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(54) **FAST PULSE MAGNETIZING APPARATUS**

(57) A fast pulse magnetizing apparatus including a magnetizing circuit provided with capacitors having a capacitance C , which are charged slowly at a voltage V , to the energy $1/2CV^2$, by means of converters; the capacitors are discharged rapidly on an inductor, which generates a magnetizing field used to magnetize a permanent magnet; the apparatus is characterized in that it includes an added resistor, which is inserted in series in the magnetizing circuit and reduces the width of the current pulse, so as to generate induced currents necessary

for magnetization. The circuit furthermore includes a GTO (gate turn-off) power thyristor used in the circuit as an electronic switch, The apparatus furthermore includes magnetization masks, which are mutually joined so that the electrical junction is far from the work area. The apparatus furthermore includes a separate solenoid, which is constituted by a flat wire bent edgewise or machined from solid copper and provided with a lateral passage to facilitate the production process and improve the uniformity of the magnetizing field.

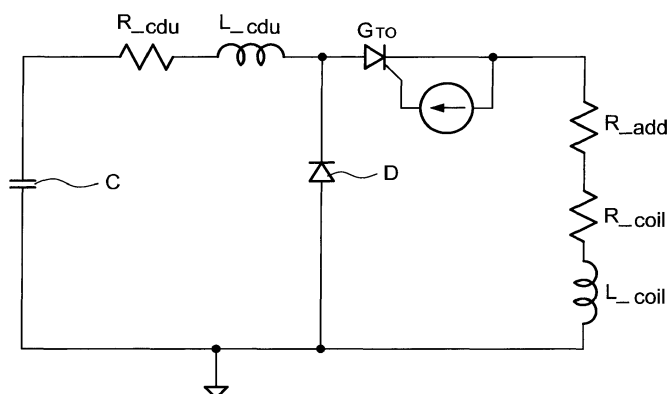


Fig. 1

Description

[0001] The present invention relates to a fast pulse magnetizing apparatus.

[0002] As is known, permanent magnets are magnetized with capacitor discharge methods, CDU (capacitor discharge units).

[0003] Capacitors with a capacitance C are slowly charged at the voltage V , i.e., at the energy $1/2CV^2$, by means of adapted switching or analog converters at industrial frequency. The capacitors are then discharged rapidly, by means of a high-current electronic switch SCR_{mag}, on an inductor L_{coil} which generates the magnetizing field.

[0004] Magnetization reaches the desired value at the current peak of the discharge pulse, when the electrostatic energy has all been converted into magnetic energy $1/2LI^2$.

[0005] The pulse current which flows through the conductors of the inductor generates a pulsed magnetic field which magnetizes the permanent magnets. The pulsed current depends on the four characteristic parameters R , L , C , V .

[0006] The circuit parameters are not necessarily constant during the pulse.

[0007] They also include the output impedance of the CDU, R_{cdu} and L_{cdu} , and the parasitic impedance of the inductor R_{coil} and L_{coil} .

[0008] The pulse would charge the capacitors, and to prevent this from occurring a recirculation diode D_{free} is used.

[0009] According to a recent method, the currents induced on appropriate blocks of copper or other conducting material, termed masks, are used in order to shape the magnetization appropriately.

[0010] GB854190 discloses a magnetizing apparatus wherein the degree of magnetization of a permanent magnet system, e.g. for an eddy current clutch or brake is adjusted by controlled current impulses. The apparatus has control coils energized with current impulses that are derived from an adjustable condenser bank, charged from a battery and discharged through a gas-filled triode. A change-over switch leads to the series or parallel connected field coils. The triode is caused to discharge by means of a switch or by adjusting the grid voltage applied from a battery. The apparatus may have an optional adjustable resistance 42 to obtain a stepless control.

[0011] The aim of the present invention is to provide a fast pulse magnetizing apparatus that is improved with respect to the systems of the prior art cited above.

[0012] Within the scope of this aim, an object of the invention is to provide an apparatus that has a circuit diagram that is advantageous from the functional and production standpoint.

[0013] Another object of the invention is to provide an apparatus that is constructively advantageous from the production standpoint and at the same time allows to obtain a superior functional performance with respect to

traditional apparatuses.

[0014] Another object of the present invention is to provide a structure which, by virtue of its particular constructive characteristics, is capable of giving the greatest assurances of reliability and safety in use.

[0015] This aim and these and other objects which will become better apparent hereinafter are achieved by a fast pulse magnetizing apparatus comprising a magnetizing circuit provided with capacitors having a capacitance C , which are charged slowly at a voltage V , to the energy $1/2CV^2$, by means of converters, said capacitors being discharged rapidly on an inductor, which generates a magnetizing field used to magnetize a permanent magnet; said apparatus being characterized in that it comprises an added resistor, which is inserted in series in said magnetizing circuit, said added resistor reducing the width of the current pulse, thus generating induced currents necessary for magnetization.

[0016] Further characteristics and advantages will become better apparent from the description of preferred but not exclusive embodiments of the invention, illustrated by way of nonlimiting example in the accompanying drawings, wherein;

Figure 1 is an electrical diagram of the apparatus according to the present invention;

Figure 2 is a chart which compares the variation of the peak of the current pulse, obtained by means of the present invention, with the curve of a conventional apparatus;

Figure 3 is a partially cutout perspective view of the apparatus according to the present invention;

Figure 4 is a partially cutout perspective view of the resistor and solenoid assembly;

Figure 5 is an enlarged-scale sectional perspective view of the resistor and solenoid assembly;

Figure 6 is another partially cutout perspective view of the resistor and solenoid assembly;

Figure 7 is a sectional perspective view of a detail of the assembly in the region of the solenoid;

Figure 8 is a perspective view of the mask assembly;

Figure 9 is a perspective view of the element that contains the solenoid;

Figure 10 is a perspective view of the solenoid;

Figure 11 is a side view of the solenoid of the preceding figure;

Figure 12 is a perspective view of the solenoid configured in a "ship coil" configuration;

Figure 13 is a perspective view of a further embodiment of the solenoid;

Figure 14 is a perspective view of a further embodiment of the solenoid.

[0017] With reference to the cited figures, the fast pulse magnetizing apparatus according to the invention, globally designated by the reference numeral 1, is used to magnetize permanent magnets by means of the discharge of capacitors CDU (capacitor discharge units).

