wire and the second wire at the second side to double back the first wire through the second channel and to double back the second wire through the first channel.

[0040] The various aspects and features described and shown in the specification can be applied, individually, wherever possible. These individual aspects, in particular the aspects and features described in the attached dependent claims, can be made subject of divisional patent applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] The invention will be elucidated on the basis of an exemplary embodiment shown in the attached schematic drawings, in which:

figure 1 shows an isometric view from above of an electrical infrastructure comprising a load, a power line and a coupling device for coupling the load to the power line according to a first embodiment of the invention;
figures 2 and 3 show isometric views from below of the electrical infrastructure according to figure 1 with the coupling device in a coupled position and a decoupled position, respectively;
figure 4 shows a cross section of the coupling device according to line IV-IV in figure 2;
figure 5 shows an isometric view from below of an alternative electrical infrastructure comprising a load, a power line and an alternative coupling device for coupling the load to the power line according to a second embodiment of the invention;
figure 6 shows a cross section of the alternative coupling device according to line VI-VI in figure 5;
figure 7A and 7B shows an alternative transformer core for use in the alternative coupling device according to figures 5 and 6;
figure 8 shows an isometric view from below of a further alternative electrical infrastructure comprising a load, a power line and a further alternative coupling device for coupling the load to the power line according to a third embodiment of the invention;
figures 9 and 10 shows isometric views from below of the further alternative coupling device according to figure 8 in a coupled position and a decoupled position, respectively;
figure 11 shows a cross section of the further alternative coupling device according to line XI-XI in figure 9;
figure 12 shows an isometric view from above of a further alternative electrical infrastructure comprising a load, a power line and a further alternative coupling device for coupling the load to the power line according to a fourth embodiment of the invention;
figures 13 and 14 show isometric views from below of the further alternative coupling device according to figure 12 in a coupled position and a decoupled position, respectively; and
figure 15 shows a cross section of the further alternative coupling device according to line XV-XV in figure 13.

DETAILED DESCRIPTION OF THE INVENTION

[0042] Figures 1-4 show an electrical infrastructure comprising a load 8, a power line 9 and a coupling device 1 for coupling the load 8 to the power line 9 according to a first embodiment of the invention.

[0043] The load 8 may for instance be a lighting feature for use in electrical infrastructure of an airfield. The power line 9 can be considered as a main power line from which various loads 8, such as the previously mentioned lighting features, draw power. Said power line 9 extends over a long distance from a base station along various loads 8. The power line 9 in this exemplary embodiment comprises a first insulated, electrically conductive wire 91 and a second insulated, electrically conductive wire 92.

[0044] As best seen in figure 3, the coupling device 1 comprises a first coupling member 21 and a second coupling member 22 which are arranged to be mated in a coupled position, as shown in figure 4, at opposite sides of a first mating plane M1. The first coupling member 21 is coupled to or integrated in the load 8. The first coupling member 21 and the second coupling member 22 may be coupled to each other mechanically by means of one or more suitable fasteners or otherwise, e.g. with means for magnetically attracting both coupling members 21, 22 to each other. The first coupling member 21 and the second coupling member 22 are arranged for holding a first transformer part 31 and a second transformer part 32, respectively, which in the coupled position of figure 4 form a transformer core 3 for receiving the power line 9. In the coupled position, the power line 9 extend into the coupling device 1 at a first side S1 of the coupling device 1 and out of the coupling device 1 at a second side S2 opposite to the first side S1. More in particular, the power line 9 is led into the coupling device 1 in a lead-in direction A parallel or substantially parallel to the first mating plane M1 and led out of the coupling device in a lead-out direction B parallel or substantially parallel to the first mating plane M1. In this exemplary embodiment, the lead-out direction B is arranged parallel to or in-line with the lead-in direction A. In other words, the power line 9 is arranged to enter and exit the coupling device 1 in the same direction.

[0045] By forming the transformer core 3 around the wires 91, 92 of the power line 9, electricity and optionally data can be transferred inductively through the magnetic field generated by the current supplied through said wires 91, 92. As shown in figure 4, the first transformer part 31 is more plate-like and in cross section resembles the letter "I". The second transformer part 32 in cross section resembles the letter "E" or the letter "M" comprising one center leg 50 and two outer legs 51, 52 on opposite sides of the center leg 50. Hence, the first transformer part 31 is an "I"-type transformer part and the second transformer part 32 is an "E"-type transformer part. The center leg 50 and one of the outer legs 51 form a first channel 61 for receiving the first wire 91 of the power line 9. The center leg 50 and the other of the outer legs 52 form a second channel 62 for receiving the second wire 92 of the power line 9. The legs 50, 51, 52 extend perpendicular or substantially perpendicular to the first mating plane M1. The channels 61, 62 extend parallel or substantially parallel to the lead-in direction A and the lead-out direction B. The first transformer part 31 is arranged for connecting, bridging, spanning and/or abutting all legs 50, 51, 52, thereby closing off the channels 61, 62 at the open side of the second transformer part 32.

[0046] The transformer core 3 in essence forms the primary side of a transformer, while the transformer core 3 may be associated with wiring in the load 8 to form a secondary side of the transformer (not shown). Electrical power may be transferred inductively from the power line 9 to the load 8 through the magnetic fields generated in the transformer core 3.

[0047] Preferably, the transformer parts 31, 32 comprise or consist of ferrite in order to be optimally permeable to magnetic fields.

[0048] So far, the coupling device 1 substantially corresponds to the known coupling device as disclosed in NL 2015819 C. The coupling device 1 according to the present invention however differs from the known coupling device in that it is arranged for receiving a first length and a second length of each of the first wire 91 and the second wire 92 through the transformer core 3. In other words, the coupling device 1 is arranged for receiving a first length of the first wire 91 in a first pass through the transformer core 3, and then a second length of the same first wire 91 in a second pass through the transformer core 3. The first length and the second length of a respective one of the wires 91, 92 are separate lengths, meaning that there is another length of the same wire that extends outside of the transformer core and that connects the first length to the second length. Hence, the first wire 91 extends through the transformer core 3 at least twice, once with the first length and once with the second length. The same applies to the second wire 92 which extends through the transformer core 3 at least twice, once with a first length and once with a second length. By receiving two length of the same wire 91, 92 through the same transformer core 3, the ratio between the primary side and the secondary side of the transformer can be altered to suit different needs.

[0049] For example, if the ratio between the primary side (coupling device 1) and the secondary side (load 8) of the transformer can be adjusted to 2:1, in comparison to 1:1 in the prior art, more power can be fed through the power line 8 thereby increasing the range of said power line 8 for which the losses are still within acceptable limits.

[0050] Figures 2 and 3 best show how the first length and the second length of each wire 91, 92 are received through the transformer core 3.

[0051] As shown in figure 3, the second coupling member 21 is removable or releasable from the first coupling member 22 in a release direction R transverse or perpendicular to the first mating plane M1. As a result, the first transformer part 31 and the second transformer part 32 are spaced apart and the transformer core 3 is disassembled. In particular, the channels 61, 62 in the second transformer part 32 are exposed and/or open so that the lengths of the wires 91, 92 may be laid in said channels 61, 62. Hence, the windings of the wires 91, 92 are prepared on the second transformer part 32 away from the rest of the coupling device 1. This can be particularly useful for those coupling the coupling device to the power line 9, especially when considering that the wires 91, 92 of the power line 9 only have limited flexibility and overlength to allow for said windings. The separately held second coupling member 22 and its second transformer part 32 can be easily positioned and manipulated with respect to the power line 9.

[0052] In this exemplary embodiment, the first wire 91 and the second wire 92 are each wound over a plurality of windings through the first channel 61 and the second channel 62, respectively. The wires 91, 92 are wound about a first winding axis W1 and a second winding axis W2 that is coaxial to the first winding axis W1. In particular, said winding axes W1, W2 extend parallel to the first mating plane M1 and transverse or perpendicular to the lead-in direction A. Hence, the first length of the first wire 91 and the second wire 92 can be led-in in the lead-in direction A directly into the first channel 61 and the second channel 62, respectively. With each subsequent winding, a next length of the respective wire 91, 92 is laid into the respective channel 61, 62. Between each pass through the channels 61, 62, the wires 91, 92 are wound around the outside of the second transformer part 32 with respect to the first transformer part 31, more specifically around the outside of the second coupling member 22 with respect to the first coupling member 21. The windings of the wires 91, 92 at the outside of the second coupling member 22 may be at least partly exposed to the outside, i.e. unshielded by the coupling device 1.

[0053] Inherent to this way of winding is that the first wire 91 and the second wire 92 are led-through their respective channels 61, 62 in the same direction, preferably in the lead-in direction A, with each winding. Hence, the current direction C1 in the first wire 91 is the same in each length of the first wire 91 that passes through the first channel 61. Similarly, the current direction C2 in the second wire 92 is the same in each length of the second wire 92 that passes through the second channel 62. In this manner, it can be ensured that the magnetic fields generated by the current in each length contribute and/or amplify rather than counteract each other.

[0054] Preferably, the current direction C1 in the first wire 91 is opposite to the current direction C2 in the second wire 92 to generate oppositely directed and mutually reinforcing magnetic fields in the transformer core 3.

[0055] Figures 5 and 6 show an alternative electrical infrastructure comprising an alternative coupling device 101 according to a second embodiment of the invention for coupling the previously introduced load 8 to the previously introduced power line 9. The alternative coupling device 101 differs from the previously discussed coupling device 1 in that the winding axes W1, W2 extend parallel to and spaced apart from each other. In particular, said winding axes extend perpendicular or substantially perpendicular to the first mating plane M1.

[0056] As shown in figure 5, the alternative coupling device 101 comprises a first coupling member 121 that now acts more like a housing for the windings and a second coupling member 122 that forms a cover for closing said housing in a direction opposite to the release direction R. In particular, the first coupling member 121 comprises a circumferential wall 125 extending upright from the first mating plane M1 and that ends with an open end facing towards the second coupling member 122 that fits like a cover onto the open end of the circumferential wall 125. The first coupling member 121 is provided with a lead-in opening 126 and a lead-out opening 127 in the circumferential wall 125 at opposite sides S1, S2 of the first coupling member 121 for leading the wires 91, 92 of the power line 9 into and out of the alternative coupling device 101. As in the previously discussed coupling device 1, the alternative coupling device 101 is arranged for receiving the power line 9 in a lead-in direction A and a lead-out direction B that is in-line with the lead-in direction A.

[0057] The first coupling member 121 holds a first transformer part 131 that is sufficiently spaced apart from said circumferential wall 125 to accommodate the windings of the wires 91, 92 therein between. The second coupling member 122 holds a second transformer part 132 that is arranged to be placed in abutting contact onto the first transformer part 131 when the coupling members 121, 122 are in the coupled position, as shown in figure 6. Hence, the windings are fully contained, confined and/or enclosed within the alternative coupling device 101.

[0058] As best seen in figure 6, the alternative coupling device 101 further optionally differs from the previously discussed coupling device 1 in that its transformer parts 131, 132 are differently shaped. In this exemplary embodiment, the first transformer part 131 is more or less formed in cross section in the shape of the letter "E" or "M", comprising three legs 150-152. The second transformer part 132 has a substantially plate-like shape with only a center leg 155 that is complementary to the center leg 150 of the first transformer part 131 to form a continuous center leg 150, 155 when the first coupling member 121 and the second coupling member 122 are in the coupled position of figure 6. It will be apparent to one skilled in the art that the lengths of the different legs 150-152, 155 may be adjusted appropriately and outer legs may be added to the second transformer part 132 to suit different dimensions of the alternative coupling device 101.

