



(43) International Publication Date  
24 September 2015 (24.09.2015)

- (51) International Patent Classification:  
*H05B 6/02* (2006.01)
- (21) International Application Number:  
PCT/US2015/021297
- (22) International Filing Date:  
18 March 2015 (18.03.2015)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
61/968,657 21 March 2014 (21.03.2014) US
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- (81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

[Continued on next page]

(54) Title: DOUBLE-SIDED FLAT INDUCTOR ASSEMBLY

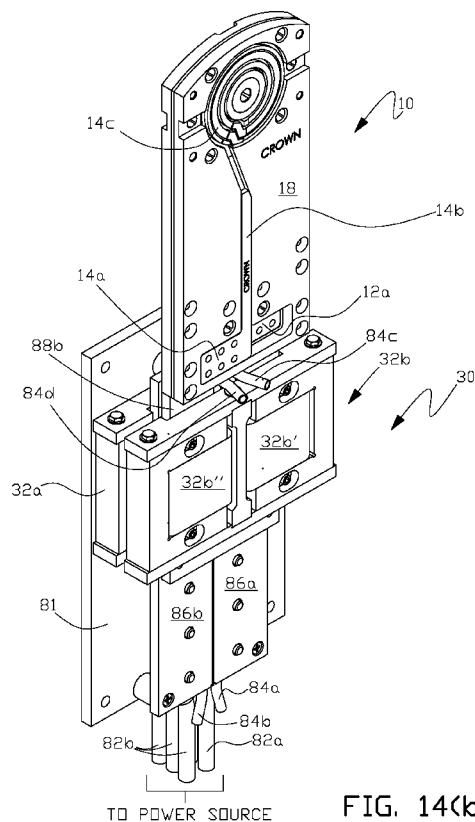


FIG. 14(b)

(57) Abstract: A double sided flat inductor assembly is provided for simultaneous induction heating of two separate workpieces positioned on opposing sides of the double sided flat inductor assembly. A double sided flat inductor extraction assembly is provided for rapid removal of the inductor assembly after completion of the simultaneous induction heating of the two separate workpieces eliminating a necessity of using flexible electrical cables and allowing improved performance of an induction system including increased reliability.

**WO 2015/143059 A1**



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SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, **Published:**  
GW, KM, ML, MR, NE, SN, TD, TG).

— *with international search report (Art. 21(3))*

**DOUBLE-SIDED FLAT INDUCTOR ASSEMBLY****Cross Reference To Related Applications**

[0001] This application claims the benefit of U.S. Provisional Application No. 61/968,657, filed March 21, 2014, hereby incorporated by reference in its entirety.

**5 Field of the Invention**

[0002] The present invention relates to double-sided flat inductor assemblies for simultaneous induction heating of two separate workpieces positioned on opposing sides of the inductor assembly.

**Background of the Invention**

10 [0003] It is advantageous in some manufacturing processes to simultaneously heat by electric induction two separate workpieces that, for example, may be different from each other and are joined together after heating.

[0004] One example of such manufacturing processes is disclosed in United States Patent No. 6,825,450 B2 (Ribeiro et al.) where the two separate workpieces are an upper crown part of a  
15 piston and the second part is the lower crown part of a piston that complements the upper part and when joined together form the piston. The upper crown part may also be called the crown and the lower crown part may also be called the skirt. The complementary sides of the upper and lower crown parts are first heated, for example, by electric induction, and then joined together, for example, by simultaneously pushing and twisting the complementary sides of the upper and  
20 lower crown parts together. United States Patent No. 6,637,642 B1 (Lingnau) describes one such joining process. It is advantageous to heat the upper and lower crown parts simultaneously to provide similar heating profiles in both the upper and lower crown parts for the subsequent welding process that joins the upper and lower crown parts together.

[0005] It is one object of the present invention to provide a double-sided flat inductor assembly  
25 for simultaneous induction heating of two separate workpieces in a manufacturing process.

[0006] It is another object of the present invention to provide a double-sided flat inductor assembly for simultaneous induction heating of complementary sides, or faces of two separate workpieces in a manufacturing process and rapid withdrawal of the inductor assembly away from complementary sides of the two separate workpieces to facilitate joining of the heated  
30 complementary sides.

**Brief Summary of the Invention**

[0007] In one aspect the present invention is a double-sided flat inductor assembly for simultaneous induction heating of two separate workpieces when the double-sided flat inductor assembly is positioned between two separate workpieces.

5 [0008] In another aspect the present invention is a double-sided flat inductor assembly for simultaneous induction heating of two separate workpieces when the double-sided flat inductor assembly is positioned between two separate workpieces and an apparatus and method of inserting and extracting the double-sided flat inductor assembly between the two separate workpieces.

