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(54) **IMPROVEMENTS IN MAGNETIC RELAYS**

(57) A method for manufacturing a magnetic relay for low-voltage electric systems, characterised in that it comprises the following steps:
- providing a semi-finished structure of magnetic relay, wherein said semi-finished structure comprises a magnetic circuit including a magnetic yoke and a magnetic armature,
wherein said magnetic yoke comprises a pair of yoke plates mechanically interconnected in such a way to be spaced one from another by a gap region, wherein said magnetic armature is movable between a coupled position, at which said magnetic armature is in contact with said yoke plates, and an uncoupled position, at which said magnetic armature is spaced apart from said yoke plates;
- inserting a magnetic material having a relative magnetic permeability value $\mu_r >= 2$ in the gap region between said yoke plates.

In a further aspect, the present invention relates to a magnetic relay including a quantity of magnetic material inserted between the yoke plates of the magnetic circuit.

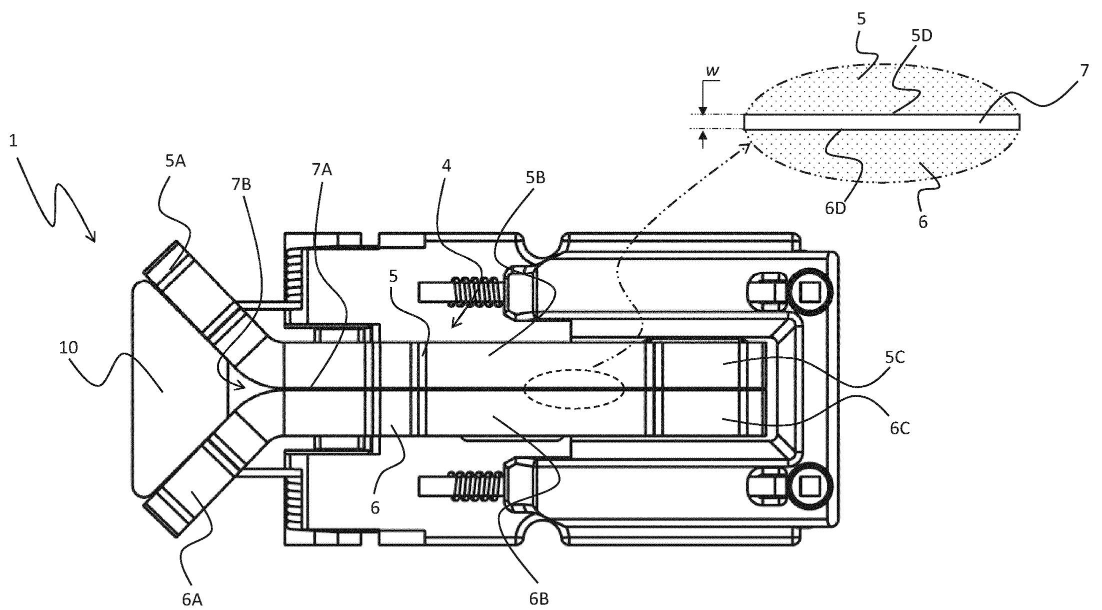

FIG. 2

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Description

[0001] The present invention concerns the technical field of magnetic relays for electric systems. In particular, the present invention, relates to a method for manufacturing a magnetic relay for low-voltage electric systems. In a further aspect, the present invention relates also to a magnetic relay for low-voltage electric systems.

[0002] As is known, a magnetic relay is normally designed to provide a mechanical actuation force to an external mechanism (e.g. the switching mechanism of a low-voltage electric or electronic protection device) in response to receiving an input electrical signal (normally a current signal).

[0003] An example of magnetic relay is described in EP0829896A2. According to the solution proposed in this document, the magnetic relay includes an actuation coil and a permanent magnet magnetically coupled to a magnetic circuit formed by a magnetic yoke and a movable magnetic armature. The magnetic yoke includes a pair of yoke plates arranged in parallel and spaced apart one from another in such a way that an airgap of about 50-100 μm is formed between them. Such an airgap region basically operates as a shunt for the magnetic circuit. The magnetic armature is rotatable about a suitable pivot axis and it is arranged, so as to bridge the spaced yoke plates when the above-mentioned magnetic circuit is closed. The magnetic armature is mechanically coupled to a preloaded spring exerting a mechanical torque directed to rotate the armature away from the polar surfaces.

[0004] In normal conditions, the magnetic armature is maintained coupled to the yoke plates due to the magnetic force deriving from the magnetic flux generated by the permanent magnet. When a trip of the magnetic relay is required, for example due to a fault current detected in an electric line, a trip current is fed into the actuation coil. The trip current generates a temporary magnetic flux in opposition to the one generated by the permanent magnet to decrease the total resulting magnetic force and causes the armature to rotate away from the yoke plates due to the mechanical force exerted by the preloaded spring. In doing so, the armature pushes a plunger, which thus exerts a mechanical actuation force on an external mechanism operatively associated to the magnetic relay.

[0005] The magnetic relays of the type described in EP0829896A2 generally show relevant advantages in terms of structural compactness and operation efficiency. However, their production at industrial level still shows some critical aspects, mostly linked to the difficulty of ensuring a satisfactory uniformity of the operating parameters (in particular the electrical parameters) characterizing the manufactured magnetic relays.

[0006] The main aim of the present invention is to provide a magnetic relay and method for manufacturing a magnetic relay for low-voltage electric systems, which allows solving or mitigating the above-mentioned technical problems.

[0007] More particularly, it is an object of the present invention to provide a manufacturing method, which ensures high process capability, uniformity and repeatability levels of the operating parameters characterizing the behaviour of the magnetic relays.

[0008] Another object of the present invention is to provide a manufacturing method that is relatively easy to carry out at industrial level, at competitive costs with respect to corresponding solutions of the state of the art.

[0009] In order to fulfill these aim and objects, the present invention provides a method for manufacturing a magnetic relay for low-voltage electric systems, according to the following claim 1 and the related dependent claims.

[0010] In a general definition, the manufacturing method of the invention comprises:

- providing a semi-finished structure of magnetic relay, which comprises at least a magnetic circuit including a magnetic yoke and a magnetic armature. Said magnetic yoke comprises a pair of yoke plates mechanically interconnected in such a way to be spaced one from another by a gap region. Said magnetic armature is movable between a coupled position, at which said magnetic armature is in contact with said yoke plates, and an uncoupled position, at which said magnetic armature is spaced apart from said yoke plates;
- inserting a magnetic material having a relative magnetic permeability value μ_r >= 2 between said yoke plates.

[0011] Preferably, said magnetic material is inserted in the gap region between the yoke plates. Preferably, said magnetic material has a relative magnetic permeability value between 10 and 40.

[0012] Preferably, the gap region between the yoke plates has a width between 0,8 mm and 1,2 mm. Preferably, said semi-finished structure comprises a permanent magnet configured to feed said magnetic circuit with a permanent magnetic flux, when said permanent magnet is in a magnetized condition.

[0013] Preferably, said semi-finished structure comprises an actuation coil configured to feed said magnetic circuit with a magnetic field having a direction opposite to the permanent magnetic field generated by said permanent magnet, when a current circulates through said actuation coil. Preferably, said magnetic material is inserted in a portion of internal volume between said permanent magnet and said yoke plates.

[0014] According to some embodiments of the invention, the step of inserting said magnetic material between the yoke plates comprises injecting said magnetic material between the yoke plates. According to other embodiments of the invention, the step of inserting said magnetic material between the yoke plates comprises welding said magnetic material between the yoke plates. In a further aspect, the present invention relates to a magnetic relay for low-voltage electric systems, according to the following claim 18.

[0015] In a general definition, the magnetic relay of the invention comprises at least a magnetic circuit including a magnetic yoke and a magnetic armature. Said magnetic yoke comprises a pair of yoke plates mechanically interconnected in such a way to be spaced one from another by a gap region. Said magnetic armature is movable between a coupled position, at which said magnetic armature is in contact with said yoke plates, and an uncoupled position, at which said magnetic armature is spaced apart from said yoke plates. Said magnetic yoke comprises a quantity of magnetic material, which has a relative magnetic permeability value μ_r>=2, inserted between said yoke plates.

[0016] Preferably, said magnetic material is inserted in the gap region between the yoke plates. Preferably, said magnetic material has a relative magnetic permeability value between 10 and 40.

[0017] Preferably, the gap region between the yoke plates has a width between 0,8 mm and 1,2 mm. Preferably, said magnetic relay comprises a permanent magnet configured to feed said magnetic circuit with a permanent magnetic flux, when said permanent magnet is in a magnetized condition.

[0018] Preferably, said magnetic relay comprises an actuation coil configured to feed said magnetic circuit with a magnetic field having a direction opposite to the permanent magnetic field generated by said permanent magnet, when a current circulates through said actuation coil. Preferably, said magnetic material is inserted in a portion of internal volume between said permanent magnet and said yoke plates.

[0019] According to some embodiments of the invention, the magnetic material between the yoke plates is injected.

[0020] According to other embodiments of the invention, the magnetic material between the yoke plates is welded.

[0021] Further characteristics and advantages of the invention will become apparent from the detailed description of exemplary embodiments, which are illustrated only by way of non-limitative examples in the accompanying drawings, wherein:

Figures 1-3 are schematic views showing a semi-finished structure of magnetic relay provided in the manufacturing method, according to the invention;

Figures 4-9 are schematic views showing different steps of the manufacturing method, according to the invention;

Figure 10 is a schematic view showing a magnetic relay, according to the invention.

[0022] With reference to the cited figures, the present invention relates to a method for manufacturing a magnetic relay for low-voltage electric systems, i.e. operating at voltage levels lower than 1 kV AC and 1.5 kV DC.