[0018] The apparatus 1 includes capacitors 2, having a capacitance C, which are charged slowly at a voltage V, i.e., to the energy $1/2CV^2$, by means of switching or analog converters at industrial frequency.

[0019] According to the present invention, the apparatus includes a GTO power thyristor for high currents, which allows to discharge the capacitors rapidly on an inductor L_{coil}, which generates the magnetizing field.

[0020] Magnetization reaches the desired value at the current peak of the discharge pulse, when the electrostatic energy has all been converted into magnetic energy $1/2LI^2$.

[0021] The pulsed current that flows through the conductors of the inductor generates a pulsed magnetic field which magnetizes the permanent magnets. The pulsed current depends on the four characteristic parameters R, L, C, V.

[0022] The circuit parameters are not necessarily constant during the pulse.

[0023] They also include the output impedance of the CDU 2, R_{cdu} and L_{cdu}, and the parasitic impedance of the inductor R_{coil} and L_{coil}.

[0024] The pulse would charge the capacitors. To prevent this from occurring, a recirculation diode D is used.

[0025] According to the present invention, the apparatus 1 includes an added resistor R_{add}, which is inserted in series in the magnetizing circuit, which allows to have a narrower current pulse which allows to generate in the masks the induced currents necessary to use magnetization and other advantages.

[0026] The added resistor is designated by the reference numeral 3 in Figures 4-6, which show a practical constructive example of the invention.

[0027] According to the present invention, the GTO (gate turn-off) power thyristor is used as an electronic switch, although it is not an element indicated in the literature for this application.

[0028] The use of the GTO power thyristor allows to utilize the diffused gate, normally used to switch off the thyristor during conduction, to withstand the high current variation over time that is required by this application. This value is referenced as di/dt.

[0029] The apparatus utilizes the currents induced on appropriate blocks of copper or other conducting material, termed masks, designated by the reference numeral 4 in Figure 8, to shape the magnetization appropriately.

[0030] According to the present invention, the masks 14 are joined so that the electrical junction is far from the work area and does not compromise their operation.

[0031] The masks 4 are joined by means of a junction element 41 and have a neck 42 for thermal conduction, between each of them and the junction element.

[0032] The junction element 41 is provided with a set of fins 43 for cooling (heat sink) and with a series of holes 44 for fixing the mask assembly.

[0033] The apparatus 1 also includes a separate solenoid 5, constituted by an enameled copper wire.

[0034] The solenoid 5 is constituted by a flat wire bent

edgeways or machined from solid copper.

[0035] In order to facilitate the production process of magnetization, the solenoid 5 has been separated, obtaining a lateral passage.

5 **[0036]** The solenoid may also have a so-called "ship coil" geometry, this embodiment being designated by the reference numeral 51 in Figure 12.

[0037] Figures 10-12 show constructive examples of the solenoid 5, 51, formed by a flat copper wire folded edgeways, while Figures 13-14 show embodiments of the solenoid 52, 53 formed by bent copper wire.

[0038] The apparatus according to the present invention has several advantages.

10 **[0039]** From the circuit standpoint, an advantage of the present invention is that the resistor and the inductor in series form a resistive divider, and all the active power is absorbed by the resistor, which is relatively far from the magnetization region and therefore can dissipate the heat better.

20 **[0040]** Also, the resistor is made of a material having a resistivity which is stable as the temperature varies, such as constantan or other alloys. The role played by a relatively high resistance in series to the RLC in the resulting peak current is dominant and therefore resistance variations due to the magnetization conductors do not vary the magnetization current. This renders the performance stable as the temperature varies and this is highly desirable.

25 **[0041]** Also, the resistor allows a rapid descent of the current peak, to the detriment however of peak current. The rapid current descent increases the effect on magnetization caused by induced currents.

30 **[0042]** Figure 2 is a view of the variation of the peak of the current pulse obtained by means of the series resistor. According to the present invention, the peak lowers but the time at half value, i.e., the pulse width at half amplitude, is reduced drastically.

35 **[0043]** A further important advantage of the invention is constituted by the use of the GTO (gate turn-off), which has a diffuse gate and therefore withstands a high rate of current over time, reaching thousands of A/us, where a conventional SCR (silicon controlled rectifier) fails at a few hundred A/us.

40 **[0044]** A further advantage of the present invention is constituted by the fact that the masks 4 are joined to each other by means of the junction element 41.

[0045] The junction of the masks allows to process them together and therefore to maintain precise alignments. This is advantageous, because the magnet to be magnetized passes between the masks and therefore the holes of the masks must be properly aligned.

[0046] Also, the junction increases the mass of the conductor and therefore the thermal capacity and therefore limits thermal excursions during the pulse.

50 **[0047]** The junction element 41 is provided with fins, so as to increase the heat dispersion surface. Thermal stability improves operation, since the currents induced at high temperatures are lower.

[0048] The junction element 41 also allows to use a fastening system constituted by holes 44, which would be otherwise impossible with bare masks.

[0049] The winding formed by a flat wire bent edge-ways of the solenoid 5, 51 allows to utilize the induced currents also inside the solenoid itself, confining a large part of the current density inward and therefore increasing the efficiency of the solenoid.

[0050] The "tunnel" passage obtained by separating the turns increases the uniformity of the field, while lowering the absolute value. It also allows easy lateral passage for the entry of magnets or thin magnetic assemblies.

[0051] The ship-coil shape allows to further increase the field at the center of the area of the solenoid, since it moves the lateral turns closer to the central point.

[0052] The ship-coil shape spaces the turns and creates such a shape as to further increase the uniformity of the field, which is a desirable effect.

[0053] In practice it has been found that the invention achieves the intended aim and objects, providing a fast pulse magnetizing apparatus that allows to provide permanent magnets, utilizing the currents induced on blocks of copper or other conducting material, known as masks, in order to shape the magnetization appropriately.

[0054] The resistor inserted in series in the magnetizing circuit facilitates the generation of the induced currents required to use magnetization and offers other advantages.

[0055] A further feature of the present invention is constituted by the "improper" use of the GTO (gate turn-off) thyristor as an electronic switch. Contrary to what is known in the art, this new and surprising application allows to utilize the diffused gate, which is normally used to switch off the thyristor during conduction, in order to withstand the high current variation over time that is required by this application.