10 [0009] In another aspect of the present invention is a high speed inductor extraction apparatus and method for positioning an inductor between a workpiece induction heating position and a workpiece non-interference position.

[0010] The above and other aspects of the invention are set forth in this specification and the appended claims.

15 **Brief Description of the Drawings**

[0011] The appended drawings, as briefly summarized below, are provided for exemplary understanding of the invention, and do not limit the invention as further set forth herein.

[0012] FIG. 1(a) is a side elevational view of a first workpiece side of one example of a double-sided flat inductor assembly of the present invention.

20 [0013] FIG. 1(b) is a cross sectional view of the double-sided flat inductor assembly through line 1-1 in FIG. 1(a).

[0014] FIG. 2 is a side perspective view of the first workpiece side of the double-sided flat inductor assembly shown in FIG. 1(a).

25 [0015] FIG. 3(a) is a side elevational view of a second workpiece side of one example of a double-sided flat inductor assembly of the present invention.

[0016] FIG. 3(b) is a cross sectional view of the double-sided flat inductor assembly through line 3-3 in FIG. 3(a).

[0017] FIG. 4 is a side perspective view of the second workpiece side of the doubled-sided flat inductor assembly shown in FIG. 3(a).

[0018] FIG. 5 is an end elevational view of the double-sided flat inductor assembly shown in FIG. 1(a) through FIG 4.

5 [0019] FIG. 6 is a side elevational view of one example of a first workpiece inductor removed from an inductor frame of a double-sided flat inductor assembly of the present invention with the second workpiece inductor positioned behind the first workpiece inductor.

[0020] FIG. 7 is an end elevational view of one example of first and second workpiece inductors removed from their inductor frames.

10 [0021] FIG. 8 is a side elevational view of one example of a second workpiece inductor removed from an inductor frame of a double-sided flat inductor assembly of the present invention with the first workpiece inductor positioned behind the second workpiece inductor.

[0022] FIG. 9 is the side perspective view of the first workpiece side of the double-sided flat inductor assembly shown in FIG. 2 with a first workpiece positioned adjacent to a face of the first  
15 workpiece inductor for induction heating.

[0023] FIG. 10 is the side perspective view of the second workpiece side of the double-sided flat inductor assembly shown in FIG. 4 with a second workpiece positioned adjacent to the face of the second workpiece inductor for induction heating.

[0024] FIG. 11 is an end elevational view of one example of the first and second sides of a  
20 double-sided flat inductor assembly with the first and second workpieces respectively positioned adjacent to the faces of the first and second workpiece inductors.

[0025] FIG. 12(a) and FIG. 12(b) illustrate one example of a first workpiece inductor used in one example of the present invention.

[0026] FIG. 12(c) and FIG. 12(d) illustrate one example of a second workpiece inductor used in  
25 one example of the present invention.

[0027] FIG. 13(a) is a front elevational view of one example of a double-sided inductor extraction assembly of the present invention for a double-sided flat inductor assembly.

[0028] FIG. 13(b) is a rear elevational view of the double-sided inductor extraction assembly shown in FIG. 13(a).

[0029] FIG. 13(c) is a side view of the double-sided inductor extraction assembly shown in FIG. 13(a).

[0030] FIG. 13(d) is a front perspective view of the double-sided inductor extraction assembly shown in FIG. 13(a).

5 [0031] FIG. 14(a) is a front elevational view of one example of a double-sided flat inductor assembly of the present invention attached to the double-sided inductor extraction assembly shown in FIG. 13(a) through 13(d) in the induction heating position.

[0032] FIG. 14(b) is a front perspective view of the double-sided flat inductor assembly attached to the inductor extraction assembly shown in FIG. 14(a).

10 [0033] FIG. 14(c) is a side elevational view of the double-sided flat inductor assembly attached to the inductor extraction assembly shown in FIG. 14(a).

[0034] FIG. 14(d) is a front perspective view of the double-sided flat inductor assembly of the present invention attached to the inductor extraction assembly shown in FIG. 14(a) with first and second workpieces in the induction heating position.

15 [0035] FIG. 14(e) is a side elevational view of the double-sided flat inductor assembly attached to the inductor extraction assembly shown in FIG. 14(a) with a first and second workpiece in the induction heating position.

[0036] FIG. 15(a) is a front perspective view of a double-sided flat inductor assembly attached to one example of an inductor extraction assembly with the inductor and extraction assemblies in  
20 an induction post-heat extracted position.

[0037] FIG. 15(b) is a side elevational view of the double-sided flat inductor assembly attached to the double-sided inductor extraction assembly shown in FIG. 15(a).

[0038] FIG. 15(c) is a rear perspective view of the double-sided flat inductor assembly attached to the double-sided inductor extraction assembly shown in FIG. 15(a) with a first and second  
25 workpieces.