[0023] The manufacturing method of the invention comprises a step of providing a semi-finished structure 1 of magnetic relay (figure 4).

[0024] Figures 1-3 show the semi-fished structure 1, according to an embodiment of the invention. The semi-finished structure 1 comprises an insulating housing 2 defining an internal volume 3 and preferably made of an electrically insulating plastic material.

[0025] Preferably, the insulating housing 2 comprises a base portion 2B and a cover portion 2A, which can be mutually joined through connection means of known type, e.g. screws or snap-fit arrangements.

[0026] The insulating housing 2 comprises (preferably at the base portion 2B) an access port 20, through which it is possible to access the internal volume 3 of the semi-finished structure. As it will better emerge in the following, the access port 20 can be suitably exploited for introducing a suitable process tool in the internal volume 3.

[0027] The semi-finished structure 1 comprises a magnetic circuit 4, 8 accommodated in the internal volume 3.

[0028] Such a magnetic circuit comprises a fixed magnetic yoke 4 including a pair of yoke plates 5, 6 made of ferromagnetic material (e.g. a nickel-iron alloy or the like), which are mechanically interconnected in such a way to be spaced one from another by a gap region 7.

[0029] Preferably, the yoke plates 5, 6 are arranged so that they have parallel facing surfaces 5D, 6D extending perpendicularly to side walls 21 of the insulating housing 2, along the shortest dimension of this latter.

[0030] The parallel facing surfaces 5D, 6D of the yoke plates define the gap region 7. The width *w* of the gap region 7 therefore corresponds to the distance between said parallel surfaces.

[0031] According to an aspect of the invention, the gap region 7 has an extended width *w* compared to the traditional solutions of the state of the art (like the one disclosed in EP0829896A2). Conveniently, the gap region 7 has a sufficient width to allow the insertion of a process tool to insert a magnetic material, as it will better emerge from the following.

[0032] Preferably, the gap region 7 has a width *w* between 0,8 mm and 1,2 mm, more preferably of 1 mm.

[0033] This solution remarkably simplifies the arrangement of the magnetic yoke 4.

[0034] Generally, capacitance measurements between the yoke plates 5, 6 are needed to set the mutual distance between said yoke plates. Such capacitance measurements are affected by smaller relative errors, if the gap region 7 has an extended width. Additionally, the influence of possible surface defects or shape distortions of the yoke plates 5, 6 is greatly reduced. In practice, the yoke plates 5, 6 can be positioned more easily, which allows reducing the manufacturing time and costs compared to the traditional solutions of the state of the art. Preferably, one or more fixing elements 15 are welded to the yoke plates 5, 6 to fix these latter together (figure 3). Additional welding points or seams between the yoke plates 5, 6 may be provided to increase the robustness and stability of the magnetic yoke 4.

[0035] In the embodiment shown in figures 1-3, the yoke plate 5 has a first main portion 5B, a first end portion 5A bent relative to the main portion 5B and second L-shaped end portion 5C opposite to the first end portion 5A. The yoke plate 6 has a second main portion 6B, a third end portion 6A bent relative to the second main portion 6B and fourth U-shaped end portion 6C opposite to the third end portion 6A. The main portions 5B, 6B and the end portions 5C, 6C of the yoke plates 5, 6 include the parallel facing surfaces 5D, 6D defining the gap region 7. The end portions 5A, 6A of the yoke plates 5, 6 are instead bent according to opposite directions, so that the magnetic yoke 4 shows a V-shape at these end portions.

[0036] The magnetic circuit of the semi-finished structure 1 further comprises a movable magnetic armature 8. This latter is preferably formed by an elongated body (e.g. having a cuboid shape) of ferromagnetic material (e.g. a nickel-iron alloy or a similar material), which extends longitudinally along the yoke plates 5, 6 perpendicularly to the thickness of these latter. When the magnetic armature 8 is coupled to the yoke plates, a magnetic circuit having a U-shaped transversal section is formed (reference is made to an observation plane perpendicular to the magnetic armature and the yoke plates). As it is easy to understand, the spacing between the legs of such a U-shaped transversal section of the magnetic circuit 4, 8 forms the above-mentioned gap region 7.

[0037] In operation, the magnetic armature 8 can reversibly move between a coupled position (figure 1), at which it is in contact with the yoke plates, and an uncoupled position (not shown), at which it is spaced apart from the yoke plates. The coupled position of the magnetic armature corresponds to a closed condition of the magnetic circuit whereas the uncoupled position of the magnetic armature corresponds to an open condition of the magnetic circuit. The transition of the magnetic armature from a coupled position with the yoke plates to an uncoupled position from the yoke plates constitutes a trip event of the magnetic circuit.

[0038] The magnetic armature 8 comprises a first end 8A pivoted on a fixed support (e.g. a wall of the insulating housing 2) at a suitable rotation axis A (perpendicular to the extension plane of the yoke plates) and a second free end 8B, opposite to said first end (figures 1 and 3).

[0039] During the transition from a coupled position with the yoke plates to an uncoupled position from the yoke plates, the magnetic armature 8 rotates about the above-mentioned rotation axis, according to the rotation direction R1 (figure 1).

[0040] In the embodiment shown in figures 1-3, the semi-finished structure 1 comprises mechanical biasing means 12 mechanically coupled to the magnetic armature 8.

[0041] The mechanical biasing means 12 are configured to exert a suitable mechanical torque to the magnetic armature 8, which is directed in such a way to move said magnetic armature away from coupled position with the yoke plates. The intensity of the mechanical force exerted by the mechanical biasing means depends on the position of the magnetic armature relative to the yoke plates.

[0042] Preferably, the mechanical biasing means 12 are formed by one or more torsional springs coupled to the magnetic armature 8 and to a fixed support 10A (e.g. an internal support structure).

[0043] In the embodiment shown in figures 1-3, the semi-finished structure 1 comprises a movable plunger 13 mechanically coupled to the magnetic armature 8. The plunger 13 extends perpendicularly to the magnetic armature 8 (when this latter is in a coupled position with the yoke plates) and it passes through a suitable guidance hole (not designated) at the top portion 2A of the insulating housing 2.

[0044] The plunger 13 has a first free end 13A protruding outside the insulating housing and a second end 13B resting on the magnetic armature 8.

[0045] In operation, the plunger 13 can reversibly move along a translation axis perpendicular to the magnetic armature 8 between a rest position (figure 1) and an extracted position (not shown). The movable plunger 13 is in the above-mentioned rest position, when the magnetic armature 8 is in the above-mentioned coupled position with the yoke plates, while it is in the above-mentioned extracted position, when the magnetic armature 8 is in the above-mentioned uncoupled position from the yoke plates.

[0046] The plunger 13 moves from the rest position to the extracted position (direction D1 - figure 1), upon actuation by the magnetic armature 8, when this latter moves from the coupled position with the yoke plates to the uncoupled position from the yoke plates (direction R1). During the transition from the rest position to the extracted position (trip event), the plunger 13 can provide an actuation force to an external mechanism.

[0047] Preferably, the plunger 13 is formed by a cylindrical body of plastic material having an enlarged head at the second end 13B.

[0048] In the embodiment shown in figures 1-3, the semi-finished structure 1 comprises a permanent magnet 9 magnetically coupled to the magnetic circuit 4, 8 and configured to feed this latter with a permanent magnetic flux having a predefined direction, when said permanent magnet is in a magnetized condition.

[0049] The permanent magnet 9 is accommodated in the internal volume 3, preferably in a seat defined by the bent ends 5A, 6A of the yoke plates (figure 2). Preferably, the permanent magnet 9 has a prismoid structure, for example with a triangular or trapezoidal base area, which extends along an axis perpendicular to the magnetic armature 8 (when this latter is in a coupled position).

[0050] As it will better emerge from the following, according to some embodiments of the invention, in the semi-finished structure 1, the permanent magnet 9 is initially in a demagnetized condition. In this case, the permanent magnet 9 is brought in a magnetized condition at a later stage. A suitable magnetization tool 51 of known type (e.g. a magnetization coil) may be used for this purpose (figure 7).

[0051] In the embodiment shown in figures 1-3, the semi-finished structure 1 comprises an actuation coil 10 accommodated in the internal volume 3 and coupled to the magnetic circuit 4, 8.

[0052] In operation, the actuation coil 10 feeds the magnetic circuit 4, 8 with a magnetic flux, which has a direction opposite to the direction of the magnetic field generated by the permanent magnet 9, when a current circulates through said actuation coil according to a suitable direction.

[0053] Preferably, the actuation coil 10 includes a support structure 10A made of electrically insulating material, which is conveniently mounted on the U-shaped end 6C of the yoke plate 6, and an electrical winding 10B wound around said support structure (figure 3).

[0054] Conveniently, the actuation coil 10 comprises power supply terminals 11 electrically connected to the electrical winding 10B. The power supply terminals 11 protrude from the insulating housing 2, preferably passing through suitable holes (not shown) at the base portion 2B.

[0055] In general, for many aspects, the semi-finished structure 1 may be realized at industrial level according to manufacturing procedures of known type, preferably according to manufacturing procedures similar to those employed for manufacturing the magnetic relay disclosed in EP0829896A2.

[0056] Following the arrangement of the semi-finished structure 1, the manufacturing method of the invention comprises the step of adding a magnetic material M between the yoke plates 5 and 6 (figures 5-6, 8).

[0057] Preferably, the magnetic material M is inserted in the gap region (7) between the yoke plates, more preferably in a portion 7A of the gap region 7 located in proximity of the permanent magnet 9.

[0058] Preferably, the magnetic material M is inserted also in a portion 7B of internal volume between the permanent magnet 9 and the yoke plates, at the bent ends 5A, 6A of these latter.