[0059] As shown in figure 5, the outer legs 151, 152 of the first transformer part 131 are exposed when the second coupling member 122 is removed in the release direction R. In particular, said exposed outer legs 151, 152 may protrude upwards so that those coupling the alternative coupling device 101 to the power line 9 may easily prepare the windings of the wires 91, 92 on or around the exposed outer legs 151, 152 of the first transformer part 131. When the windings have been prepared, the second coupling member 132 is reattached to complete the transformer core 103.

[0060] Figures 7A and 7B show an alternative transformer core 403 for use in the alternative coupling device 101 according to the second embodiment of the invention. The alternative transformer core 403 differs from the previously discussed transformer core 103 in that the first transformer part 431 comprises a fixed center leg 450 and two outer legs 451, 452 that are removable from in between the first transformer part 431 and the second transformer part 432 in a lateral direction L transverse or perpendicular to the lead-in direction A and parallel or substantially parallel to the first mating plane M1. Hence, the outer legs 451, 452 can be moved away from the center leg 450. With the outer legs 451, 452 spaced apart or taken out of the alternative transformer core 403, it can be easily positioned and/or manipulated with respect to the wires 91, 92 for winding said wires 91, 92 around the respective outer legs 451, 452. Once, the winding is completed, the outer legs 451, 452 carrying said windings can be reinserted in between the first transformer part 431 and the second transformer part 432.

[0061] Figures 8-11 show a further alternative electrical infrastructure comprising a further alternative coupling device 201 according to a third embodiment of the invention for coupling the previously introduced load 8 to the previously introduced power line 9. The further alternative coupling device 201 differs from the previously discussed coupling devices 1, 101 in that the power line 9 is led-in in a lead-in direction A and led-out in a lead-out direction B opposite to the lead-in direction A. To achieve this, the first wire 91 and the second wire 92 are doubled-back through the further alternative coupling device 201.

[0062] In particular, as best seen in figure 10, the further alternative coupling device 201 comprises a first coupling member 221 and a second coupling member 222 for holding a first transformer part 231 and a second transformer part 232 that in the coupled position of the coupling members 221, 222, as shown in figure 9 and 11, form a transformer core 203. Each transformer part 231, 232 is formed in cross section in the shape of the letter "E" or "M". As best seen in figure 11, the first transformer part 231 comprises a first center leg 250 and two outer legs 251, 252. Similarly, the second transformer part 232 comprises a second center leg 255 and two outer legs 253, 254. In the coupled position, the first center leg 250 and the second center leg 255 are arranged to be in abutment to form a continuous center leg 250, 255. Similarly, the outer legs 251-254 are arranged to be in abutment to form two continuous outer legs 251, 253; 252, 254. Together, the transformer parts 231, 232 define a first channel 261 and a second channel 262 in the transformer core 203 for receiving the wires 91, 92.

[0063] As shown in figure 10, a first length of the first wire 91 and a first length of the second wire 92 are initially led-in from the first side S1 of the further alternative coupling device 201 through the first channel 261 and the second channel 262, respectively. The wires 91, 92 are then doubled back and simultaneously crossed or twisted at a first crossing T1 at the second side S2 of the further alternative coupling device 201 so that a second length of the first wire 91 is doubled-back through the second channel 62 and a second length of the second wire 92 is doubled-back through the first channel 61. Note that in this manner, when the current directions C1, C2 are opposite in the first lengths of the first wire 91 and the second wire 92, the current directions C1, C2 in the second lengths of the first wire 91 and the second wire 92, once doubled-back, correspond to the current direction C1, C2 in the first lengths of the second wire 92 in the same channels 261, 262. Hence, the magnetic fields generated in the transformer core 203 by the currents in the wires 91, 92 contribute to rather than counteract each other.

[0064] Figures 12-15 show a further alternative electrical infrastructure comprising a further alternative coupling device 301 according to a fourth embodiment of the invention for coupling the previously introduced load 8 to the previously introduced power line 9. The further alternative coupling device 301 differs from the previously discussed further alternative coupling device 201 in that it comprises a third coupling member 323 in addition to a first coupling member 321 and a second coupling member 322. Said third coupling member 323 is stacked on the second coupling member 322 in a stacking direction V opposite to the release direction R. The second coupling member 322 and the third coupling member 323 are arranged to be mated in a coupled position at opposite sides of a second mating plane M2 parallel to and spaced apart from the first mating plane M1.

[0065] As best seen in figure 15, the first coupling member 321 and the second coupling member 322 hold a first transformer part 331 and a second transformer part 332 which, in the coupled position, form a transformer core 303. The third coupling member 323 holds a third transformer part 333 which in the coupled position of the coupling members 321-323 forms an extension 304 of the transformer core 303. The further alternative coupling device 301 is arranged for receiving a third length and a fourth length of each of the first wire 91 and the second wire 92 through the extension 304 of the transformer core 303. The second transformer part 332 is arranged in abutment with both the first transformer part 331 and the third transformer part 333 in the coupled position of figure 15. More in particular, both the first transformer part 331 and the third transformer part 333 are formed in cross section to resemble the letter "E" or "M", each with a center leg 350, 355 and two outer legs 351, 352, 353, 354 facing towards each other in the stacking direction V. The second transformer part 332 is formed by three intermediate legs 356-358 that connect the center leg 350 and the outer legs 351, 352 of the first transformer part 331 to the corresponding center leg 355 and outer legs 353, 354 of the third transformer part 333. In other words, the legs 350-358 of the three transformer parts 331, 332, 333 are continuous.

[0066] As best seen in figure 15, the transformer core 303 forms a first channel 361 and a second channel 362 and the extension of the transformer core 304 forms a third channel 363 and a fourth channel 364. In this particular example, the first channel 361 and the third channel 363 are stacked in the stacking direction V and the second channel 362 and the fourth channel 364 are stacked in the same stacking direction V. The second transformer part 332 is discontinuous in the stacking direction V between the first channel 361 and the third channel 363 and between the second channel 362 and the fourth channel 364 so as not to interrupt the flow of the magnetic fields. Hence, the first channel 361 in the transformer core 303 and the third channel 363 in the extension of the transformer core 303 essentially form a single channel. Similarly, the second channel 362 in the transformer core 303 and the fourth channel 364 in the extension of the transformer core 303 essentially form a single channel.

[0067] The third channel 363 is arranged for receiving a third length of the first wire 91 and a fourth length of the second wire 92. The fourth channel 364 is arranged for receiving a third length of the second wire 92 and a fourth length of the first wire 91.

[0068] As shown in figure 12, the first wire 91 and the second wire 92 are arranged to be doubled-back and twisted or crossed in a first twist T1 at the second side S2 of the further alternative coupling device 301 in substantially the same manner as in the previously described embodiment of the invention. However, instead of leading out the wires 91, 92 from the further alternative coupling device 301 at the first side S1 in a lead-out direction B opposite to the lead-in direction A, the further alternative coupling device 301 is arranged for receiving the first wire 91 and the second wire 92 extending in the lead-out direction B from the transformer core 303 in the lead-in direction A into the extension 304 of the transformer core 303 at the first side S1. As shown in figure 13, the wires 91, 92 are thus again doubled back into the further alternative coupling device 301 via a second twist T2 at the first side S1. Then, the wires 91, 92 are doubled-back yet again while crossing or twisting them in a third twist T3 at the second side S2 of the further alternative coupling device 301 back into the extension 304 of the transformer core 303. The wires 91, 92 ultimately exit the extension 304 of the transformer core 303 in the lead-out direction B.

[0069] By twisting or crossing the wires 91, 92 in each twist T1, T2, T3, it can be ensured that the current running in opposite current directions C1, C2 through the respective wires 91, 92 are always oriented in the same direction through each of the channels 361-364. Hence, the magnetic fields generated by said currents contribute to rather than counteract each other. In the present embodiment, the combination of the first channel 361 and the third channel 363 and the combination of the second channel 362 and the fourth channel 364 each hold two lengths of the first wire 91 and two lengths of the second wire 92 with aligned current directions C1, C2.

[0070] Figure 14 illustrates the order in which the wires 91, 92 are laid into the respective channels 361-364 and how the respective coupling members 321-323 are coupled to each other to arrive at the coupled position of figures 12, 13 and 15. In particular, figure 14 shows how the coupling members 321-323 may be placed in a decoupled position to prepare the wires 91, 92 in their respective channels and to prepare twists T1, T2, T3 in the wires 91, 92 between the coupling members 321-323. Subsequently, the second coupling member 322 may be flipped over and placed on top of the first coupling member 321 in the stacking direction V. Subsequently, the lengths of the wires 91, 92 between the second twist T2 and the third twist T3 may be laid into the channels which in figure 14 are at the bottom of the second coupling member 322. Finally, the third coupling member 323 may be flipped on top of the second coupling member 322 to complete the coupling.

[0071] In the coupled position thus obtained, as shown in figure 15, the first length of the first wire 91 is positioned in the first channel 361, the first length of the second wire 92 is positioned in the second channel 362, the second length of the first wire 91 is positioned in the second channel 362 and the second length of the second wire 92 is positioned in the first channel 361. Additionally, the third length of the first wire 91 is positioned in the third channel 363, the third length of the second wire 92 is positioned in the fourth channel 364, the fourth length of the first wire 91 is positioned in the fourth channel 364 and the fourth length of the second wire 92 is positioned in the third channel 363.

[0072] It is to be understood that the above description is included to illustrate the operation of the preferred embodiments and is not meant to limit the scope of the invention. From the above discussion, many variations will be apparent to one skilled in the art that would yet be encompassed by the scope of the present invention.

Claims

1. Coupling device for coupling a load to a power line and for inductively transferring electrical power between the power line and the load, wherein the coupling device comprises a first coupling member and a second coupling member which are arranged to be mated in a coupled position at opposite sides of a first mating plane, wherein the first coupling member and the second coupling member are arranged for holding a first transformer part and a second transformer part, respectively, which in the coupled position form a transformer core for receiving the power line, wherein the power line comprises a first insulated, electrically conductive wire and a second insulated, electrically conductive wire, wherein the coupling device is arranged for receiving a first length and a second length of each of the first wire and the second wire through the transformer core.

2. Coupling device according to claim 1, wherein the transformer core comprises a first channel for receiving the first length and the second length of the first wire and a second channel for receiving the first length and the second length of the second wire, preferably wherein the coupling device is arranged for receiving at least two or at least three windings of each of the first wire and the second wire through the first channel and the second channel, respectively.

3. Coupling device according to claim 2, wherein the coupling device is arranged for receiving the windings of the first wire about a first winding axis and for receiving the windings of the second wire about a second winding axis that is coaxial or parallel to the first winding axis.

4. Coupling device according to any one of the preceding claims, wherein the coupling device is arranged for leading-in the first wire and the second wire in a lead-in direction and for leading-out the first wire and the second wire in a lead-out direction in-line or substantially in-line with the lead-in direction.