[0056] Another advantage of the present invention is constituted by the electrical junction of the masks. In this manner, the electrical junction is far from the work area and does not compromise the operation of the masks.

[0057] A further advantage of the present invention is constituted by the separation of the solenoid and by its particular geometric shape, which facilitate the production process.

[0058] The materials used, as well as the dimensions, may of course be any according to the requirements and the state of the art.

to magnetize a permanent magnet; said apparatus being **characterized in that** it comprises an added resistor, which is inserted in series in said magnetizing circuit, said added resistor reducing the width of the current pulse, thus generating induced currents necessary for magnetization.

2. The apparatus according to claim 1, **characterized in that** said magnetizing circuit comprises a GTO (gate turn-off) thyristor used as an electronic switch, said power thyristor allowing to discharge the capacitors rapidly on said inductor.

3. The apparatus according to claim 1, **characterized in that** it comprises a plurality of blocks made of conducting material, on which currents produced by said inductor are induced; said blocks being mutually joined by an electrical junction element.

4. The apparatus according to claim 3, **characterized in that** each one of said blocks is provided with a neck for thermal conduction which is arranged between said block and said junction element.

5. The apparatus according to claim 3, **characterized in that** said junction element is provided with a set of fins for cooling and with a series of holes for fixing the block-junction element assembly.

6. The apparatus according to claim 1, **characterized in that** it comprises a separate solenoid.

7. The apparatus according to claim 6, **characterized in that** said solenoid has a lateral passage.

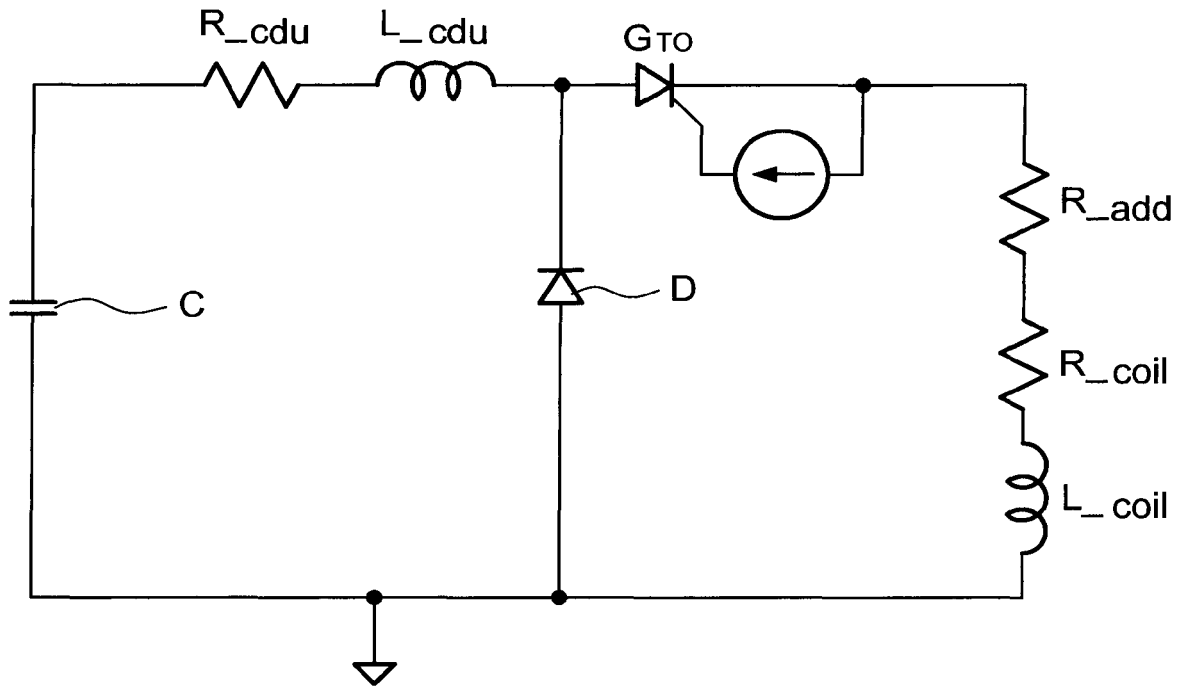
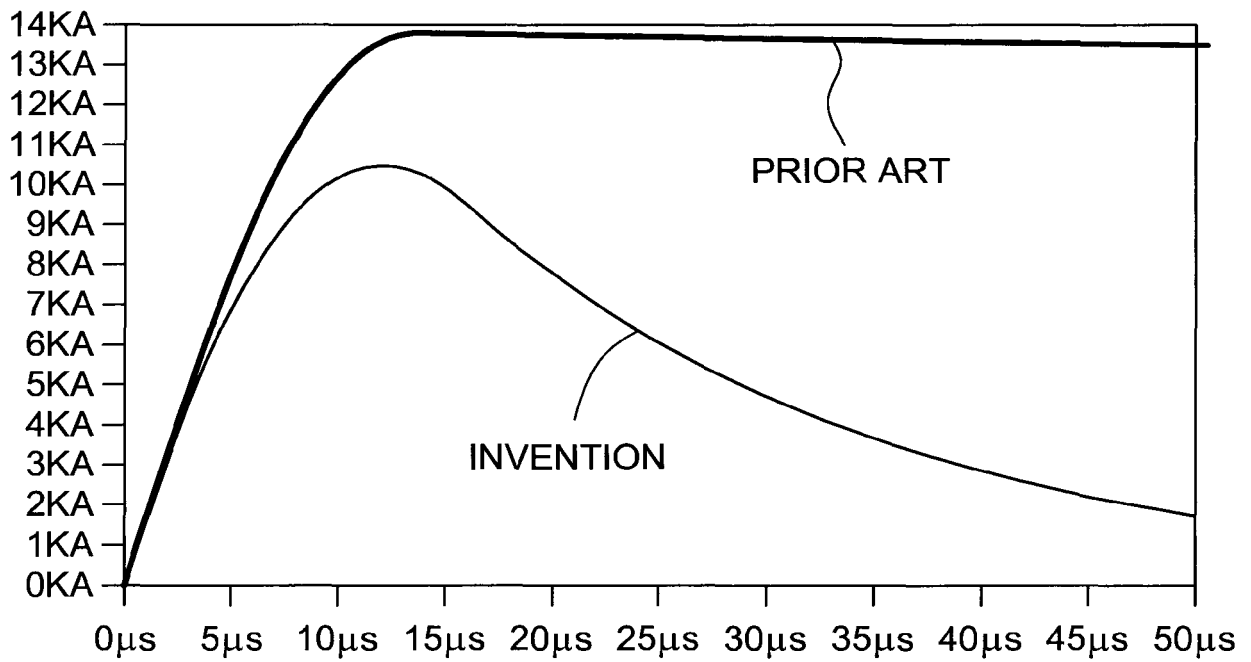
8. The apparatus according to claim 6, **characterized in that** said solenoid has a ship-like geometric shape.