[0059] For the sake of clarity, the material M is defined "magnetic" since it is sensitive to magnetic fields and it generally has a relative magnetic permeability value μ_r>=1.

[0060] According to the invention, however, the magnetic material M has a relative magnetic permeability value μ_r >= 2. Preferably, the relative magnetic permeability value μ_r of the magnetic material M is in the order of few tens, for example in a range between 10 and 40. According to some embodiments of the invention, the magnetic material M is inserted between the yoke plates 5, 6 through an injection process.

[0061] The injected magnetic material M may be a viscous magnetic epoxy resin, for example an epoxy resin charged with powder of ferromagnetic material. This solution is particularly advantageous as it allows reducing the number of possible welding points between the yoke plates. The arrangement of the yoke plate 4 thus results simplified.

[0062] As an alternative, the injected magnetic material M may be a melted material having the above-illustrated magnetic properties.

[0063] The magnetic material M can be injected through a suitable process tool 50 (for example an injection needle), which is conveniently inserted through the access port 20 of the insulating housing 2. The magnetic material M is conveniently injected at a melted state and it solidifies shortly after having come in contact with the yoke plates 5 and 6 or, if necessary, upon a suitable curing process.

[0064] According to other embodiments of the invention, the magnetic material M is inserted between the yoke plates 5, 6 through a welding process, preferably a laser welding process. In practice, the material M is inserted between the yoke plates by forming suitable seam regions between said yoke plates. The quantity of welded magnetic material may be regulated by controlling the size and the shape of these seam regions.

[0065] The welded magnetic material M may be a suitable filler material having the above-illustrated magnetic properties.

[0066] The magnetic material M can be welded through a suitable process tool 50 (for example a laser welding head), which is conveniently inserted through the access port 20 of the insulating housing 2.

[0067] The insertion of a magnetic material M between the yoke plates 5, 6 provides relevant advantages.

[0068] On one hand, this solution allows the magnetic circuit 4, 8 to operate efficiently even if the gap region 7 has an extended width *w*, as explained above.

[0069] On the other hand, as it will be more apparent from the following, the insertion of a magnetic material M allows tuning the operating parameters (in particular the electrical parameters) of the magnetic relay in a very accurate manner. The manufactured magnetic relays thus show a reduced spread of the operating parameters characterizing their behaviour.

[0070] Furthermore, the insertion of magnetic material M between the yoke plates facilitates compensation of possible variations of the magnetic reluctance of the magnetic circuit 4, 8 due to variations of the operating temperature of the magnetic relay. The magnetic circuit 4, 8 includes a paramagnetic material: therefore, it shows a temperature dependent behaviour more similar to the temperature behaviour of the ferromagnetic material of the magnetic yoke 4 and of the magnetic armature 8 unlike an airgap (typically present between the yoke plates in the traditional solutions of the state of the art) which has substantially a temperature independent behaviour. Therefore, self-compensation of the temperature drifts of the magnetic relay is made easier and more effective.

[0071] According to some embodiments of the invention (figures 4-5, 7, 9-10), the step of inserting the magnetic material M includes inserting a predefined quantity of magnetic material M or, alternatively, a quantity of magnetic material M established from time to time. In both these cases, the quantity of material M to be inserted may be determined based on experimental tests carried out on preceding lots of magnetic relays.

[0072] According to these embodiments, if the permanent magnet 9 is in an initial demagnetized condition, the manufacturing method of the invention includes the step of magnetizing the permanent magnet 9 to cause this latter to pass from the initial demagnetized condition to a magnetized condition (figure 7). In principle, the magnetization of the permanent magnet 9 may be carried out before or following the insertion of the magnetic material M (as shown in figure 7).

[0073] According to these embodiments, the manufacturing method of the invention includes the step of closing the access port 20 of the insulating housing 2, when the insertion of the magnetic material M is completed (figures 9-10). This allows sealing the internal volume 3 from the outer environment. The sealing of the access port 20 may be carried out through a suitable welding process of known type. In principle, the access port 20 may be closed before or following the magnetization of the permanent magnet 9 (as shown in figure 7).

[0074] According to other embodiments of the invention (figures 4, 6, 7, 9-10), the step of inserting the magnetic material M includes a first insertion procedure that allows tuning the quantity of magnetic material M to be inserted based on measurements of some electrical parameters of the magnetic relay.

[0075] The first insertion procedure can be carried out when the semi-finished structure 1 has the permanent magnet 9 in an initial demagnetized condition (figure 4).

[0076] The first insertion procedure comprises the step of maintaining the magnetic armature 8 in a coupled position with the yoke plates 5, 6. Since the permanent magnet 9 is demagnetized, this can be achieved by applying a predefined force on the plunger 13 through a suitable mechanical tool.

[0077] The first insertion procedure comprises the step of feeding the power supply pins 11 of the actuation coil 10 with a first current I_1 (figure 6), preferably of AC type. The first current I_1 has a first predefined RMS value I_{T1} corresponding to the expected minimum RMS value that a current circulating along the actuation coil 10 must have to cause a trip event (transition of the magnetic armature from a coupled position with the yoke plates to an uncoupled position from the yoke plates).

[0078] The first insertion procedure comprises the step of measuring a first induced voltage Vi at the power supply pins 11, while the actuation coil 10 is fed with the first current I_1 (figure 6). Conveniently, RMS measurements of the voltage Vi are carried out.

[0079] The first insertion procedure comprises the step of inserting the magnetic material M between the yoke plates, while feeding the first current I_1 and measuring the first voltage Vi. The magnetic material M is inserted until the first voltage Vi measured at the power supply pins 20 reaches a predefined RMS value V_{TH}.

[0080] According to the above-illustrated first insertion procedure, the magnetic reluctance of the magnetic circuit 4, 8 is tuned through the arrangement of the magnetic material 9, until target electrical parameters are reached.

[0081] The first insertion procedure thus allows compensating possible deviations of the electric parameters of the magnetic relay, which are caused by material, manufacturing or mounting variabilities and/or tolerances and/or defects of the magnetic circuit 4, 8 and the actuation coil 10. It is evidenced how such a compensation action results particularly effective as it is carried out when the magnetic circuit 4, 8 and the actuation coil 10 are already installed in their definitive operating positions.

[0082] According to these embodiments of the invention, following the execution of the above-mentioned first insertion procedure, the manufacturing method may comprise the step of magnetizing the permanent magnet 9 to cause this latter to pass from the initial demagnetized condition to a magnetized condition (figure 7).

[0083] Additionally, the manufacturing method may comprise the step of closing the access port 20 of the insulating housing 2, when the insertion of the magnetic material M is completed (figures 9-10). In principle, the access port 20 may be closed before or following the magnetization of the permanent magnet 9 (as shown in figure 7).

[0084] According to some embodiments of the invention (figures 7-10), the step of inserting the magnetic material M includes a second insertion procedure that allows further calibrating the quantity of magnetic material M to be inserted based on measurements of some electrical parameters of the magnetic relay.

[0085] The second insertion procedure can be advantageously carried out when the semi-finished structure 1 has the permanent magnet 9 in a magnetized condition and a certain quantity of magnetic material M has already been inserted in the gap region 7. Further, in this case, the semi-finished structure is conveniently pre-calibrated at a tripping power close to the power control point (e.g. 25μYA).

[0086] The second insertion procedure comprises the step of feeding the power supply pins 11 of the actuation coil 10 with a second current I_2 (figure 8), preferably of AC type. Conveniently, the second current I_2 has a second predefined RMS value I_{T2} corresponding to the expected RMS value that a current circulating along the trip coil 10 must have to cause a trip event of the magnetic relay. Conveniently, also the second predefined RMS value I_{T2} can be established through suitable tests.

[0087] The second insertion procedure comprises the step of measuring a second induced voltage V_2 at the power supply pins 11 of the trip coil 10, while the trip coil 10 is fed with the second current I_2 (figure 8).

[0088] The second insertion procedure comprises the step of inserting the magnetic material M between the yoke plates, while feeding the second current I_2 and measuring the second voltage V_2. The magnetic material M is inserted until a trip event (i.e. a transition of the magnetic armature 8 from a coupled position with the yoke plates 5 and 6 to an uncoupled position from the yoke plates 5 and 6 is identified by observing the measured second voltage V_2. A trip event of the magnetic armature 8 can be easily identified since the measured second voltage V_2 shows a sudden perturbation when such a trip event occurs.

[0089] The second insertion procedure allows tuning the electrical parameters of the magnetic relay when the permanent magnet 9 is already in a magnetized condition.

[0090] The magnetic reluctance of the magnetic circuit 4, 8 is tuned through the arrangement of the magnetic material M, until a trip event of the magnetic relay is achieved.

[0091] The second insertion procedure therefore allows compensating possible variations of the electric parameters of the magnetic relay due to material, manufacturing or mounting variabilities and/or tolerances and/or defects. Also in this case, such a compensation action is particularly effective as it is carried out when the permanent magnet 9 and the remaining components are already installed in their definitive operating position and the permanent magnet 9 is already magnetized.

[0092] According to these embodiments of the invention, following the execution of the above-illustrated second insertion procedure, the manufacturing method comprises the step of closing the access port 20 of the insulating housing 2, when the arrangement of the magnetic material M is completed (figures 9-10).

[0093] Figure 10 shows a magnetic relay 100, according to the invention. The magnetic relay 100 is preferably manufactured through the manufacturing method, according to the invention. In principle, however, such a magnetic relay could also be manufactured through different manufacturing methods.

[0094] The magnetic relay 100 is particularly adapted for use in low-voltage switchboards or electric lines. As an example, the magnetic relay can be included or operatively associated to an electronic protection device, e.g. a residual current device (RCD) or a similar device, to actuate a suitable switching mechanism of said electronic protection device, when a fault current is detected in an electric line.