5. Coupling device according to claim 1, wherein the transformer core comprises a first channel and a second channel for receiving the first length of the first wire and the first length of the second wire, respectively, wherein the first channel is arranged for receiving, in addition to the first length of the first wire, a second length of the second wire, wherein the second channel is arranged for receiving, in addition to the first length of the second wire, a second length of the first wire,
preferably wherein the coupling device is arranged for leading-in the first wire and the second wire in a lead-in direction and for leading-out the first wire and the second wire in a lead-out direction opposite to the lead-in direction,
preferably wherein the coupling device has a first side where the first wire and the second wire are led-in, wherein the coupling device is arranged for doubling the first wire and the second wire back through the transformer core at a second side of the coupling device opposite to the first side,
preferably wherein the coupling device comprises a third coupling member, wherein the second coupling member and the third coupling member are arranged to be mated in a coupled position at opposite sides of a second mating plane parallel to and spaced apart from the first mating plane, wherein the third coupling member is arranged for holding a third transformer part which in the coupled position forms an extension of the transformer core, wherein the coupling device is arranged for receiving a third length and a fourth length of each of the first wire and the second wire through the extension of the transformer core,
preferably wherein the second transformer part is arranged in abutment with both the first transformer part and the third transformer part in the coupled position,
preferably wherein the extension of the transformer core comprises a third channel and a fourth channel for receiving the third length of the first wire and the third length of the second wire, respectively, wherein the third channel is arranged for receiving, in addition to the third length of the first wire, the fourth length of the second wire, wherein the fourth channel is arranged for receiving, in addition to the third length of the second wire, the fourth length of the first wire,
preferably wherein the first channel and the third channel are stacked in a stacking direction perpendicular to the first mating plane and wherein the second channel and the fourth channel are stacked in the same stacking direction, wherein the second transformer part is discontinuous in the stacking direction between the first channel and the third channel and between the second channel and the fourth channel.

6. Coupling device according to claim 1, wherein the transformer core comprises a first channel and a second channel for receiving the first length of the first wire and the first length of the second wire, respectively, wherein the first channel is arranged for receiving, in addition to the first length of the first wire, a second length of the second wire, wherein the second channel is arranged for receiving, in addition to the first length of the second wire, a second length of the first wire, wherein the coupling device is arranged for leading-in the first wire and the second wire in a lead-in direction and for leading-out the first wire and the second wire in a lead-out direction opposite to the lead-in direction, wherein the coupling device has a first side where the first wire and the second wire are led-in, wherein the coupling device is arranged for doubling the first wire and the second wire back through the transformer core at a second side of the coupling device opposite to the first side, wherein the coupling device comprises a third coupling member, wherein the second coupling member and the third coupling member are arranged to be mated in a coupled position at opposite sides of a second mating plane parallel to and spaced apart from the first mating plane, wherein the third coupling member is arranged for holding a third transformer part which in the coupled position forms an extension of the transformer core, wherein the coupling device is arranged for receiving a third length and a fourth length of each of the first wire and the second wire through the extension of the transformer core, wherein the coupling device is arranged for receiving the first wire and the second wire extending in the lead-out direction from the transformer core in the lead-in direction into the extension of the transformer

core at the first side of the coupling device, preferably wherein the coupling device is arranged for doubling the first wire and the second wire back through the extension of the transformer core at the second side of the coupling device.

7. Coupling device according to any one of the preceding claims, wherein one of the first transformer part and the second transformer part is an "E"-type transformer part comprising three legs that extend perpendicular or substantially perpendicular to the first mating plane, wherein the other of the first transformer part and the second transformer part is arranged for abutting all legs of the "E"-type transformer part, preferably wherein the three legs comprise a fixed center leg and two removable outer legs which are removable from in between the first transformer part and the second transformer part in a direction parallel to the first mating plane and away from the center leg.

8. Coupling device according to any one of the preceding claims, wherein the transformer core comprises or consist of ferrite.

9. Electrical infrastructure comprising a coupling device according to any one of the preceding claims and a power line, wherein the power line comprises a first insulated, electrically conductive wire and a second insulated, electrically conductive wire.

10. Electrical infrastructure comprising a coupling device according to claim 1 and a power line, wherein the transformer core comprises a first channel and a second channel for receiving the first length of the first wire and the first length of the second wire, respectively, wherein the first channel is arranged for receiving, in addition to the first length of the first wire, a second length of the second wire, wherein the second channel is arranged for receiving, in addition to the first length of the second wire, a second length of the first wire, wherein the coupling device is arranged for leading-in the first wire and the second wire in a lead-in direction and for leading-out the first wire and the second wire in a lead-out direction opposite to the lead-in direction, wherein the coupling device has a first side where the first wire and the second wire are led-in, wherein the coupling device is arranged for doubling the first wire and the second wire back through the transformer core at a second side of the coupling device opposite to the first side, wherein the power line comprises a first insulated, electrically conductive wire and a second insulated, electrically conductive wire, wherein the first wire and the second wire are crossed at the second side to double back the first wire through the second channel and to double back the second wire through the first channel.

11. Method for coupling a load to a power line and for inductively transferring electrical power between the power line and the load using a coupling device according to any one of claims 1-8, wherein the method comprises the steps of:

- providing the first coupling member and the second coupling member in a decoupled position;
- positioning the first length of the first wire and the first length of the second wire in relation to one of the first transformer part and the second transformer part;
- positioning the second length of the first wire and the second length of the second wire in relation to one of the first transformer part and the second transformer part; and
- coupling the first coupling member and the second coupling member in the coupled position to form the transformer core around the power line, wherein the previously positioned first length and second length of each of the first wire and the second wire extend through the transformer core.

12. Method according to claim 11, wherein the transformer core comprises a first channel and a second channel, wherein the method comprises the steps of:

- positioning the first length and the second length of the first wire in the first channel; and
- positioning the first length and the second length of the second wire in the second channel,

preferably wherein the method comprises the step of winding the first wire and the second wire through the first channel and the second channel, respectively, over at least two or at least three windings.

13. Method according to claim 11 or 12, wherein the method comprises the steps of:

- leading-in the first wire and the second wire in an lead-in direction; and
- leading-out the first wire and the second wire in a lead-out direction in-line or substantially in-line with the lead-in direction.

14. Method according to claim 11, wherein the transformer core comprises a first channel and a second channel, wherein the method comprises the steps of:

- positioning the first length of the first wire in the first channel;
- positioning the first length of the second wire in the second channel;
- positioning the second length of the first wire in the second channel; and

- positioning the second length of the second wire in the first channel,

preferably wherein the method comprises the steps of:

- leading-in the first wire and the second wire in an lead-in direction; and
- leading-out the first wire and the second wire in a lead-out direction opposite to the lead-in direction,

preferably wherein the coupling device has a first side where the first wire and the second wire are led-in, wherein the method comprises the step of doubling the first wire and the second wire back through the transformer core at a second side of the coupling device opposite to the first side,
preferably wherein the coupling device comprises a third coupling member, wherein the second coupling member and the third coupling member are arranged to be mated in a coupled position at opposite sides of a second mating plane parallel to and spaced apart from the first mating plane, wherein the third coupling member is arranged for holding a third transformer part which in the coupled position forms an extension of the transformer core, wherein the method further comprises the steps of:

- providing the second coupling member and the third coupling member in a decoupled position;
- positioning the third length of the first wire and the third length of the second wire in relation to one of the second transformer part and the third transformer part;
- positioning the fourth length of the first wire and the fourth length of the second wire in relation to one of the second transformer part and the third transformer part; and
- coupling the second coupling member and the third coupling member in the coupled position to form the extension of the transformer core around the power line, wherein the previously positioned third length and fourth length of each of the first wire and the second wire extend through the extension of the transformer core,

preferably wherein the extension of the transformer core comprises a third channel and a fourth channel, wherein the method comprises the steps of:

- positioning the third length of the first wire in the third channel;
- positioning the third length of the second wire in the fourth channel;
- positioning the fourth length of the first wire in the fourth channel; and
- positioning the fourth length of the second wire in the third channel,

preferably wherein the method further comprises the steps of:

- positioning the first wire and the second wire such that they extend in the lead-out direction from the transformer core; and
- directing the first wire and the second wire extending in the lead-out direction from the transformer core in the lead-in direction into the extension of the transformer core at the first side of the coupling device,

preferably wherein the method further comprises the steps of doubling the first wire and the second wire back through the extension of the transformer core at the second side of the coupling device.

15. Method according to any one of claims 11-14, wherein the method further comprises the step of forming an electrical infrastructure using one or more of the coupling device coupled to the power line.

16. Method according to claim 11, wherein the transformer core comprises a first channel and a second channel, wherein the method comprises the steps of:

- positioning the first length of the first wire in the first channel;
- positioning the first length of the second wire in the second channel;
- positioning the second length of the first wire in the second channel;
- positioning the second length of the second wire in the first channel;
- leading-in the first wire and the second wire in an lead-in direction; and
- leading-out the first wire and the second wire in a lead-out direction opposite to the lead-in direction;

wherein the coupling device has a first side where the first wire and the second wire are led-in, wherein the method comprises the step of doubling the first wire and the second wire back through the transformer core at a second side of the coupling device opposite to the first side,
wherein the method further comprises the step of crossing the first wire and the second wire at the second side to double back the first wire through the second channel and to double back the second wire through the first channel.