9. The apparatus according to claim 6, **characterized in that** said solenoid is formed by a flat copper wire bent edgewise.

10. The apparatus according to claim 6, **characterized in that** said solenoid is obtained from solid copper.

Claims

1. A fast pulse magnetizing apparatus comprising a magnetizing circuit provided with capacitors having a capacitance C, which are charged slowly at a voltage V, to the energy $1/2CV^2$, by means of converters; said capacitors being discharged rapidly on an inductor, which generates a magnetizing field used

*Fig. 1**Fig. 2*

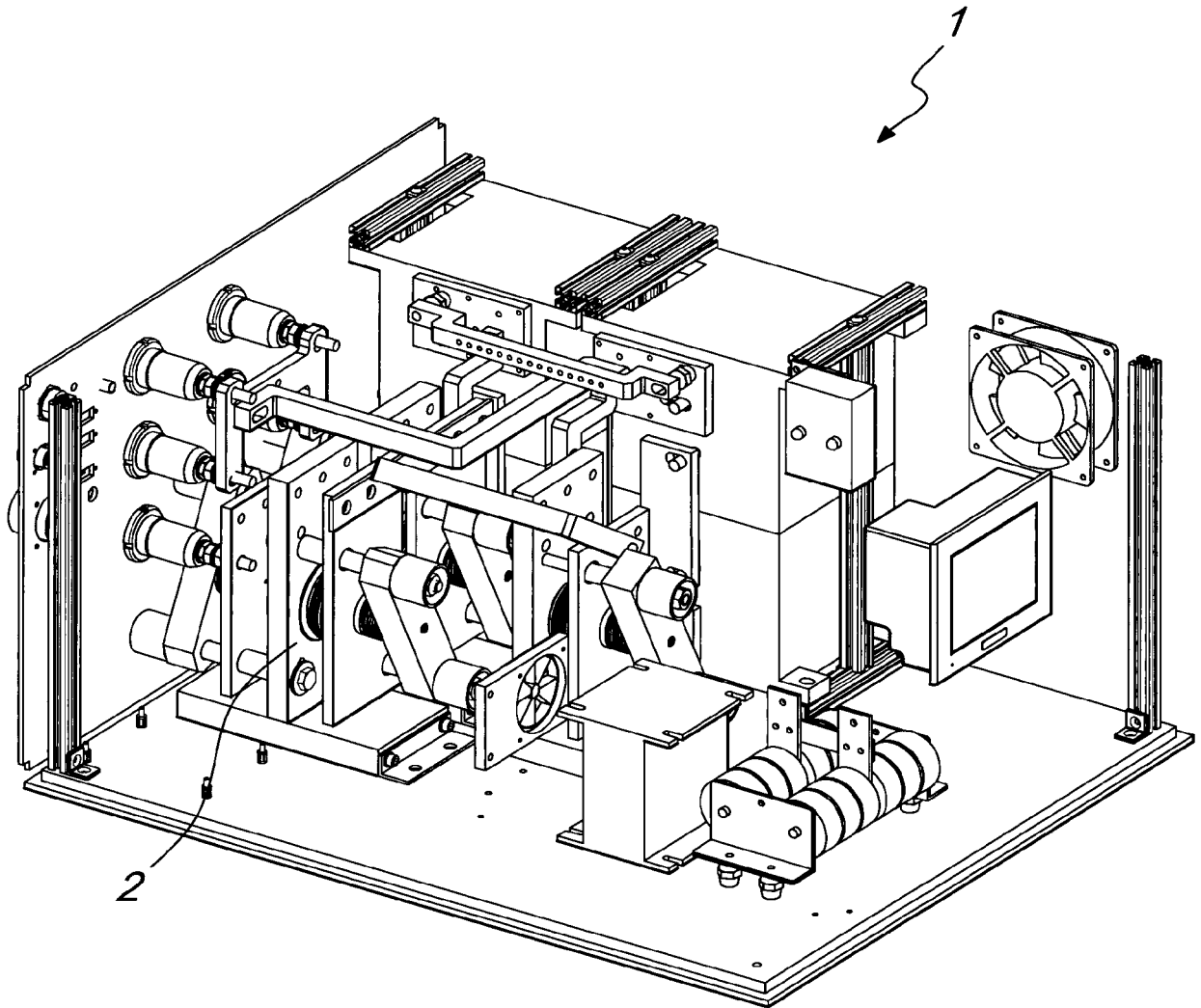


Fig. 3

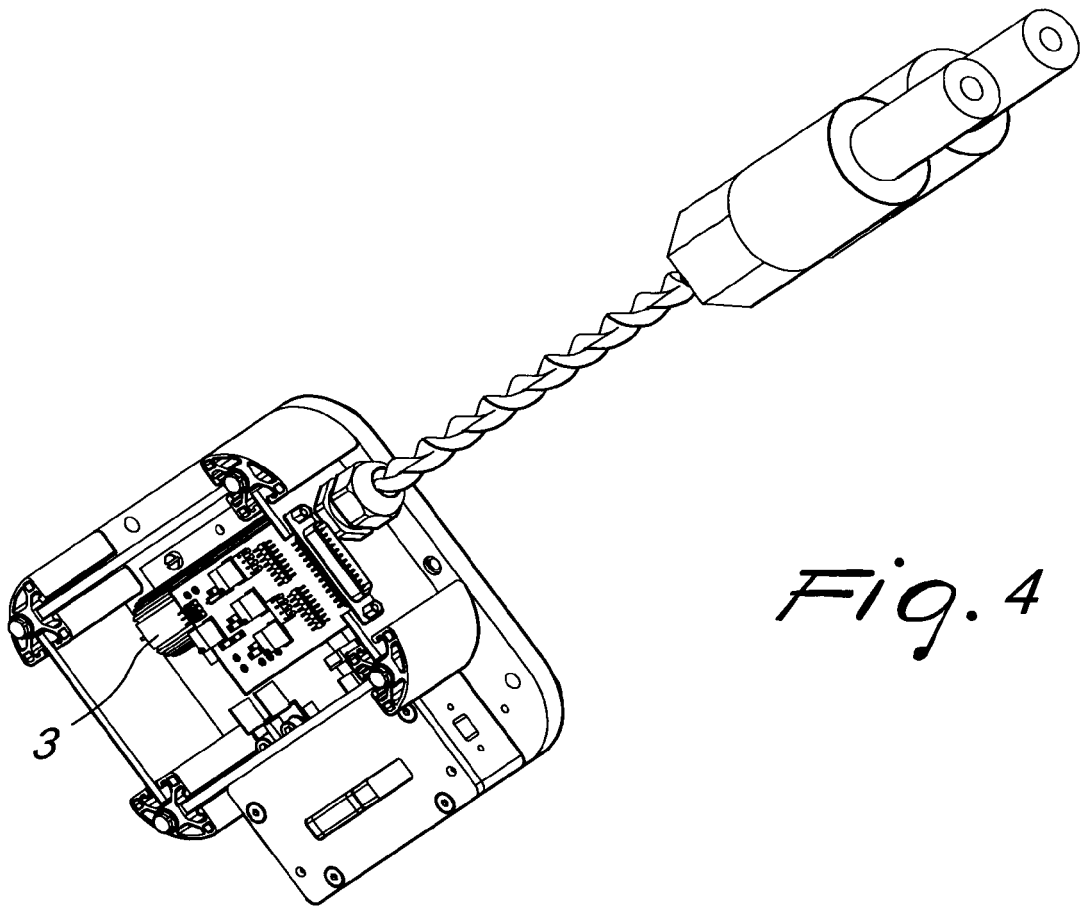


Fig. 4

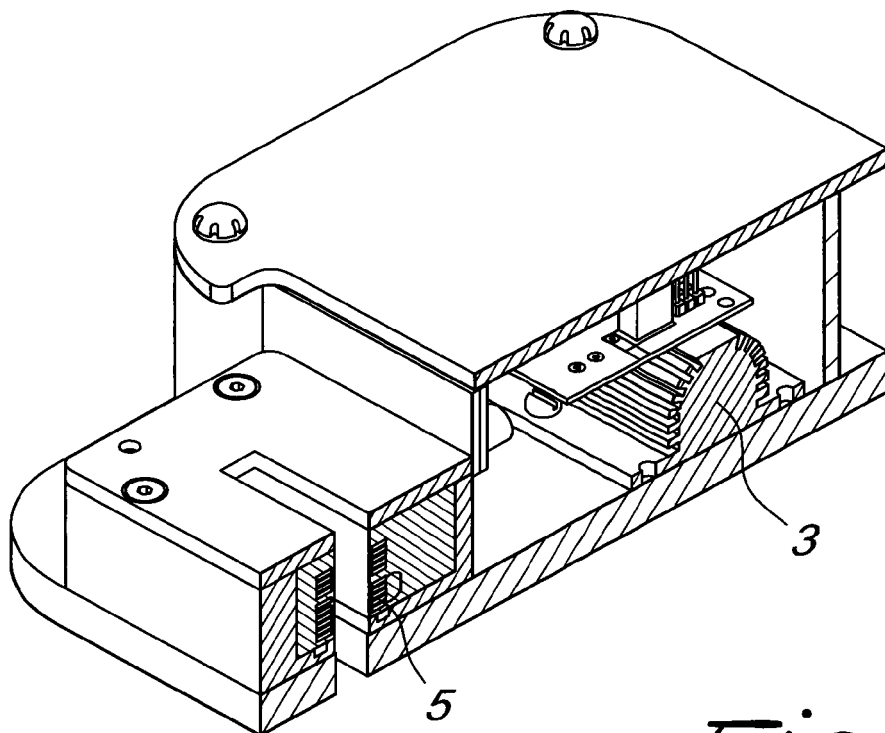