[0095] In a general definition, the magnetic relay 100 comprises at least a magnetic circuit including a magnetic yoke 4 and a magnetic armature 8. The magnetic yoke 4 comprises a pair of yoke plates 5 and 6 mechanically interconnected in such a way to be spaced one from another by gap region 7, which preferably has a width w between 0,8 mm and 1,2 mm.

[0096] The magnetic armature 8 is movable between a coupled position, at which it is in contact with said yoke plates, and an uncoupled position, at which it is spaced apart from said yoke plates. The magnetic yoke 4 comprises a quantity of magnetic material inserted between the yoke plates. The inserted magnetic material has a relative magnetic permeability value μ_r>= 2. The magnetic material is preferably inserted in the gap region 7 between the yoke plates.

[0097] In the embodiment shown in figure 10, the magnetic relay 100 comprises an insulating housing 2 defining an internal volume 3 of said magnetic relay. The magnetic circuit 4, 8 is accommodated in said internal volume.

[0098] The magnetic relay 100 comprises a permanent magnet 9 accommodated in the internal volume 3 and coupled to the magnetic circuit 4, 8. The permanent magnet 9 is configured to feed the magnetic circuit 4, 8 with a permanent magnetic field having a predefined direction.

[0099] The magnetic material M is preferably inserted in a portion 7A of the gap region 7, which is located in proximity of the permanent magnet 9.

[0100] Preferably, the magnetic material M is inserted also in a portion 7B of internal volume, which is located between the permanent magnet 9 and the yoke plates.

[0101] The magnetic relay 100 comprises an actuation coil 10 accommodated in the internal volume 3 and coupled to the magnetic circuit 4, 8. The actuation coil 10 is configured to feed the magnetic circuit 4, 8 with a magnetic field having a direction opposite to the permanent magnetic field generated by the permanent magnet 9, when a current circulates through said actuation coil according to a suitable direction.

[0102] The magnetic relay 100 comprises mechanical biasing means 12 accommodated in the internal volume 3. The mechanical biasing means 12 are mechanically coupled to the magnetic armature 8 and configured to exert, on said magnetic armature, a suitable mechanical torque directed to move it away from the coupled position with the yoke plates.

[0103] The magnetic relay 100 comprises a movable plunger 13 protruding from the insulating housing 2 and mechanically coupled to the magnetic armature 8 in such a way to be actuated by said magnetic armature when said magnetic armature moves from a coupled position with the yoke plates to an uncoupled position with the yoke plates.

[0104] The above-mentioned components of the magnetic relay 100 can be realized in practice as illustrated above in connection to the semi-finished structure 1.

[0105] The general operation of the magnetic relay 100 is substantially similar to the corresponding devices of the state of the art.

[0106] In normal conditions, the magnetic armature 8 is maintained coupled to the yoke plates 5, 6 due to the magnetic force deriving from the magnetic flux generated by the permanent magnet 9. When a trip event of the magnetic relay is required, for example due to a fault current detected in an electric line, a trip current is fed into the actuation coil 10. The trip current generates a temporary magnetic flux that weakens the permanent magnetic flux generated by the permanent magnet 9 and causes the armature 8 to move away from the yoke plates

5, 6 due to the mechanical force exerted by the mechanical biasing means 12. In doing so, the magnetic armature 8 pushes the plunger 13 towards an extracted position. The plunger 13 can thus exert an actuation force on an external mechanism operatively associated to the magnetic relay.

[0107] In practice, it has been found that the manufacturing method and the magnetic relay, according to the invention, fully achieves the intended aim and objects.

[0108] The manufacturing method of the invention ensures to achieve a high uniformity and repeatability of the operating parameters characterizing the behaviour of the manufactured magnetic relays.

[0109] In particular, the magnetic relays of the invention show a reduced spread of their electrical parameters (in particular input impedance, trip power) compared to the traditional devices of the state of the art.

[0110] The magnetic relays of the invention ensure high quality performances, which makes easier and cheaper the electric systems intended to incorporate them, in particular the protection devices (e.g. RCDs) operatively associated to or including said magnetic relays. As an example, the design of the current transformer, which is normally included in said protection devices, is greatly simplified.

[0111] The manufacturing method of the invention is relatively easy to carry out at industrial level. A suitable industrial equipment for inserting the magnetic material M and, at the same time, carrying out the requested test measurements at the power supply pins 11 of the actuation coil 10 can be easily realized for industrial purposes without significant design efforts.

[0112] The manufacturing method of the invention thus generally results less expensive and with a higher yield compared to the traditional manufacturing methods of the state of the art.

[0113] The magnetic relays of the invention thus have overall industrial costs that are very competitive in comparison to similar devices of the state of the art.

Claims

1. A method for manufacturing a magnetic relay (100) for low-voltage electric systems, **characterised in that** it comprises the following steps:

- providing a semi-finished structure (1) of magnetic relay, wherein said semi-finished structure comprises a magnetic circuit including a magnetic yoke (4) and a magnetic armature (8),

  wherein said magnetic yoke (4) comprises a pair of yoke plates (5, 6) mechanically interconnected in such a way to be spaced one from another by a gap region (7), wherein said magnetic armature (8) is movable between a coupled position, at which said magnetic armature is in contact with said yoke plates, and an uncoupled position, at which said magnetic armature is spaced apart from said yoke plates;

- inserting a magnetic material (M) between said yoke plates, said magnetic material having a relative magnetic permeability value μ_r>= 2.

2. Method, according to claim 1, **characterised in that** said magnetic material (M) is inserted in the gap region (7) between the yoke plates.

3. Method, according to one of the previous claims, **characterised in that** said magnetic material (M) has a relative magnetic permeability value between 10 and 40.

4. Method, according to one of the previous claims, **characterised in that** said gap region (7) has a width between 0,8 mm and 1,2 mm.

5. Method, according to one of the previous claims, **characterised in that** said semi-finished structure (1) comprises:

- a permanent magnet (9) configured to feed said magnetic circuit (4, 8) with a permanent magnetic flux, when said permanent magnet is in a magnetized condition;
- an actuation coil (10) configured to feed said magnetic circuit (4, 8) with a magnetic field having a direction opposite to the permanent magnetic field generated by said permanent magnet, when a current circulates through said actuation coil.

6. Method, according to claim 5, **characterised in that** said magnetic material (M) is inserted in a portion (7B) of internal volume between said permanent magnet (9) and said yoke plates (5, 6).

7. Method, according to one of the claims from 5 to 6, **characterised in that** said permanent magnet (9) is in a demagnetized condition.

8. Method, according to claim 7, **characterised in that** the step of inserting said magnetic material comprises a first insertion procedure including the following steps:

- maintaining said magnetic armature (8) in a coupled position with the yoke plates (5, 6);
- feeding a first current (Ii) at power supply pins (11) of said actuation coil, wherein said first current has a first predefined RMS value (I_{T1});
- measuring a first voltage (Vi) at said power supply pins (11) while feeding said actuation coil

with said first current;

- inserting said magnetic material (M) while feeding said first current (Ii) and measuring said first voltage (Vi), wherein magnetic material is inserted until the first voltage (Vi) measured at said power supply pins (11) reaches a predefined RMS value (V_{TH}).

9. Method, according to one of the claims from 6 to 8, **characterised in that** it comprises, following the insertion of said magnetic material (M), the step of magnetizing said permanent magnet (9) to cause said permanent magnet to pass from said demagnetized condition to a magnetized condition.

10. Method, according to claim 9, **characterised in that** the step of inserting said magnetic material comprises a second insertion procedure including the following steps:

- feeding a second current (I_2) at power supply pins (11) of said actuation coil, wherein said second current has a second predefined RMS value (I_{T2});
- measuring a second voltage (V_2) at said power supply pins (11) while feeding said actuation coil with said second current;
- inserting said magnetic material (M) while feeding said second current (I_2) and measuring said second voltage (V_2), said magnetic material being inserted until a transition of said magnetic armature (8) from said coupled position to said uncoupled position is detected by observing the measured second voltage (V_2).

11. Method, according to one of the previous claims, **characterised in that** said semi-finished structure (1) comprises an insulating housing (2) defining an internal volume (3).

12. Method, according to claim 11, **characterised in that** said magnetic material (M) is inserted between the yoke plates by means of a process tool (50) passing through an access port (20) of said insulating housing (2).

13. Method, according to claim 12, **characterised in that** it comprises the step of closing the access port (20) of said insulating housing (2), when the insertion of said magnetic material (M) is completed.

14. Method, according to one of the previous claims, **characterised in that** said semi-finished structure (1) comprises mechanical biasing means (12) configured to exert, on said magnetic armature (8), a mechanical torque directed to move said magnetic armature away from said coupled position.