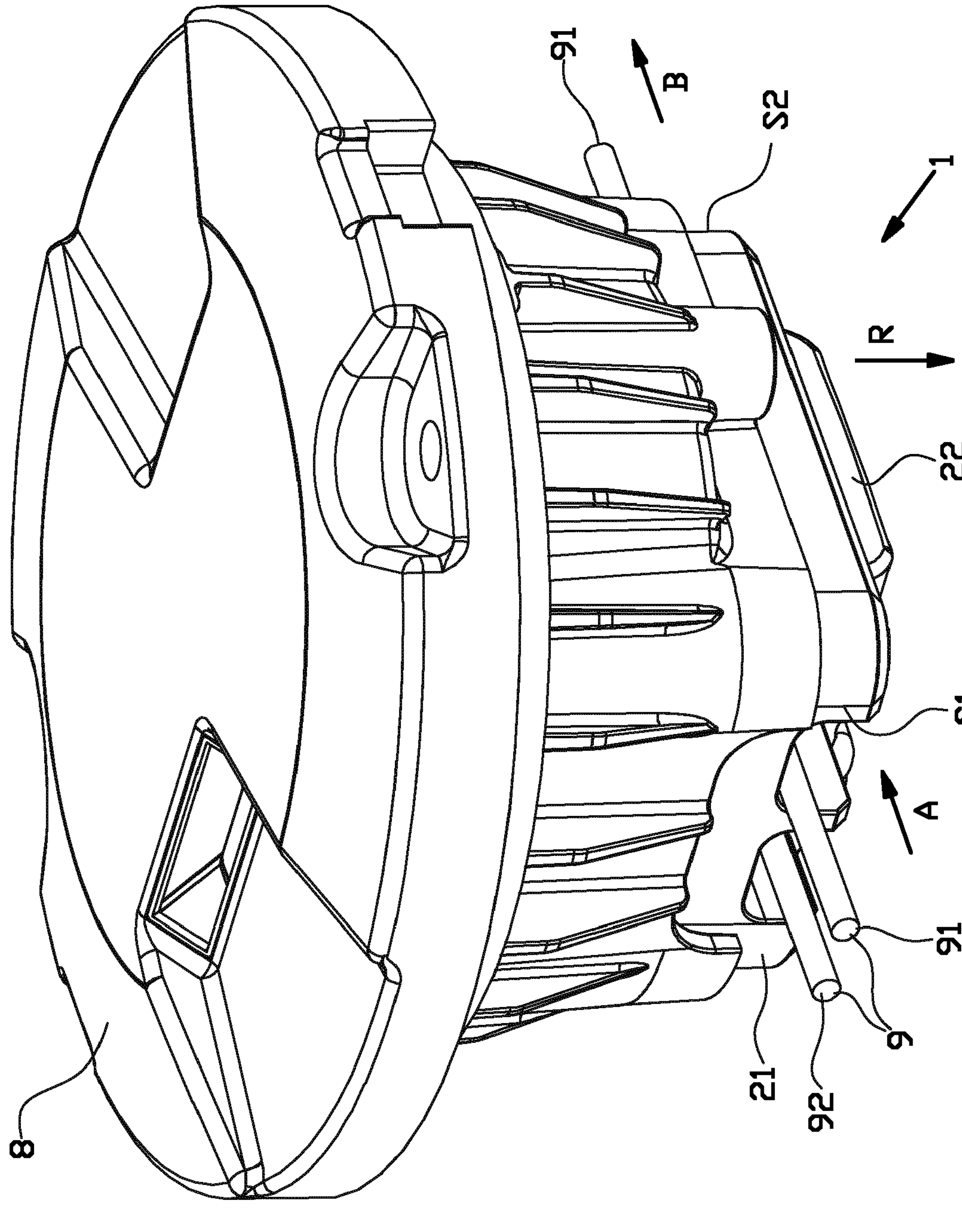


FIG. 1

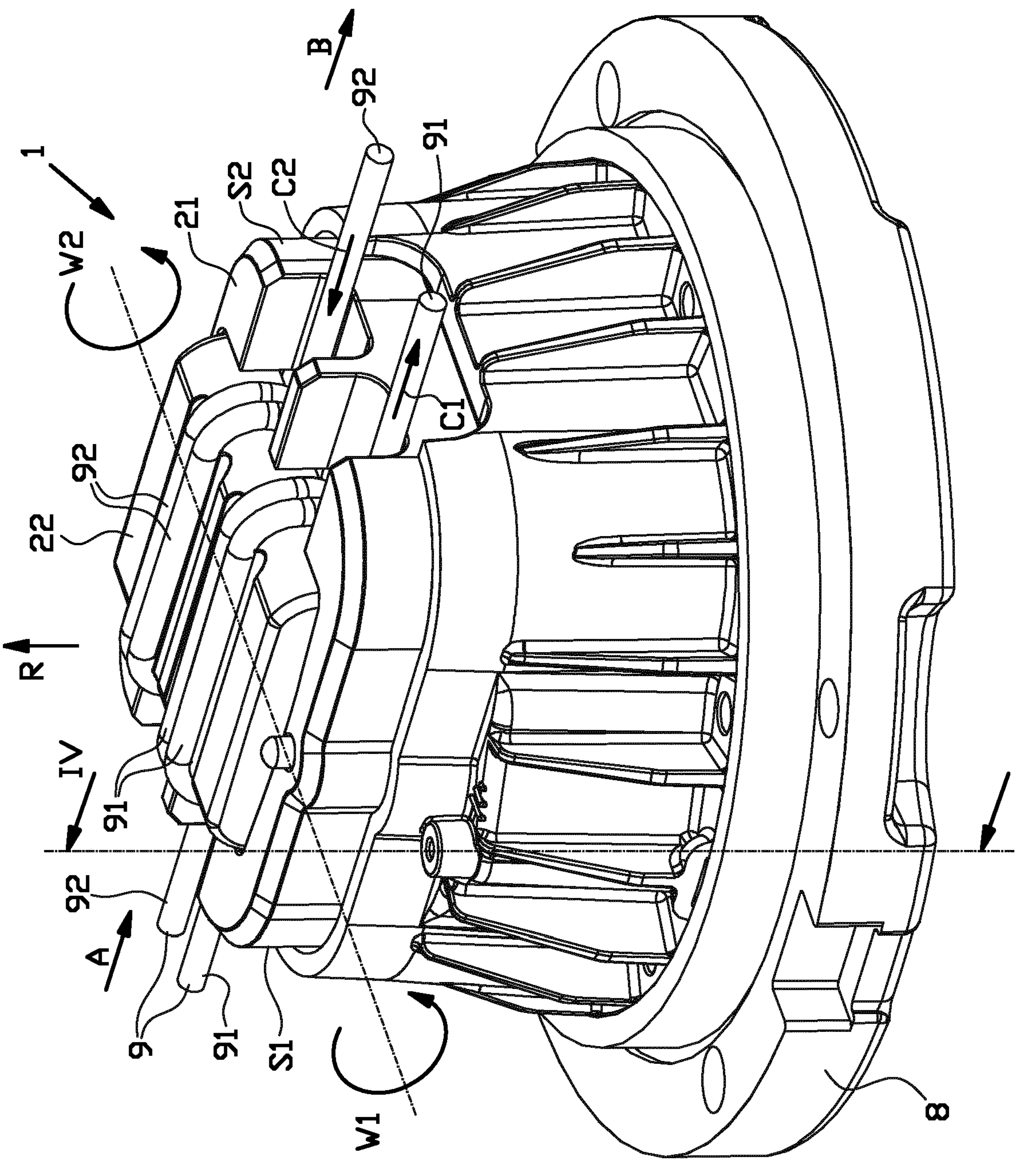


FIG. 2

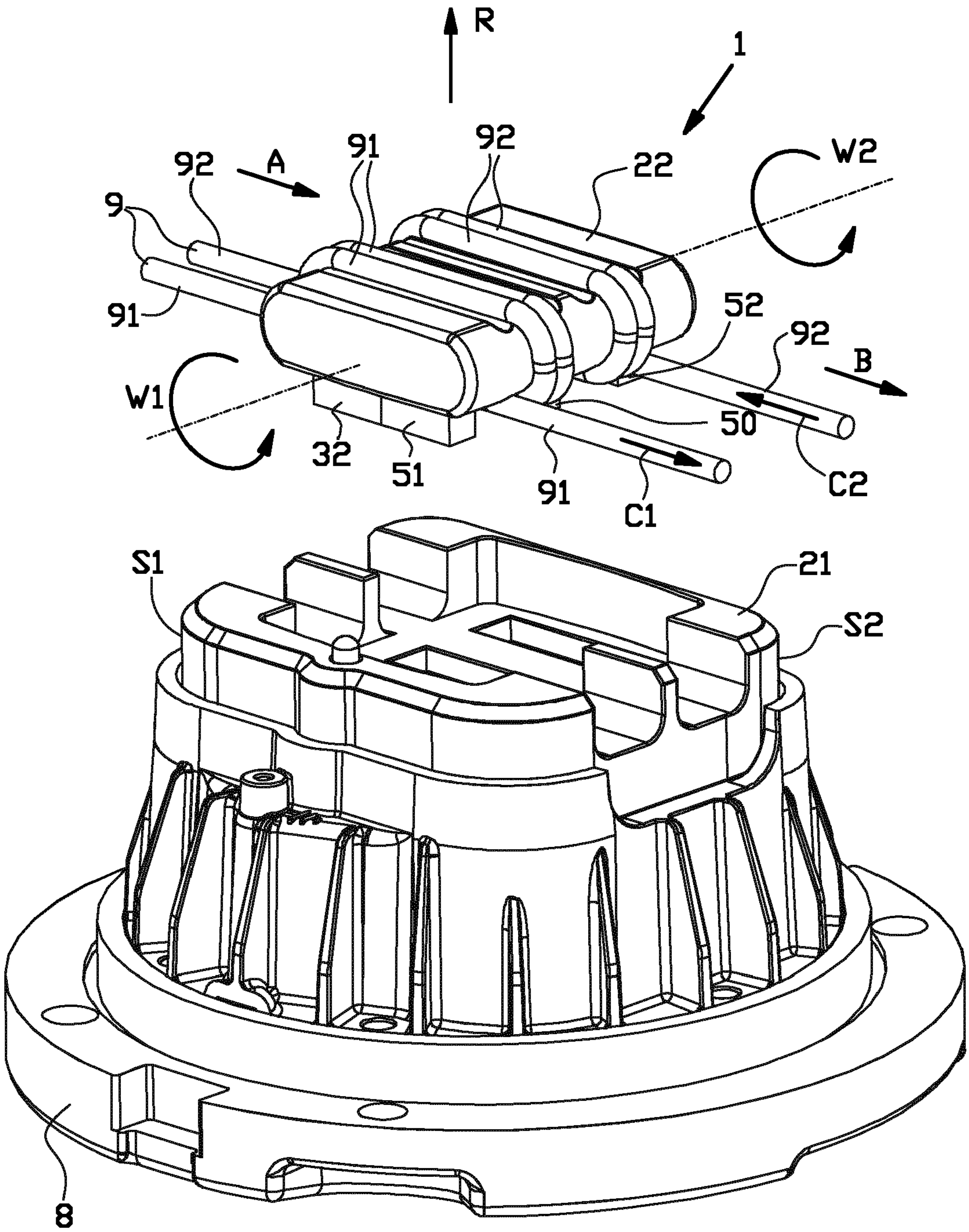


FIG. 3

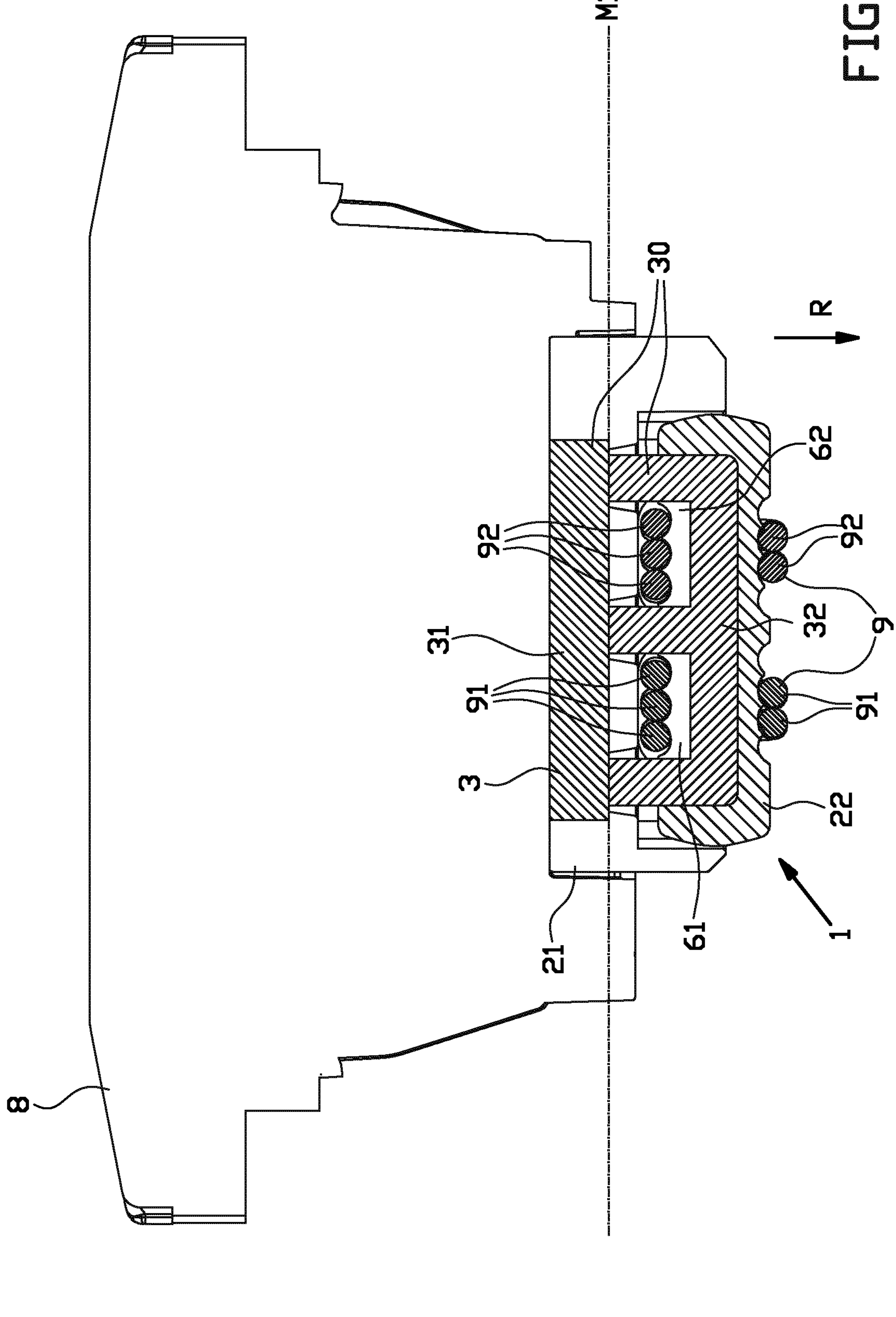


FIG. 4

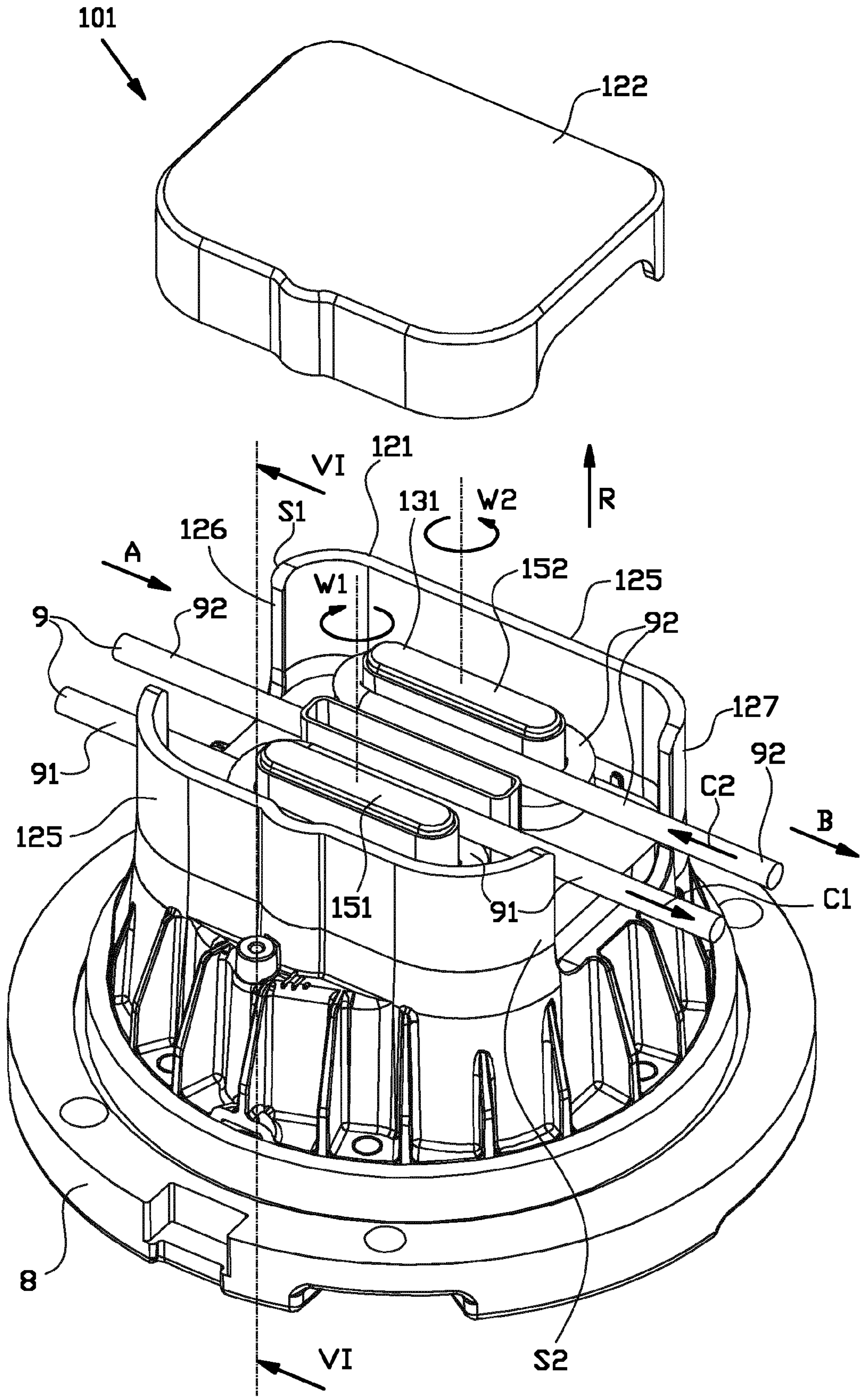
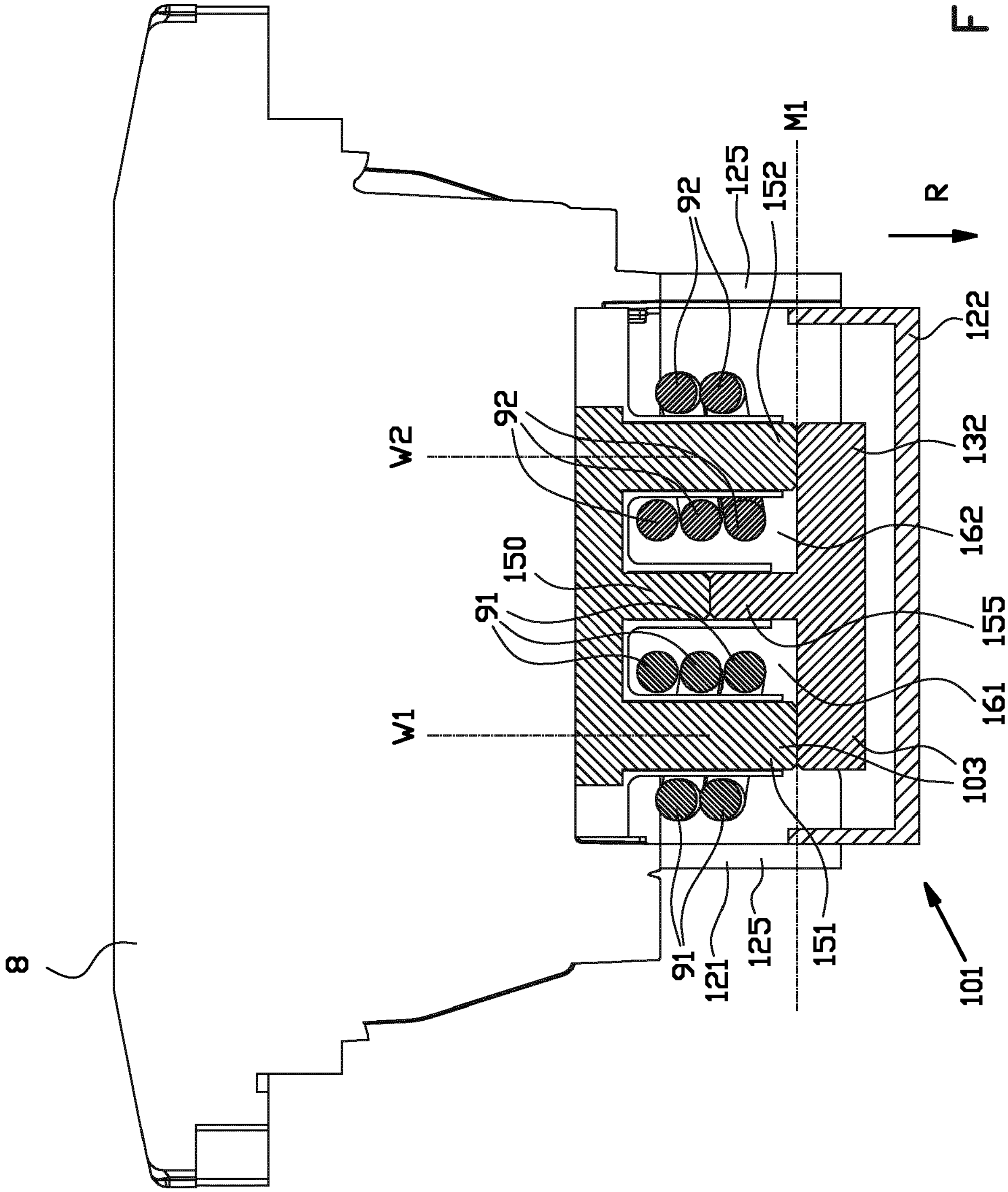