Fig. 5

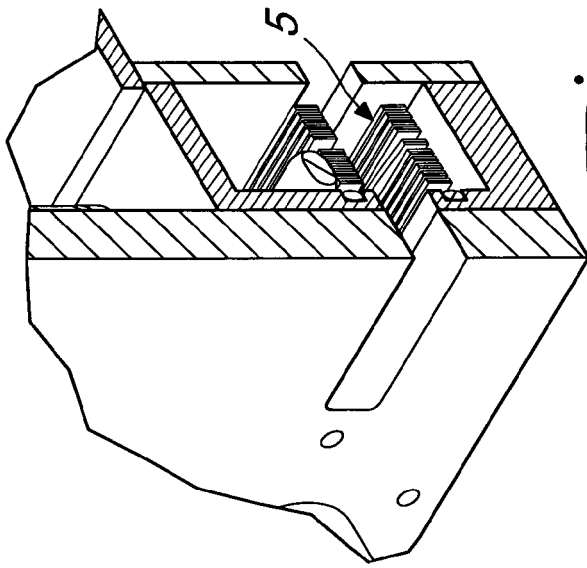


Fig. 7

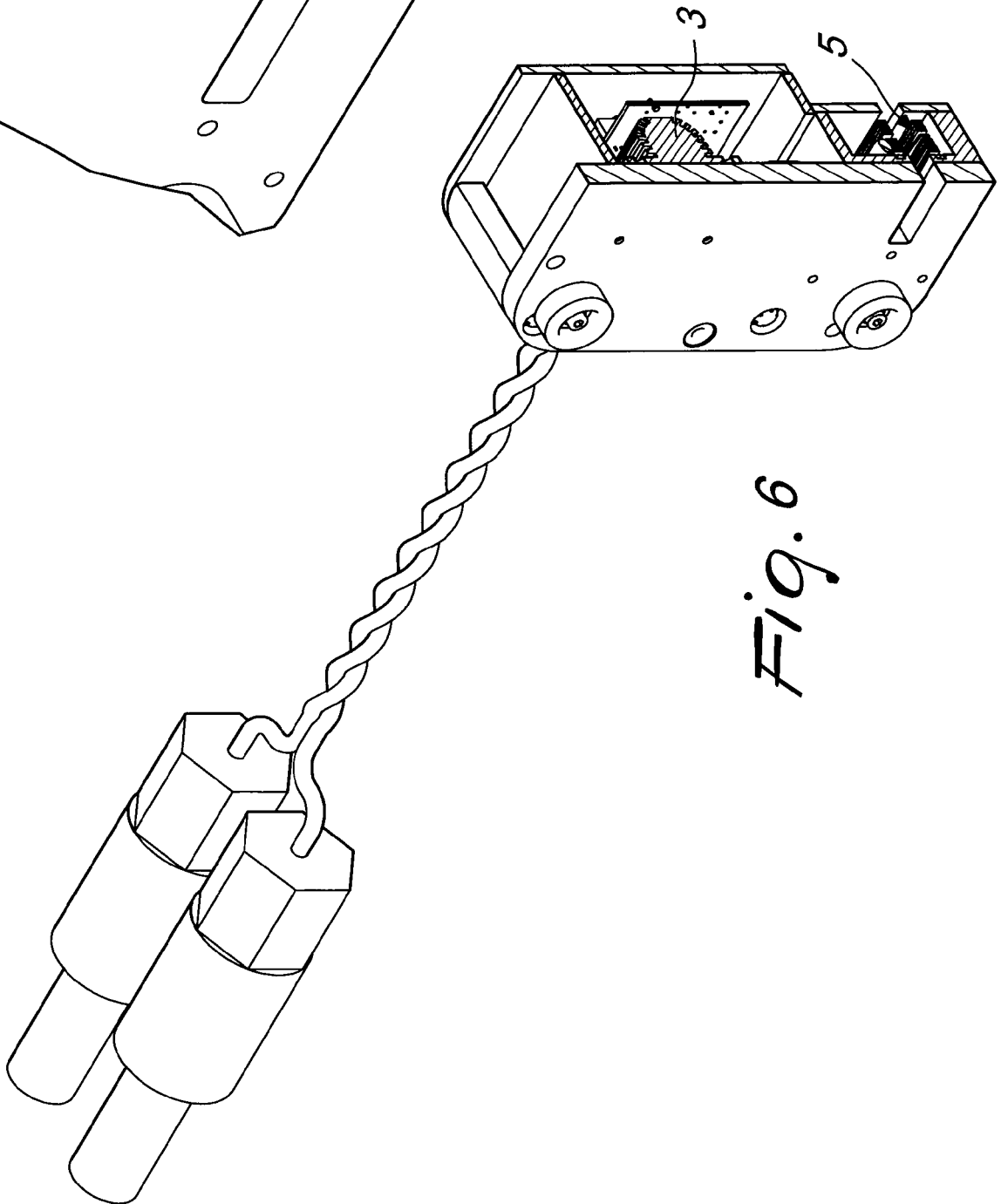
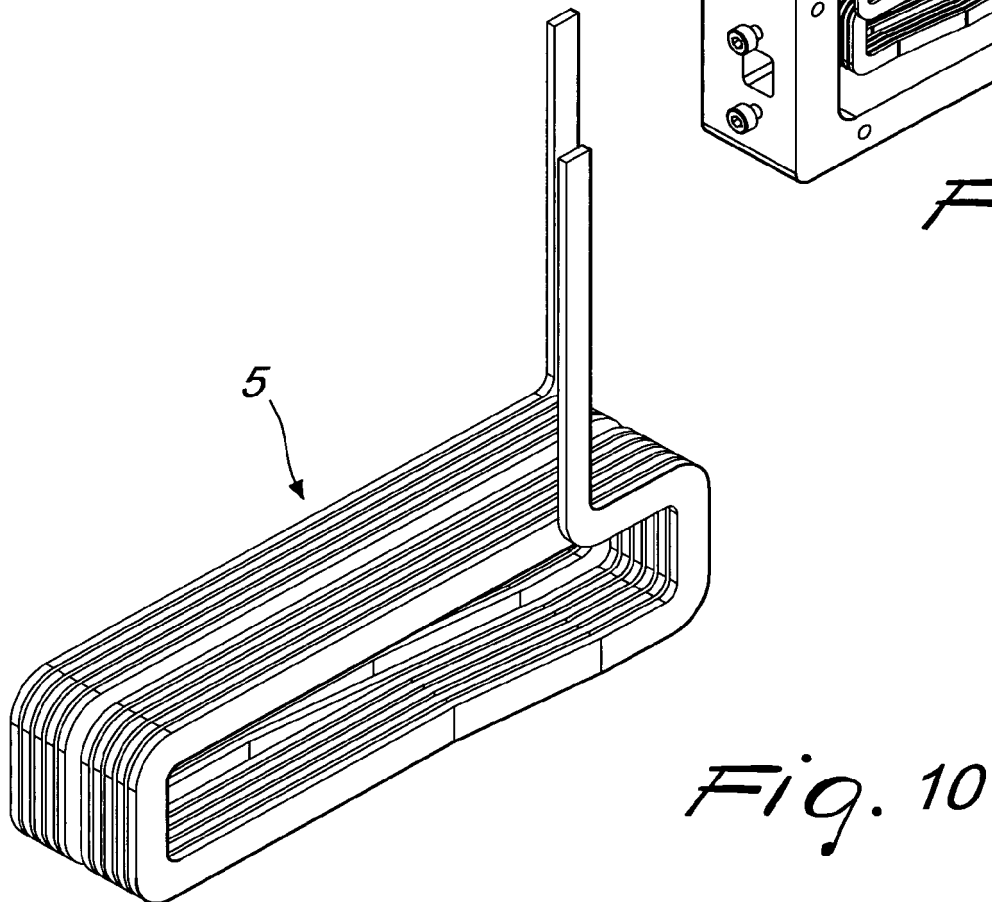
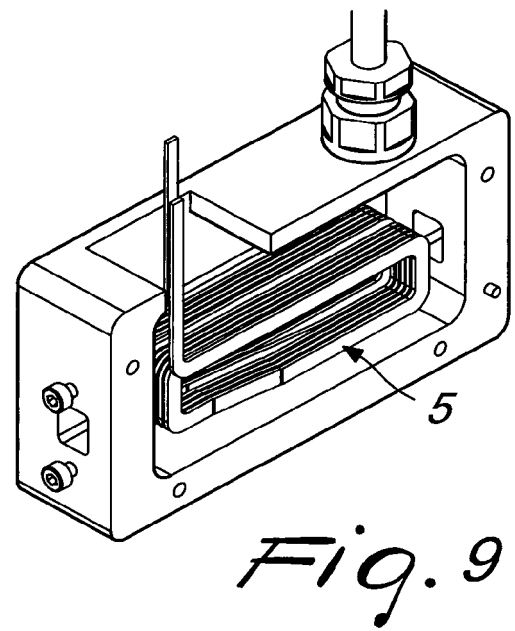
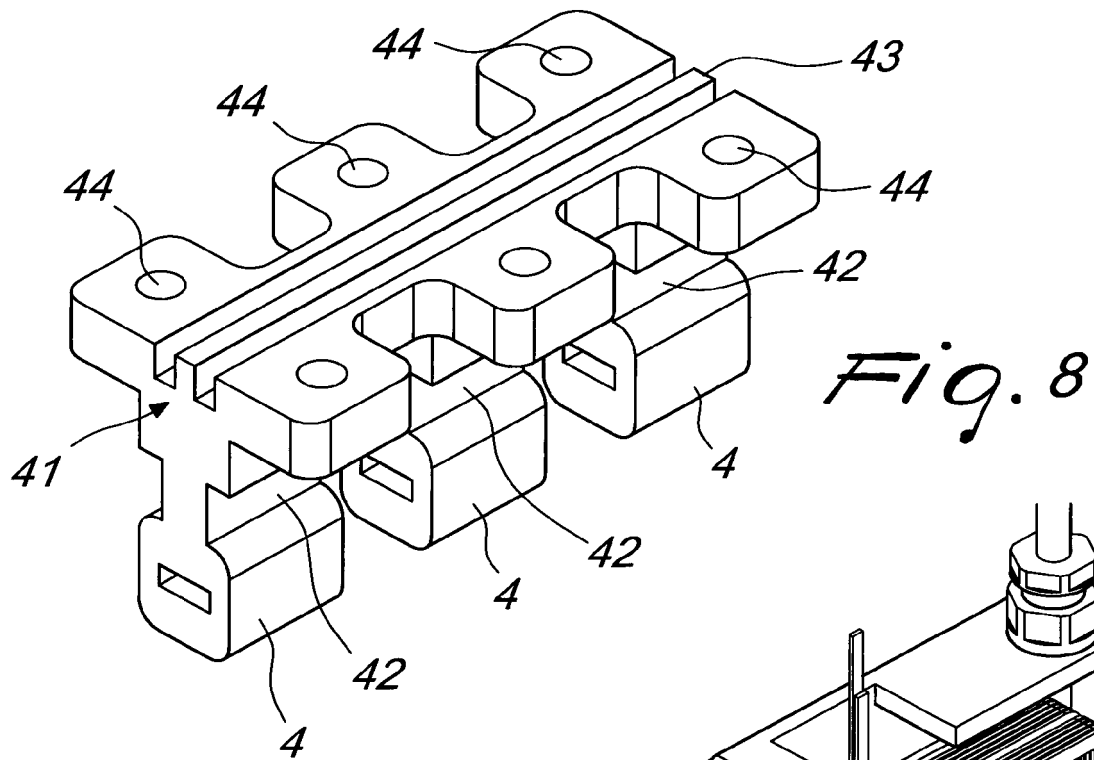