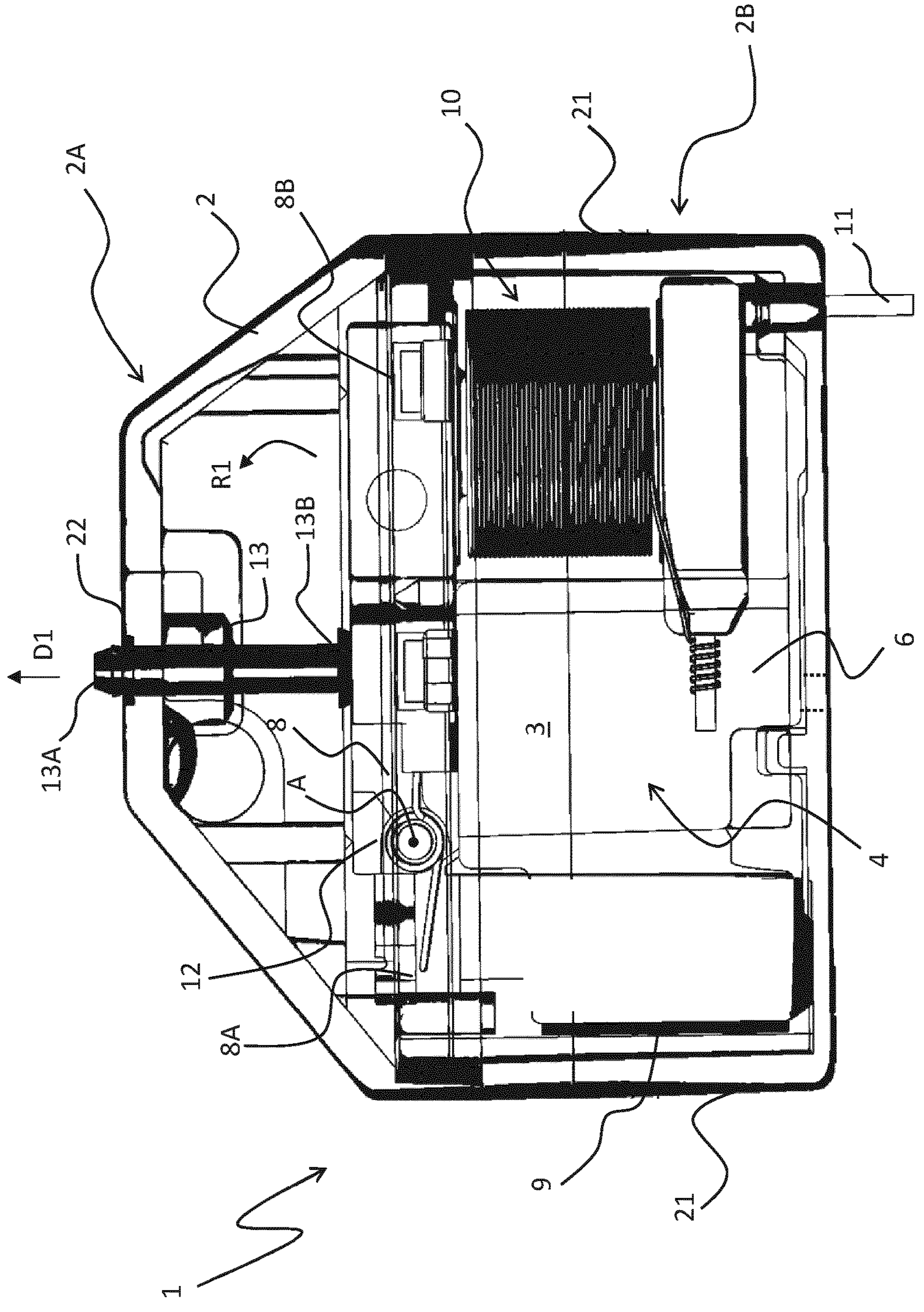
15. Method, according to one of the previous claims, **characterised in that** said semi-finished structure (1) comprises a movable plunger (13) configured to be actuated by said magnetic armature (8), when said magnetic armature moves from said coupled position to said uncoupled position.

16. Method, according to one of the previous claims, **characterised in that** the step of inserting said magnetic material (M) between the yoke plates includes injecting said magnetic material between the yoke plates.

17. Method, according to one of the claims from 1 to 15, **characterised in that** the step of inserting said magnetic material (M) between the yoke plates includes welding said magnetic material between the yoke plates.

18. A magnetic relay (100) for low-voltage electric systems **characterised in that** it comprises a magnetic circuit including a magnetic yoke (4) and a magnetic armature (8), wherein said magnetic yoke comprises a pair of yoke plates (5, 6) mechanically interconnected in such a way to be spaced one from another by a gap region (7), wherein said magnetic armature is movable between a coupled position, at which said magnetic armature is in contact with said yoke plates, and an uncoupled position, at which said magnetic armature is spaced apart from said yoke plates, wherein said magnetic yoke (4) comprises a quantity of magnetic material inserted between the yoke plates, said magnetic material having a relative magnetic permeability value $\mu_r >= 2$.