101
122
121
VI
R
131
W2
S1
126
A
152
125
W1
9
92
92
127
91
92
C2
125
B
151
91
C1
8
VI
S2

FIG. 5

FIG. 6


8
W2
W1
92
92
91
91
150
M1
125
152
R
122
132
162
155
161
103
121
125
151
101

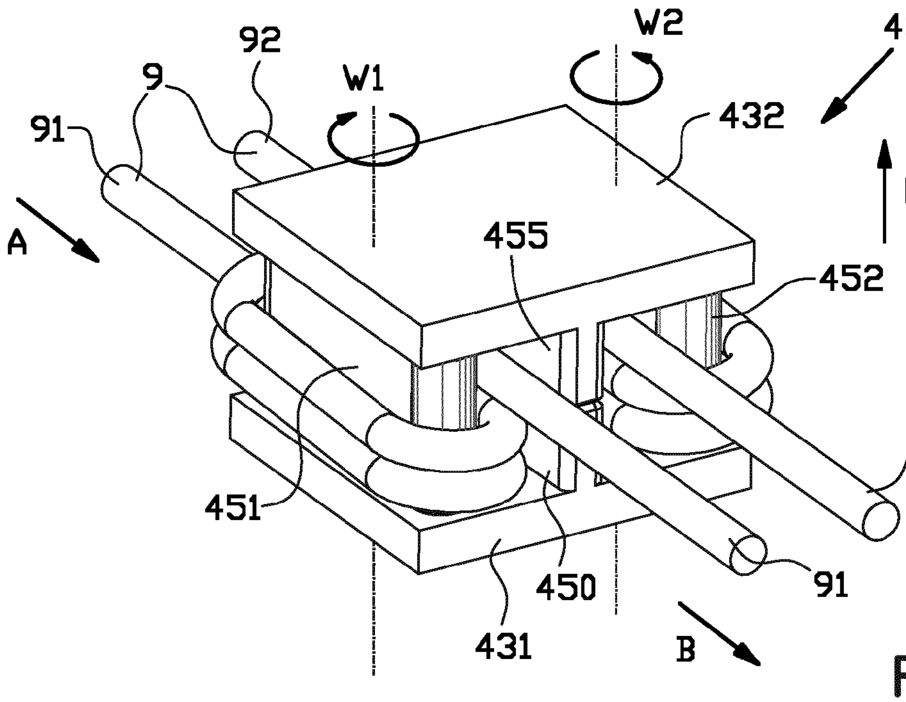
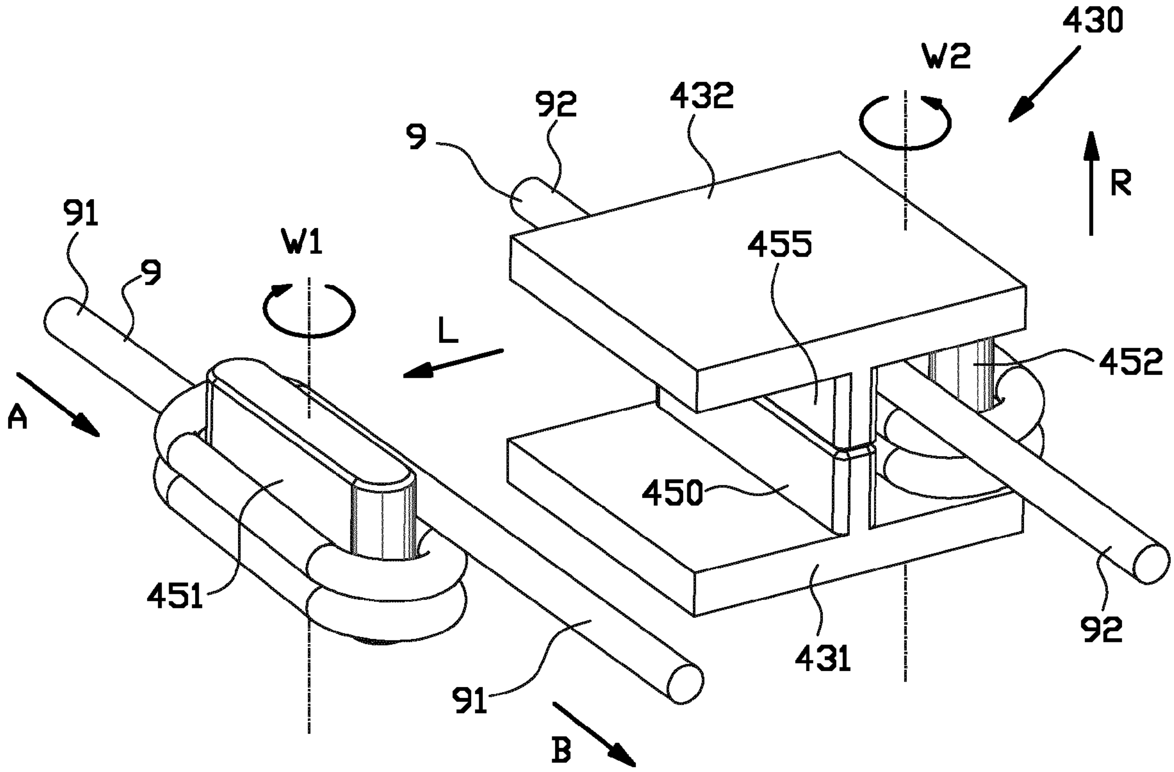