Fig. 6



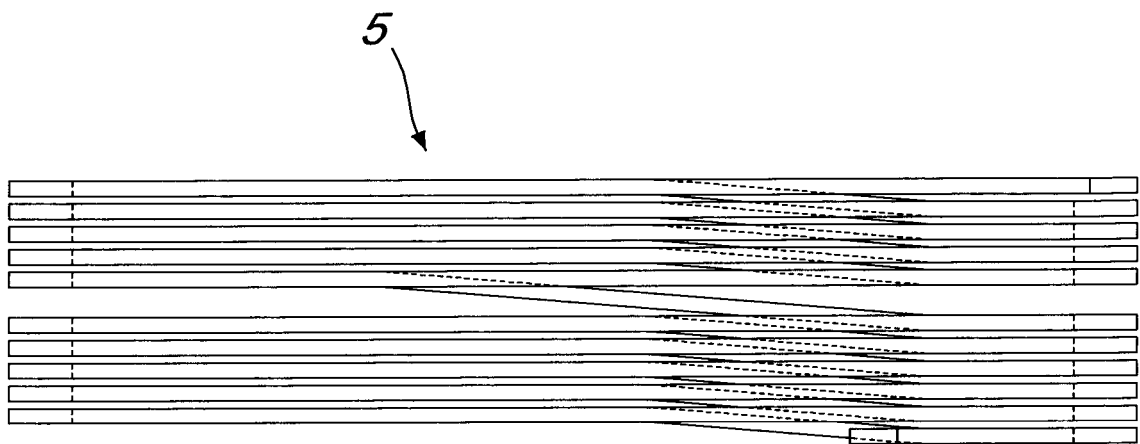


Fig. 11

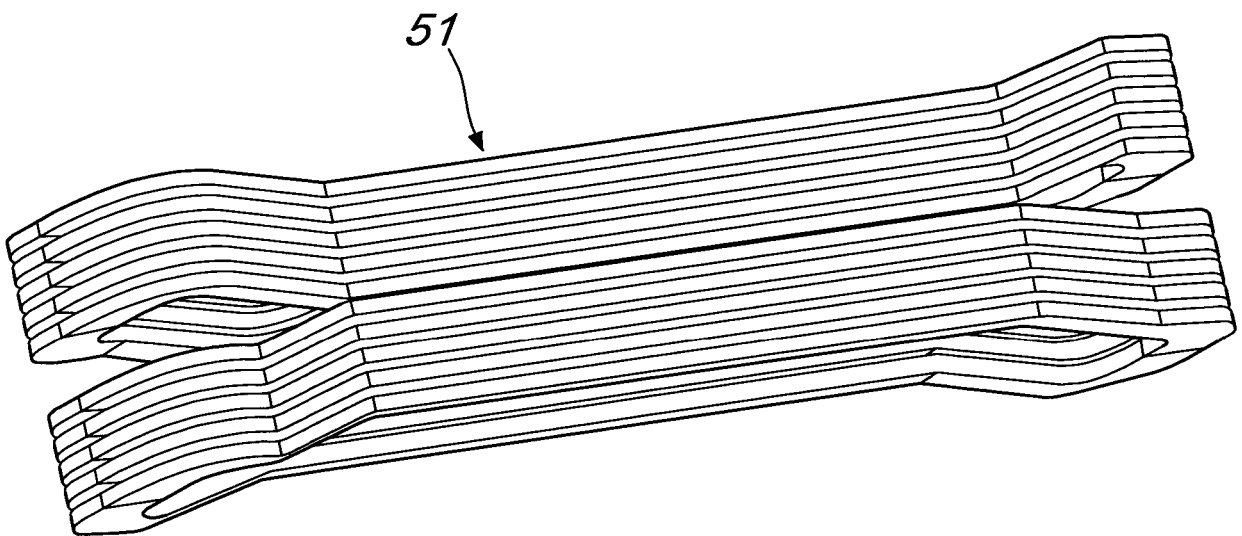


Fig. 12

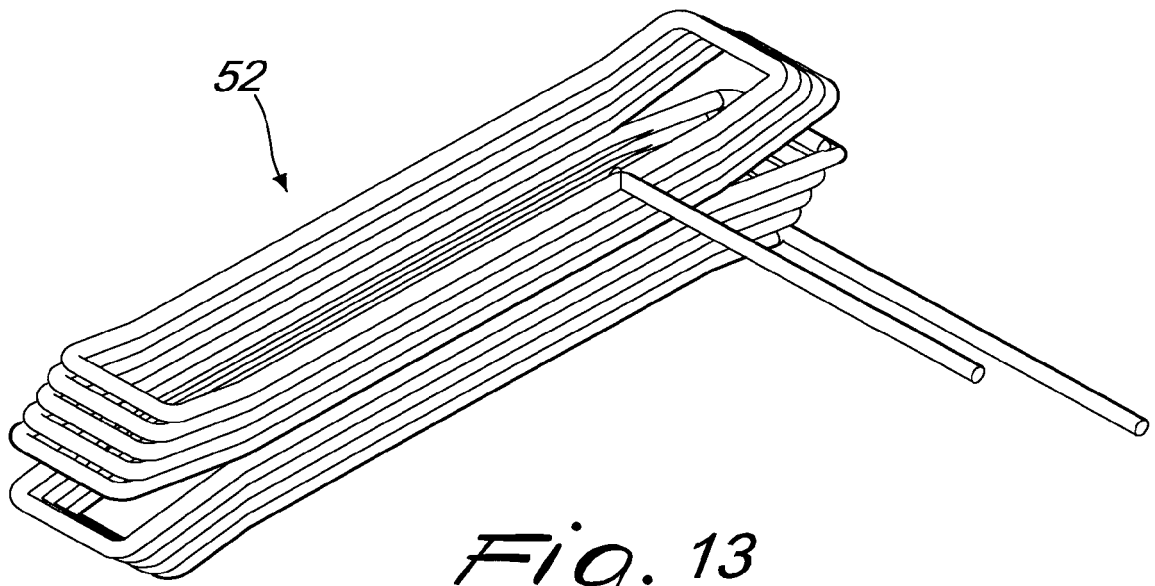


Fig. 13

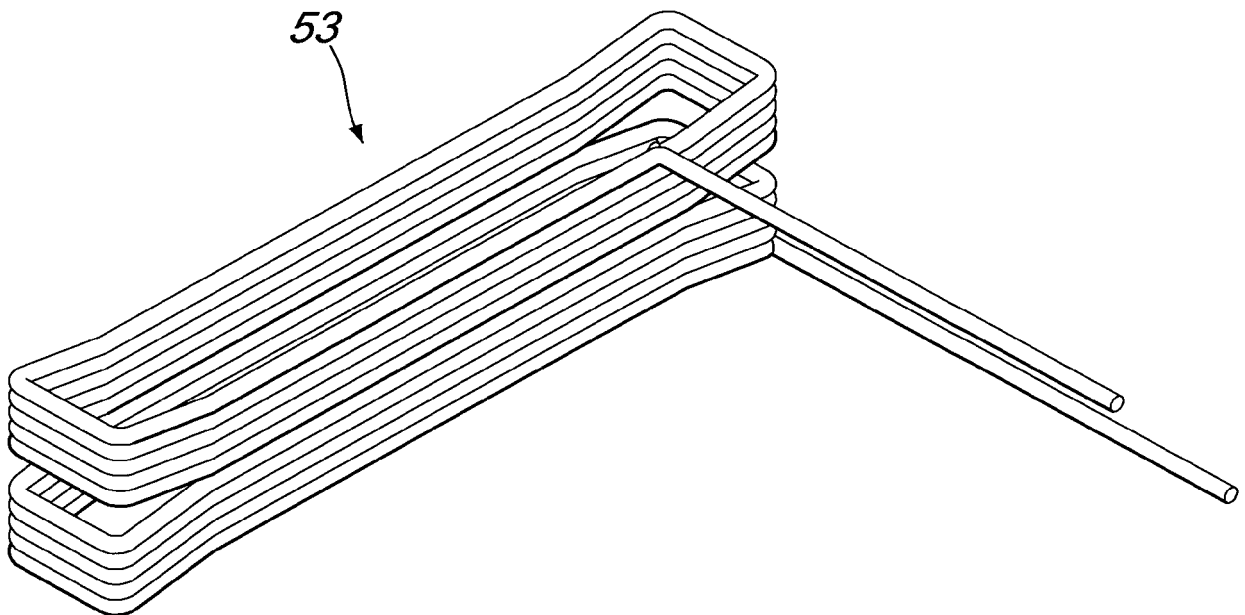


Fig. 14



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Application Number
EP 17 00 1884

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 23 March 2018	Examiner Tano, Valeria
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