FIG. 1



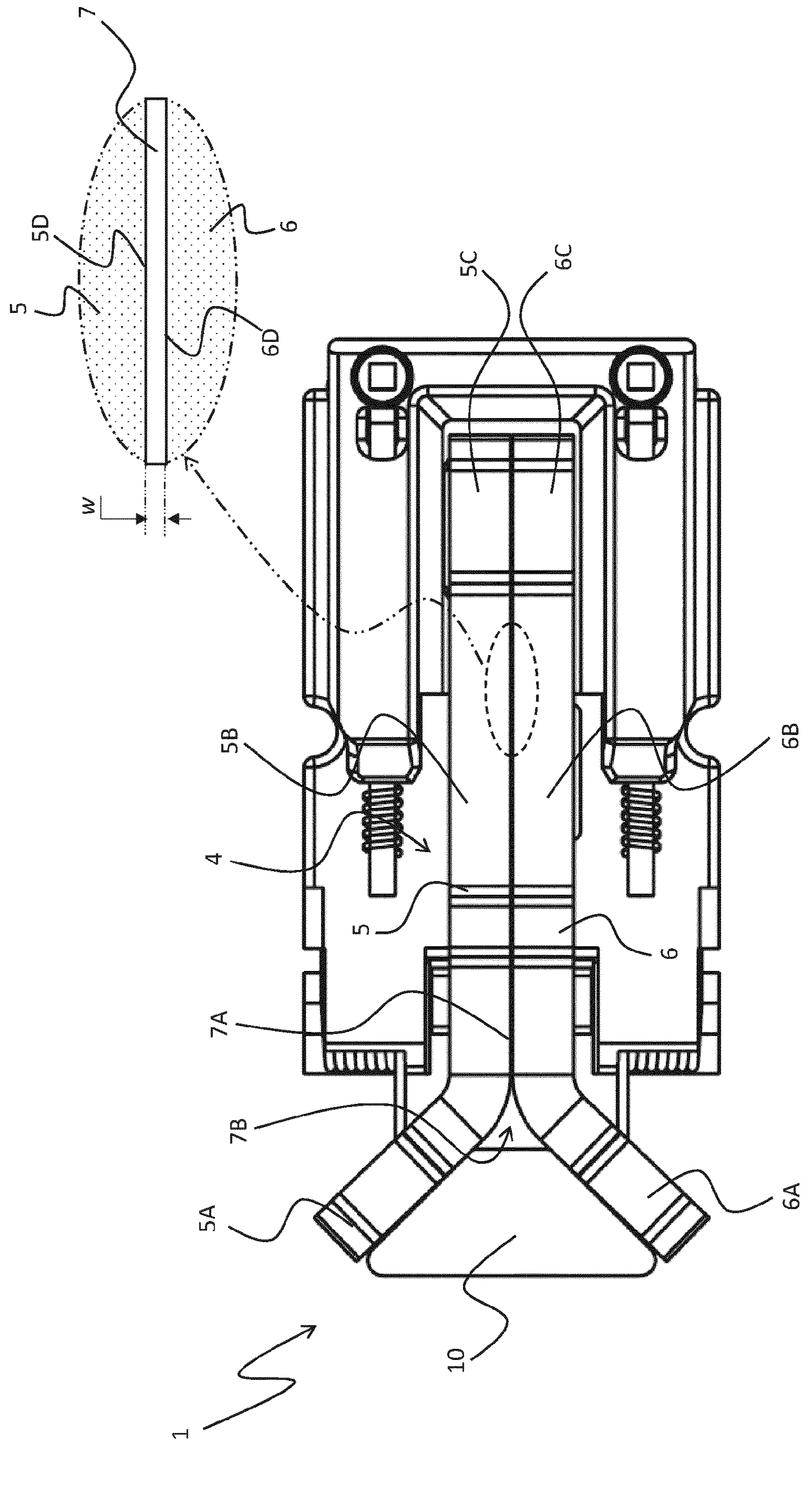


FIG. 2

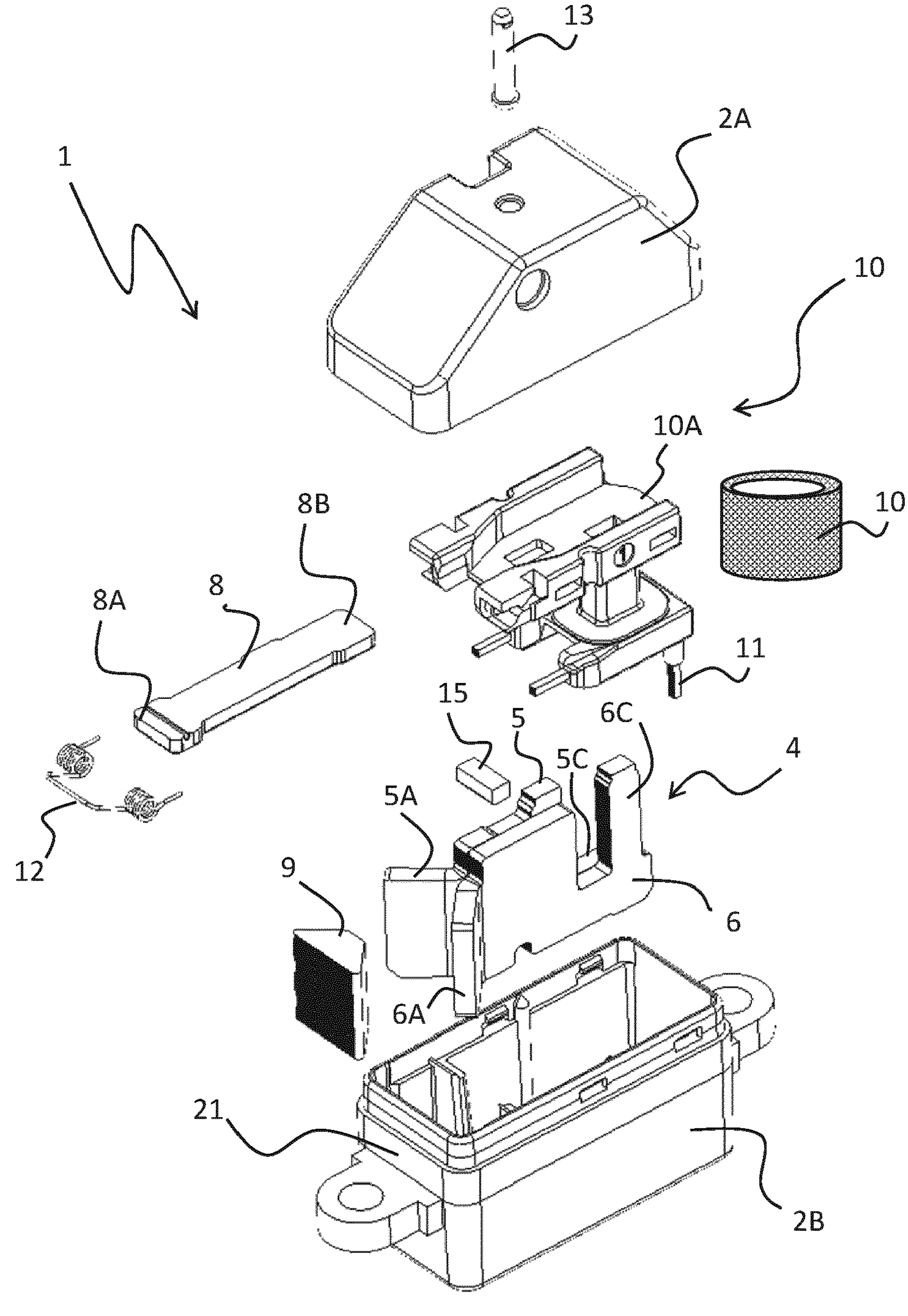


FIG. 3

FIG. 4