92
9
91
W1
W2
430
432
R
A
455
452
451
450
92
91
431
B

FIG. 7A


430
W2
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R
91
W1
9
455
L
452
A
450
451
431
92
91
B

FIG. 7B

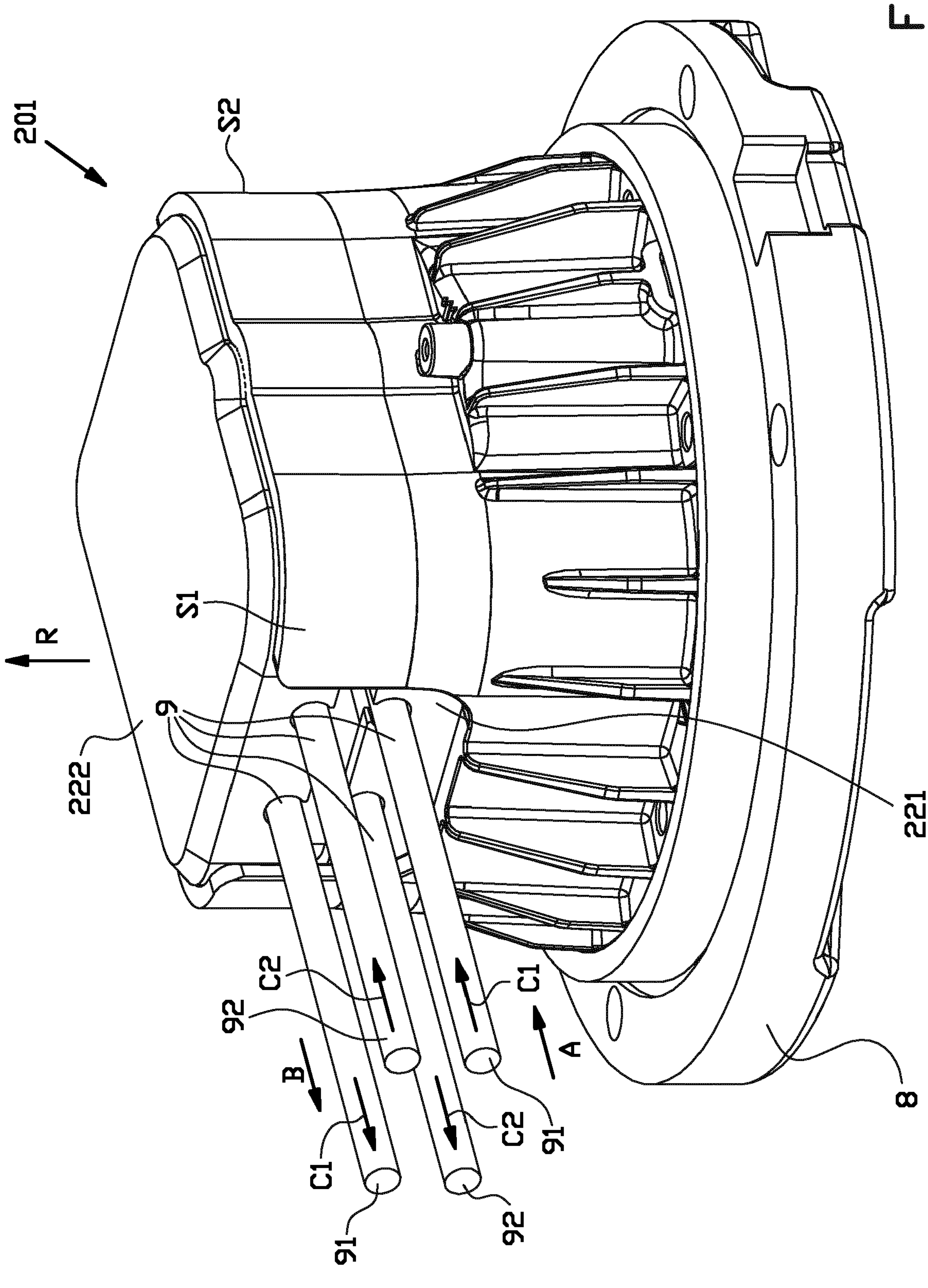


FIG. 8

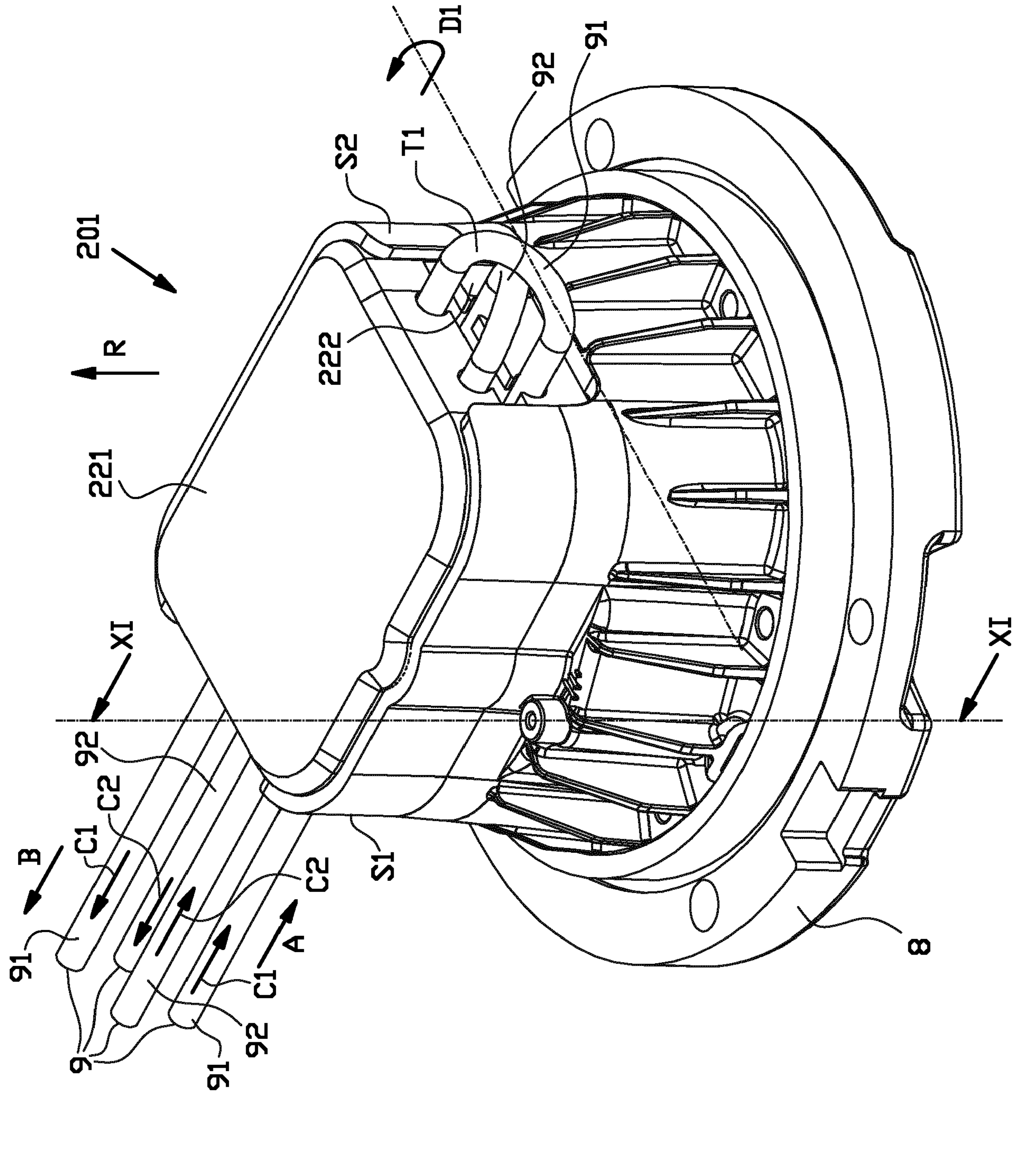
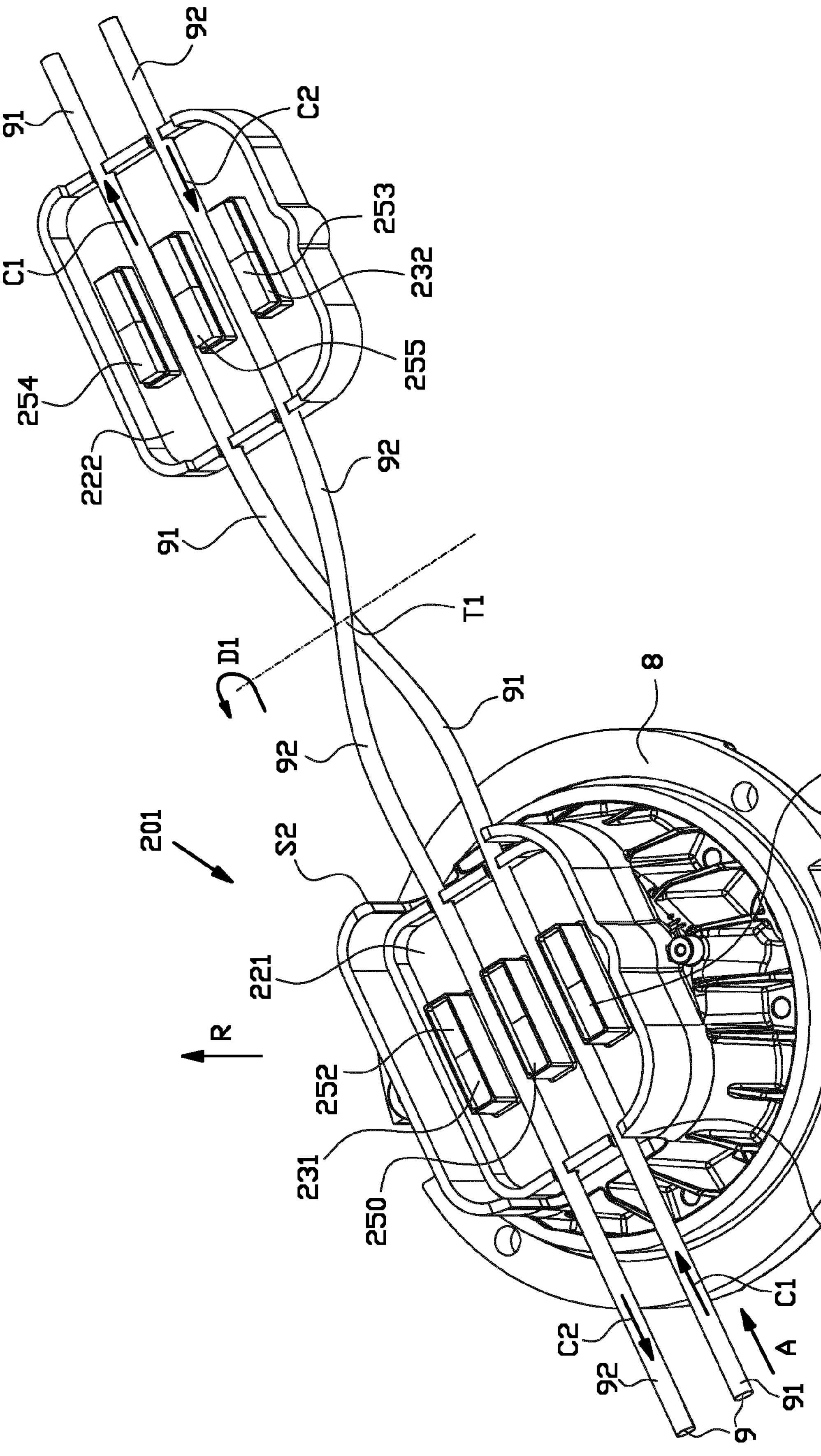