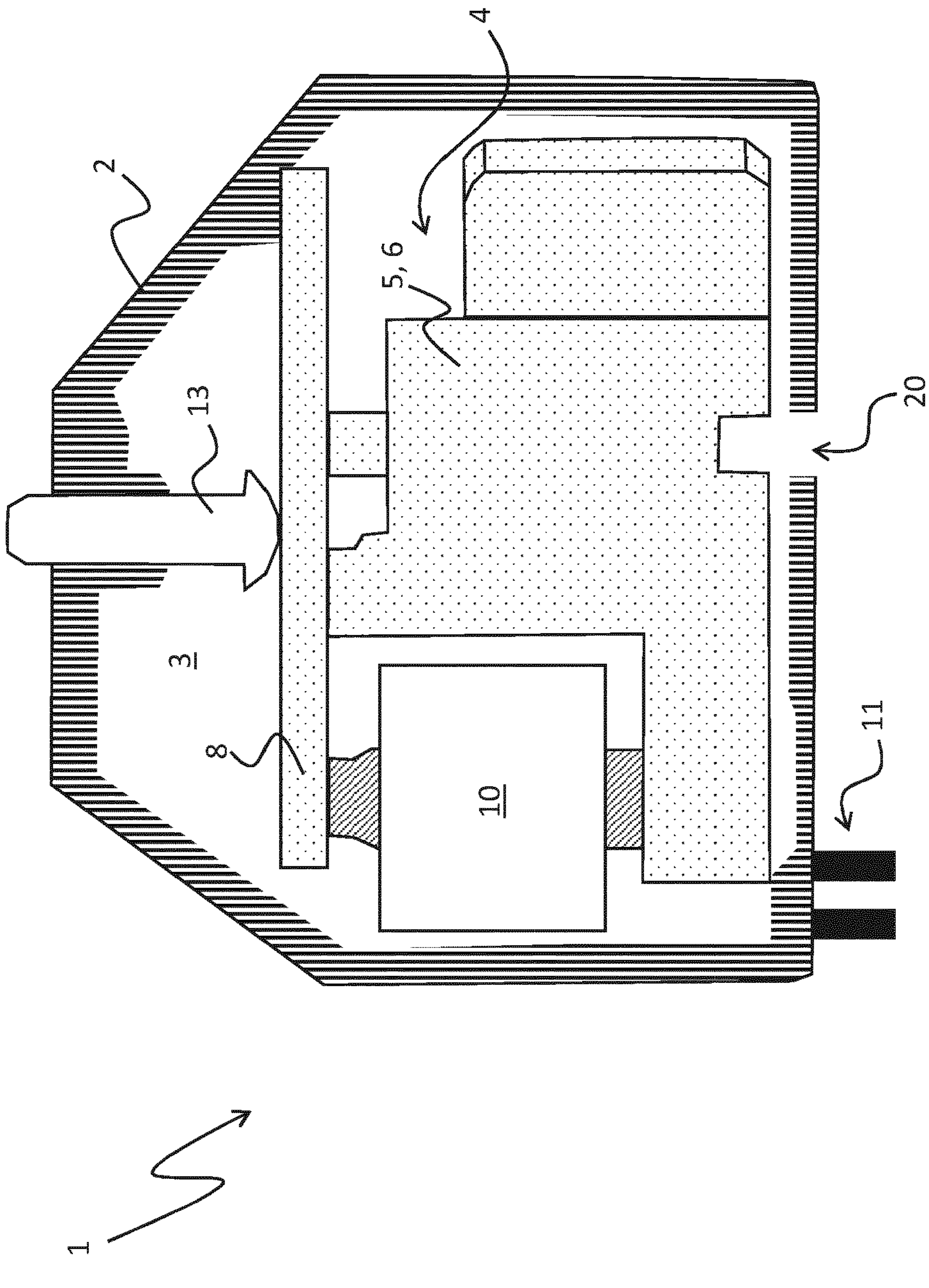


FIG. 5

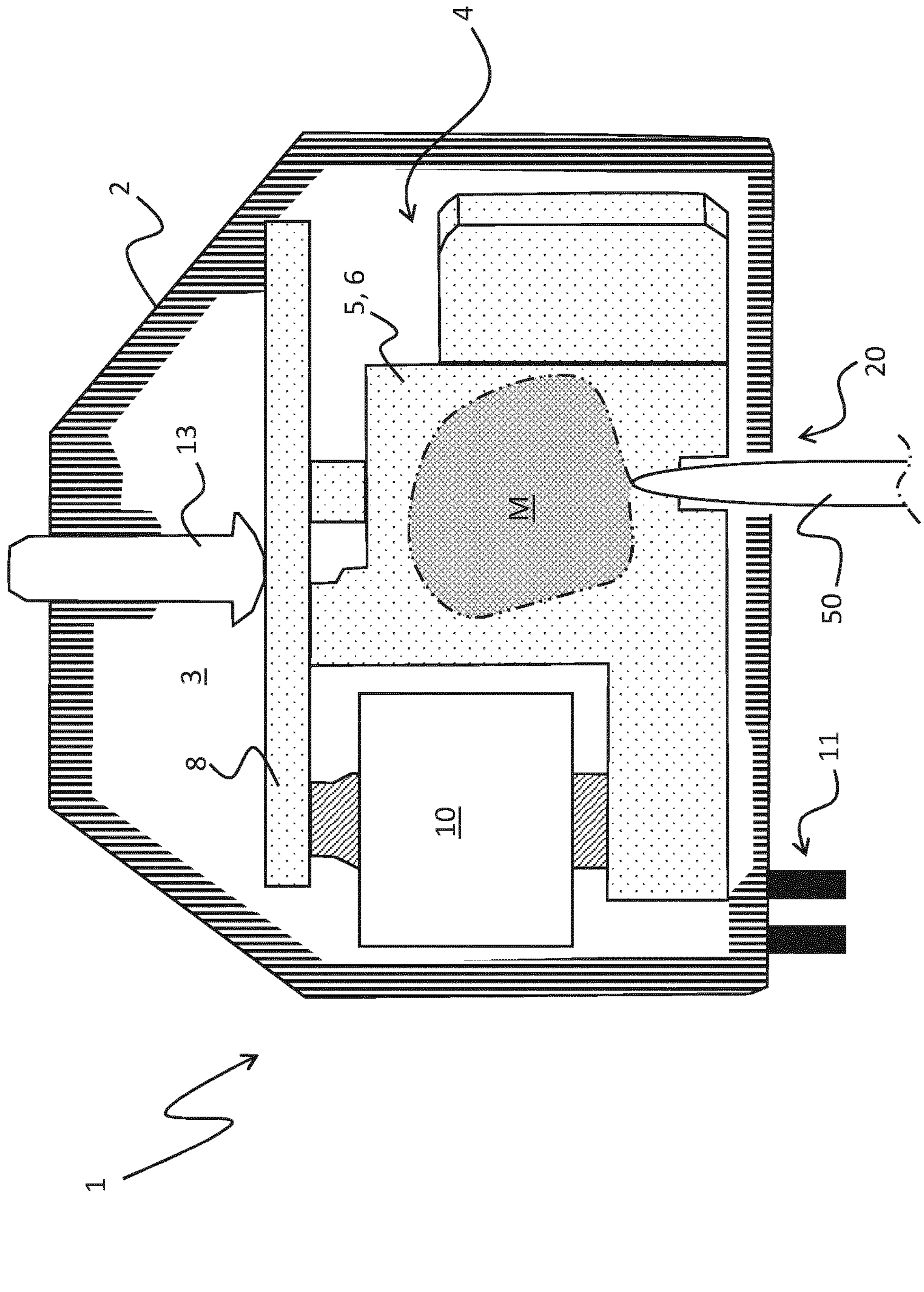
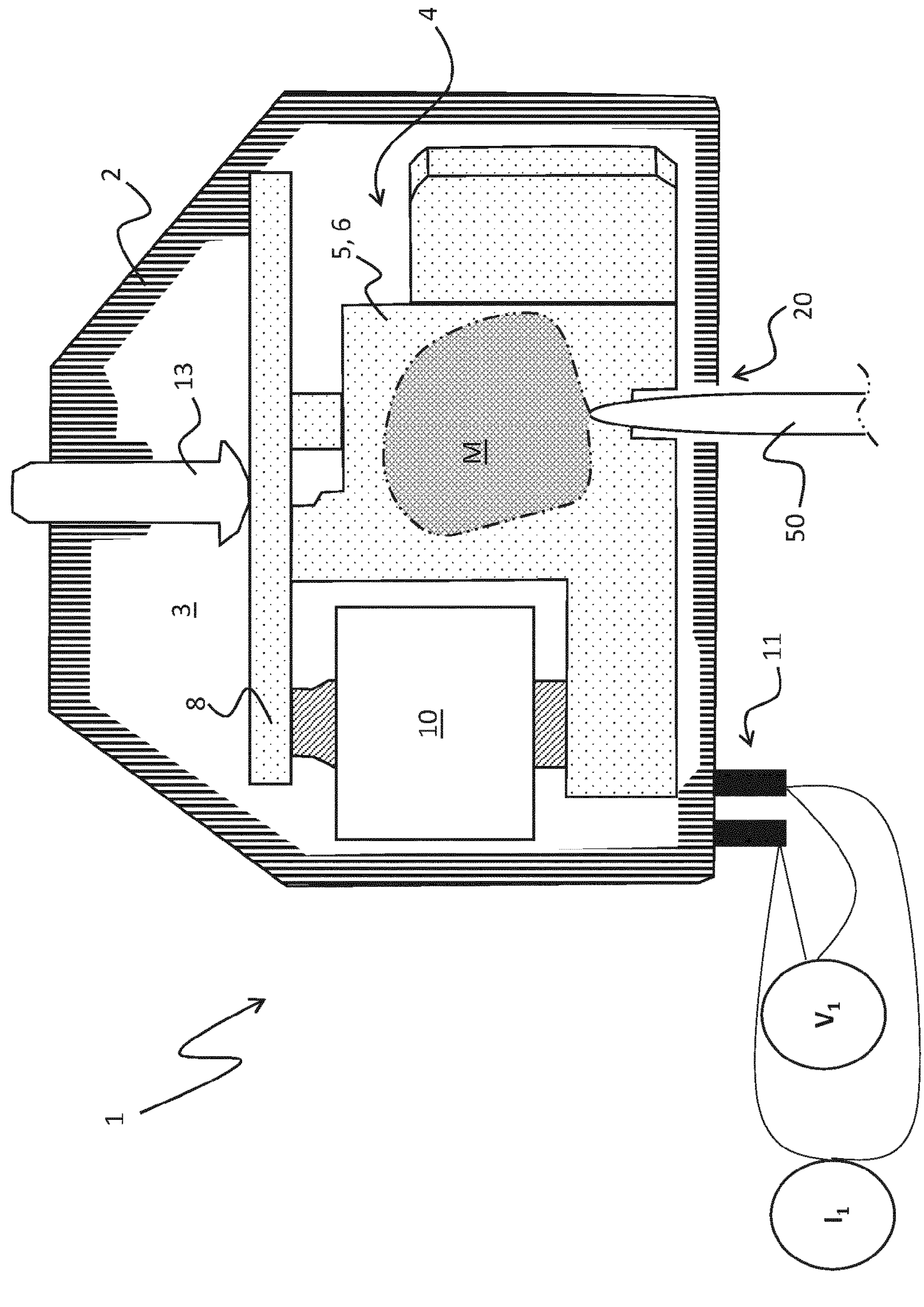