FIG. 9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91
C2
C1
253
232
255
254
222
92
91
T1
D1
8
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201
S2
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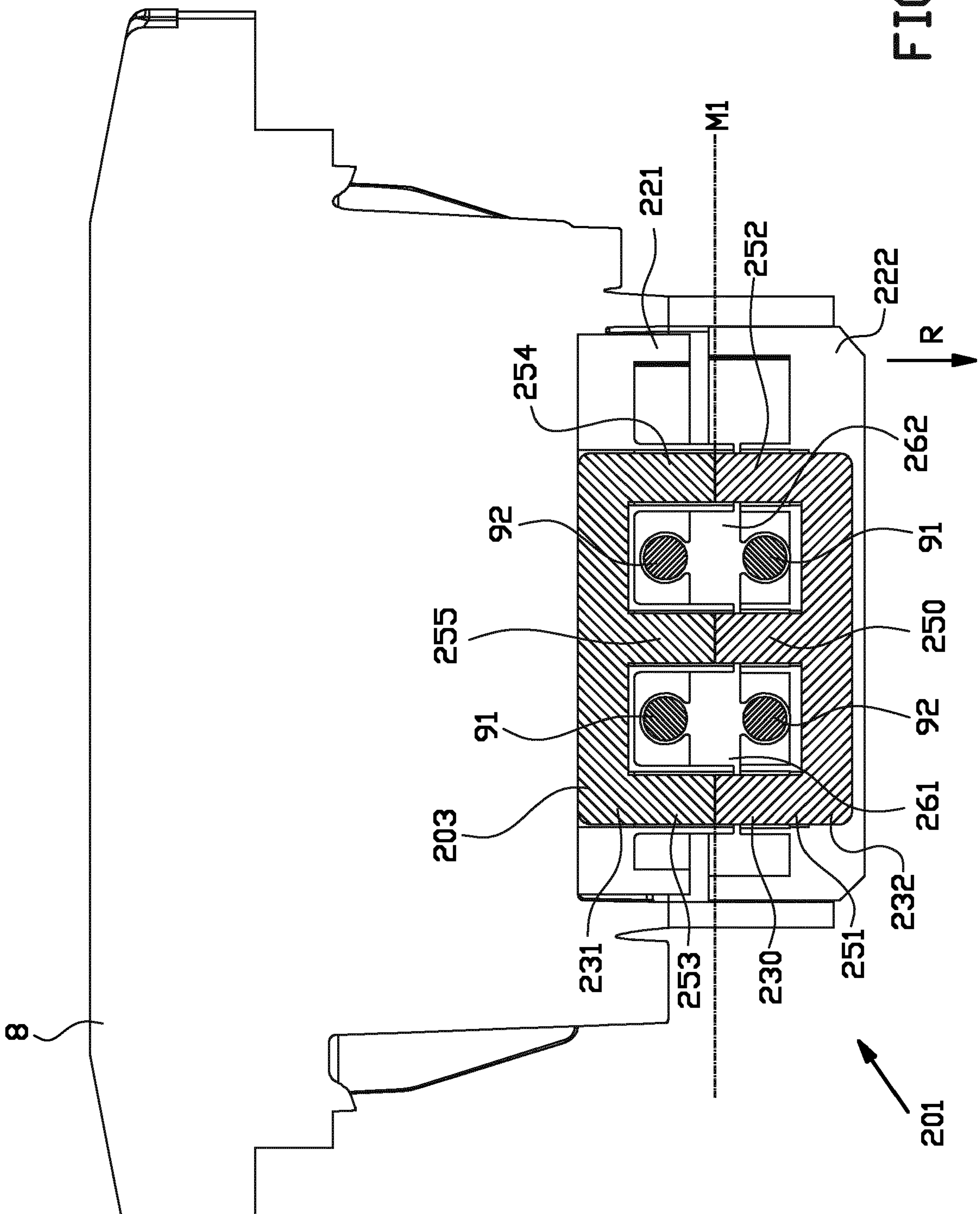
R
252
231
250
S1
C1
C2
A
92
91
9

FIG. 10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M1
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R
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92
203
261
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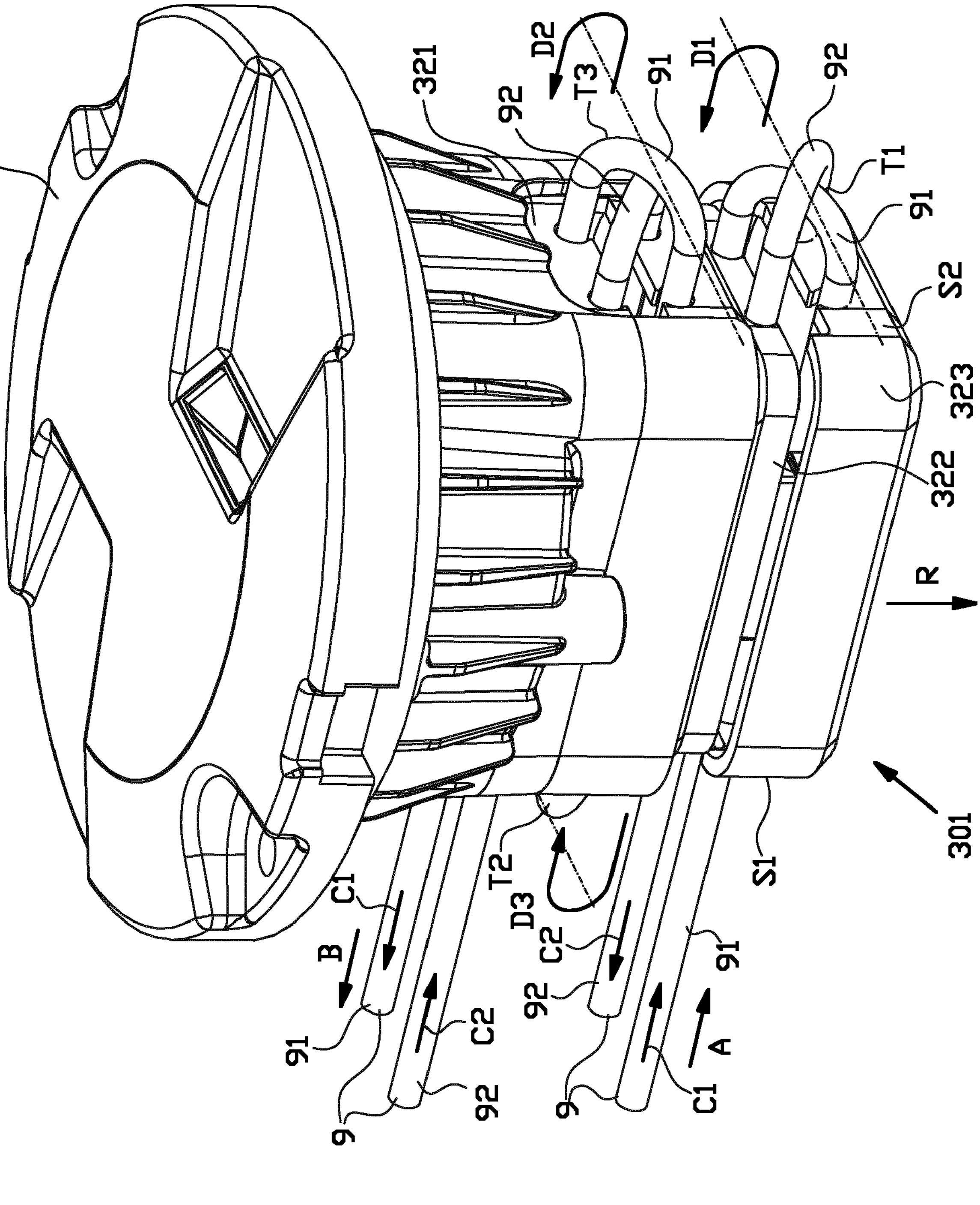
253
230
251
201

FIG. 11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T3
D2
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D1
92
T1
91
S2
323
322
R
301
S1
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C1
A
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92
C2
D3
T2
C1
B
91
9
C2
92