FIG. 6



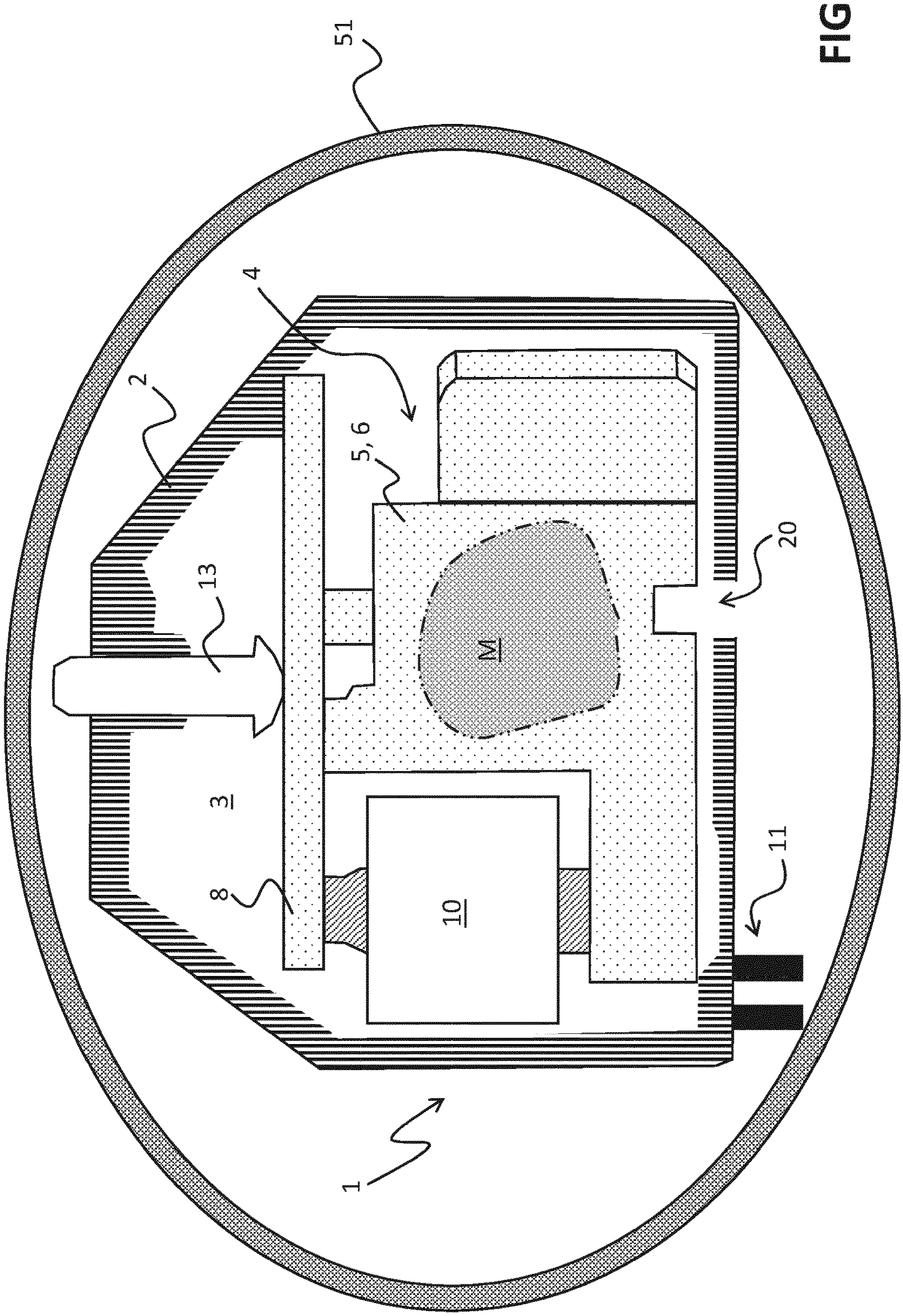


FIG. 7

FIG. 8

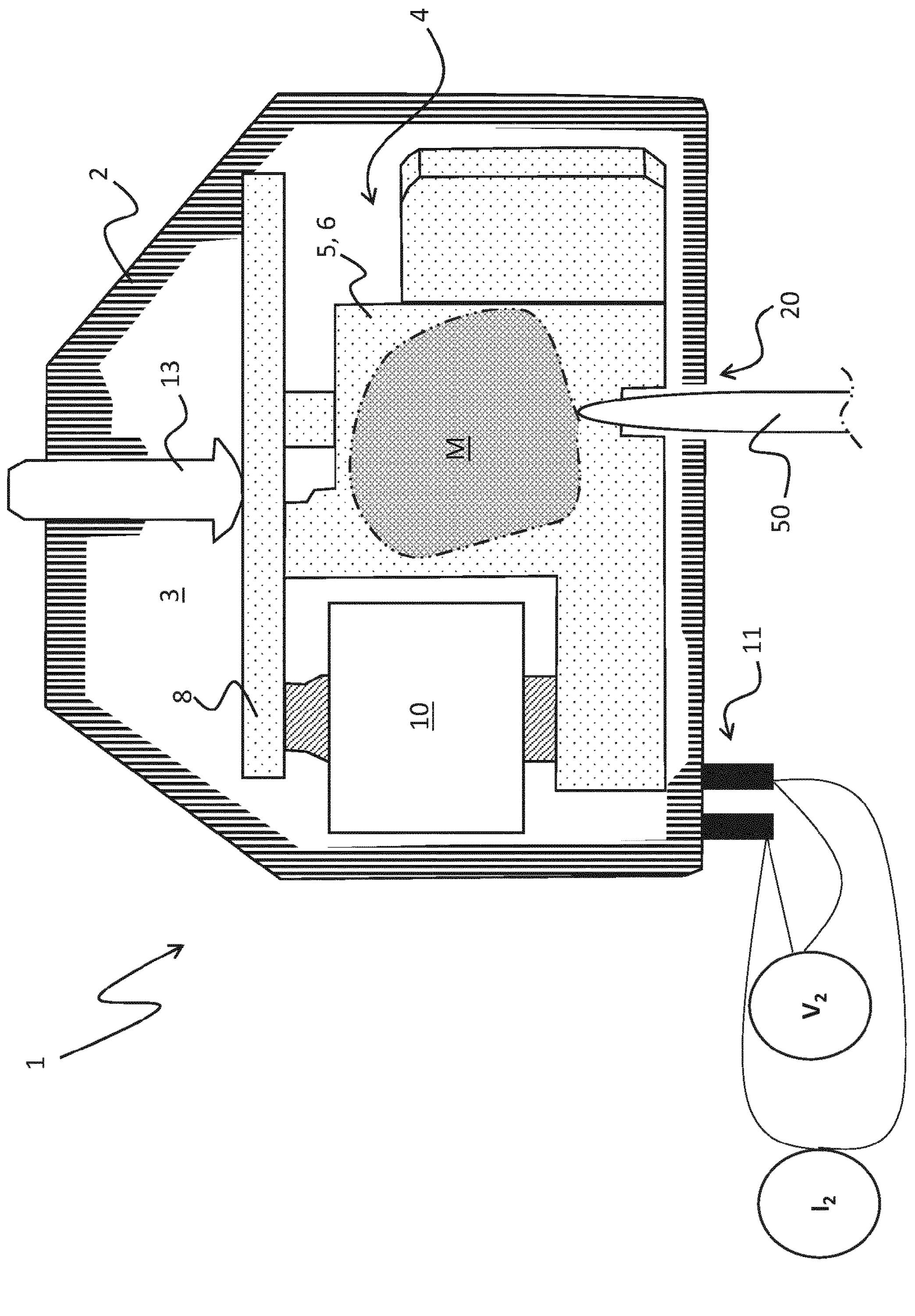


FIG. 9

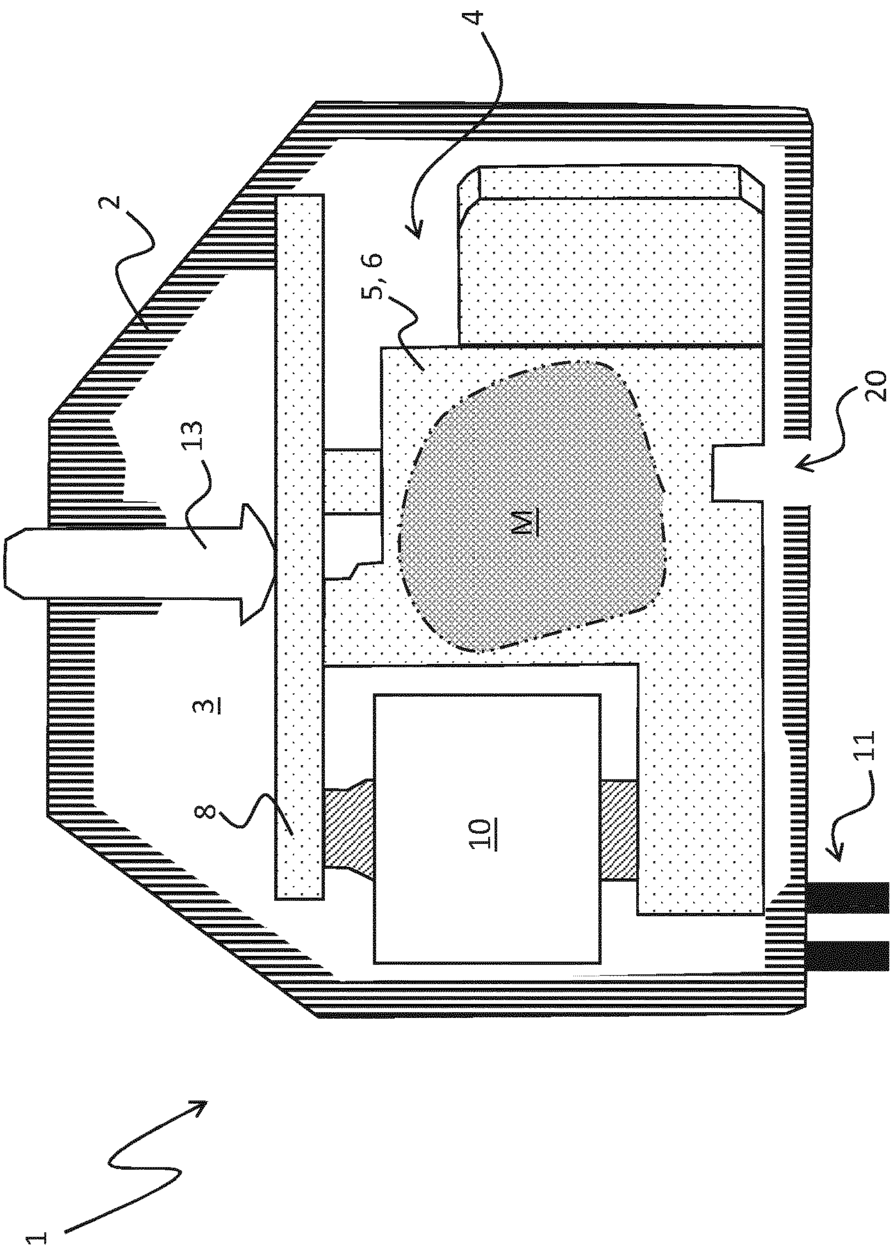
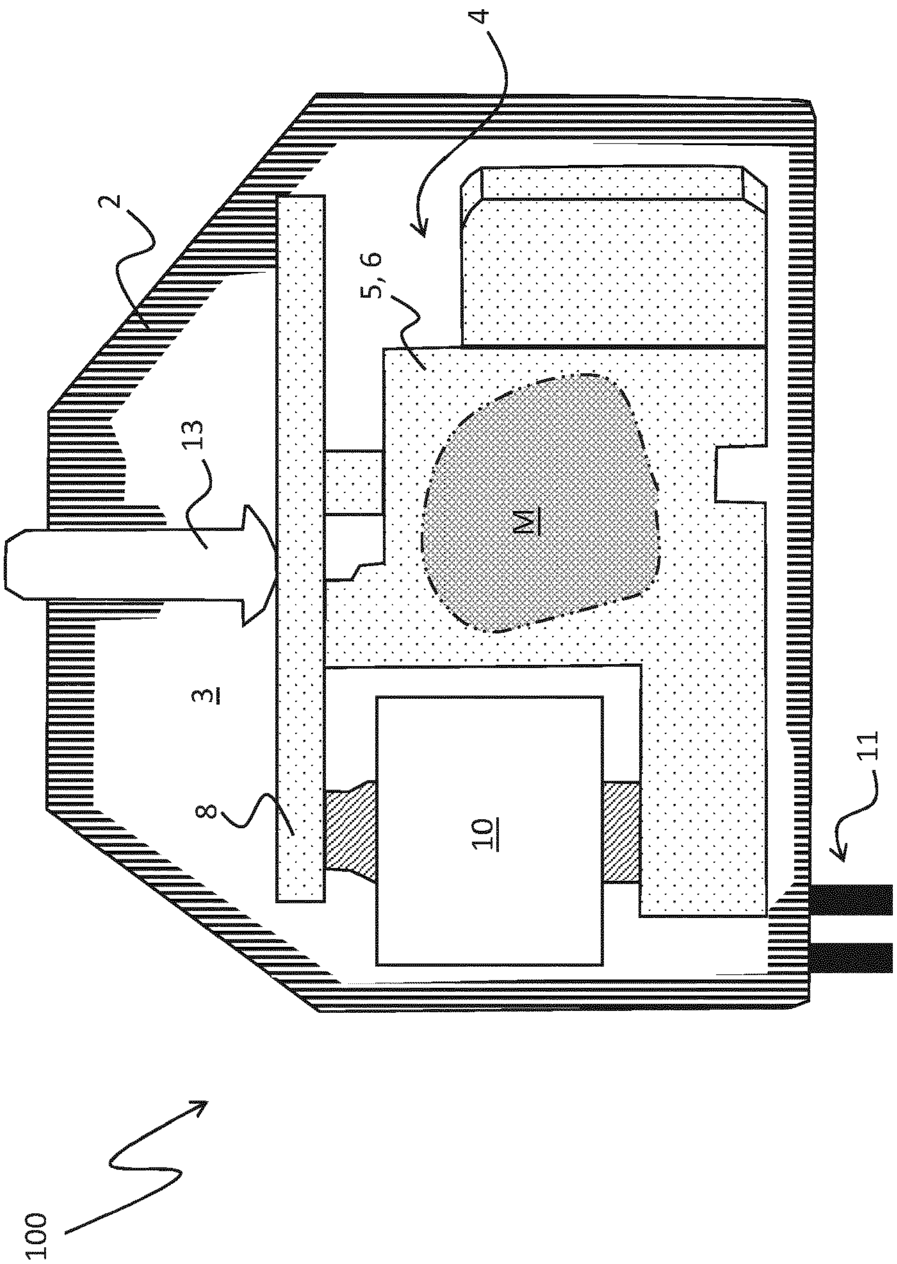


FIG. 10



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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 9435

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	WO 2012/169975 A1 (ETI ELEKTROELEMENT DD [SI]; KOPRIVSEK MITJA [SI] ET AL.) 13 December 2012 (2012-12-13) * the whole document * -----	1-6, 11-16,18 7,9,17 8,10	INV. H01H49/00 H01F7/122 H01F7/127 H01H50/16 H01H50/36
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TECHNICAL FIELDS SEARCHED (IPC)

H01H
H01F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	14 October 2022	Ledoux, Serge

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14-10-2022

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