FIG. 12

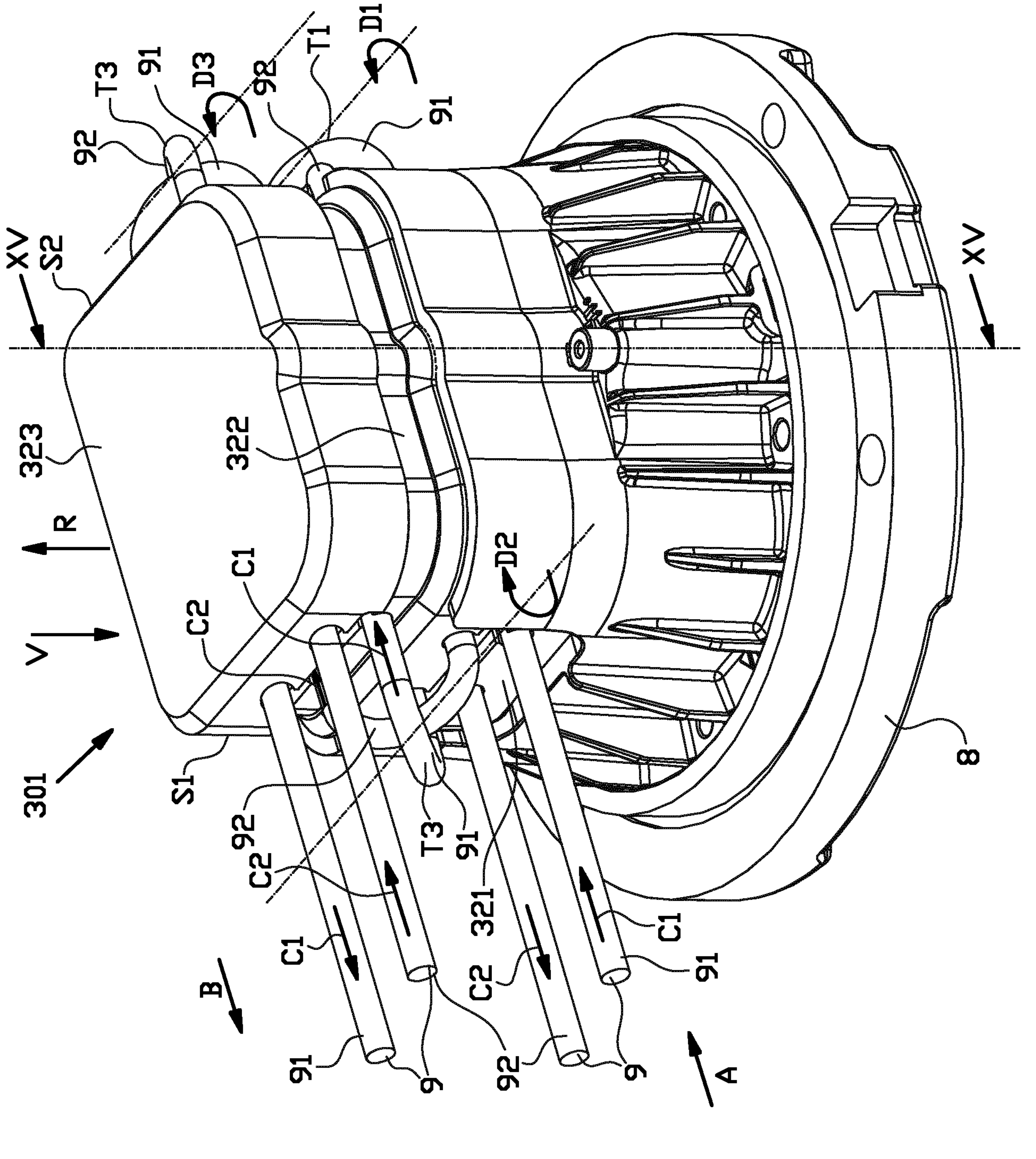
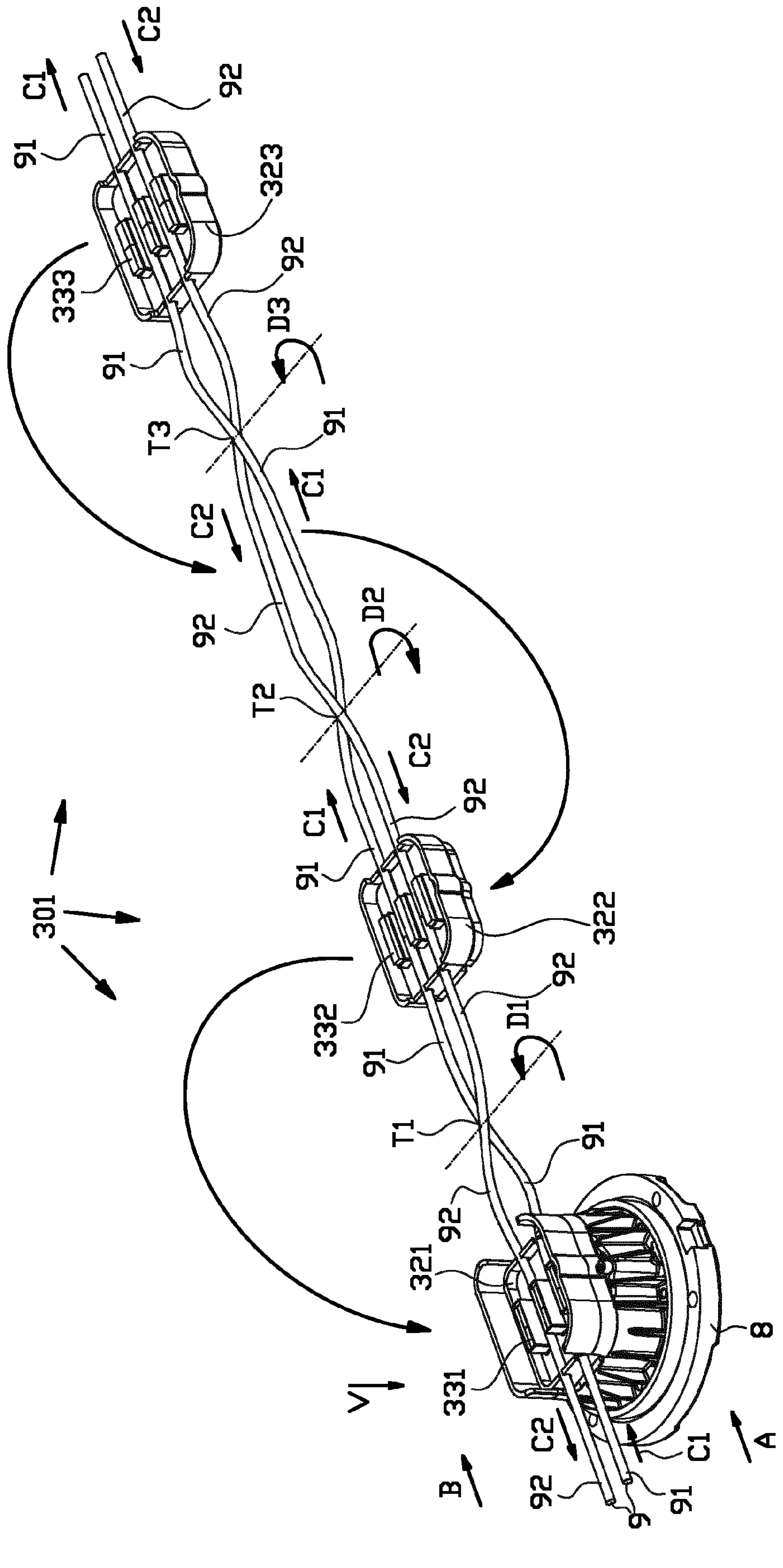


FIG. 13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C2
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92
91
322
332
301
92
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T1
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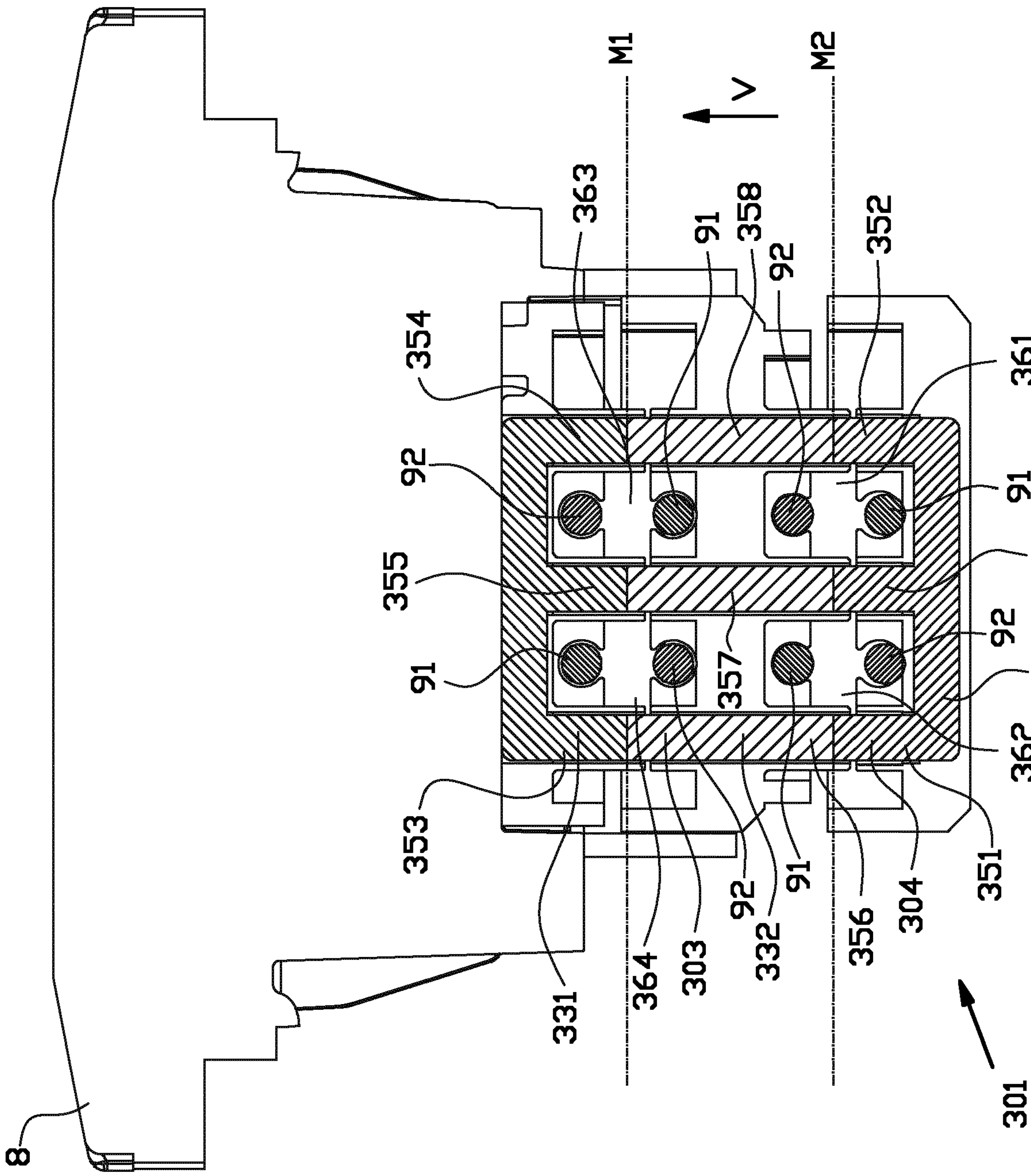
321
8
331
V
C2
C1
A
B
92
91
9

FIG. 14


R
V
M1
M2
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91
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92
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92
91
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92
333
362
353
92
91
331
364
303
332
356
304
351
8
301

FIG. 15

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 18 0073

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	EP 3 171 377 A1 (USE SYSTEM ENG HOLDING B V [NL]) 24 May 2017 (2017-05-24) * paragraphs [0001], [0005], [0028], [0035] - [0037], [0040] * * figures 1 - 3 * -----	1-16	INV. H01F27/26 H01F38/14
A	GB 2 497 428 A (ISOTERA LTD [GB]) 12 June 2013 (2013-06-12) * page 1, lines 5 - 7 * * page 2, lines 15 - 31 * * page 3, lines 10, 11 * * page 4, lines 13 - 26 * * page 14, lines 24 - 31 * * figures 1 - 3, 22, 31 * -----	1-16	
A	US 3 549 990 A (HOCHHEISER JEROME S) 22 December 1970 (1970-12-22) * column 1, lines 11 - 40 * * column 2, lines 5 - 14 * * column 3, lines 30 - 38, 57 - 66 * * column 7, lines 13 - 24 * * figures 1, 5 - 7 * -----	1-16	TECHNICAL FIELDS SEARCHED (IPC) H01F H05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 September 2018	Van den Berg, G

CATEGORY OF CITED DOCUMENTS

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