[0039] FIG. 15(d) is a side elevational view of the double-sided flat inductor assembly attached to the double-sided inductor extraction assembly shown in FIG. 15(a) with a first and second workpieces.

[0040] FIG. 16 is a diagrammatic electrical circuit representation for the embodiment of the double-sided inductor extraction assembly shown in the figures.

### Detailed Description of the Invention

[0041] FIG. 1(a) through FIG. 12(d) illustrate one embodiment of a double-sided flat inductor assembly 10 of the present invention comprising first workpiece inductor 12 and second workpiece inductor 14 respectively mounted in first inductor frame 16 and second inductor frame 18. For convenience first workpiece 90a in this example is also referred to as the skirt and the first workpiece inductor frame 16 is correspondingly labeled "SKIRT" in some of the figures. Similarly the second workpiece 90b in this example is also referred to as the crown and the second workpiece inductor frame 18 is correspondingly labeled "CROWN" in some of the figures. The inductor frames are configured as required for use in a particular application and represented in the figures in one embodiment.

[0042] As shown in one embodiment of the invention, first workpiece inductor 12 comprises a first inductor terminal section 12a (also referred to as skirt inductor foot 12a), first inductor riser section 12b (also referred to as skirt inductor leg 12b) and first inductor coil section 12c (also referred to as skirt coil 12c).

[0043] As shown in one embodiment of the invention, second workpiece inductor 14 comprises a second inductor terminal section 14a (also referred to as crown inductor foot 14a), second inductor riser section 14b (also referred to as crown inductor leg 14b) and second inductor coil section 14c (also referred to as crown coil 14c).

[0044] The first inductor riser section and the second inductor riser section are optional in other embodiments and are a means for electrically interconnecting the first inductor coil section to the first inductor terminal section, and the second inductor coil section to the second inductor terminal section, respectively, if there is a requirement to physically separate the inductor coil sections from the inductor terminal sections.

[0045] In this embodiment of the invention first and second inductor coil sections 12c and 14c are each shaped as a spirally-coiled induction coil (or inductor) that is sometimes referred to as a "pancake" coil. The spacing between turns of the spirally-coiled inductor may vary based upon the workpiece geometry being heat treated. For example symmetric spacing between all turns of the coil can result in an electromagnetic ring effect where stronger magnetic fields occur on the inner radial region of the workpiece face being heat treated compared with the outer radial regions. To compensate in some embodiments of the invention the outer turns may be more

closely spaced together than the inner turns. For example in FIG. 1(a) the two outer turns of the first inductor coil sections 12c' and 12c'' are more closely spaced together, and separated further apart from the single inner coil turn 12c''' to provide a more uniform induction heating across the surface (or face) of the workpiece with reduced sensitivity in coil position relative to the surface of the workpiece. In other embodiments of the invention other coil turn arrangements can be provided to compensate for selected regions of the first or second workpiece in a particular application.

[0046] Generally the first inductor coil section and the second inductor coil section, as disclosed herein, can be referred to as planarly oriented coil section with the two planarly oriented coil sections being planarly disposed opposing each other. Deviations from planar, for example, the profiling described herein are within the terminology of a planarly oriented coil section. While the embodiment of the inductor coil sections shown in the drawings is circular other configurations can be used in other embodiments of the invention. In other embodiments the entire first workpiece inductor and the entire second workpiece inductor can be referred to as planarly oriented inductors with the two planarly oriented inductors being planarly disposed opposing each other.

[0047] First and second workpiece inductors are suitably joined together electrically, for example, by brazing to form a series electrical circuit between the first and second inductor terminal sections 12a and 14a. First workpiece inductor 12 and second workpiece inductor 14 are connected electrically in series as diagrammatically shown in FIG. 16 for orientation of electrical current through the inductors that allows magnetic fluxes generated by each inductor to complement each other rather than allowing maximum density of alternating current electrical current density to shift towards respected turns of the two inductors that results in a dramatic reduction of heating efficiency of respected areas of the first (skirt) workpiece 90a and the second (crown) workpiece 90b.

[0048] As shown in FIG. 6 first inductor riser section 12b includes riser-coil interface subsection 12b'. Similarly in FIG. 8 second inductor riser section 14b includes riser-coil interface subsection 14b'. In this embodiment of the invention crown inductor foot 14a is preferably flush with the outer surface of skirt inductor foot 12a on the SKIRT side of the inductor assembly to facilitate connections to a single phase alternating current source (not shown in the figures) in some embodiments of the invention.

[0049] In this embodiment of the invention the inner coil terminus 12c' of skirt coil 12c is electrically connected to the inner coil terminus 14c' of crown coil 14c as shown in FIG. 6, 7 and



8 by electrical connecting element 13, which as mentioned above, can be accomplished by brazing the inner coil termini of the first and second inductor coils to form a series circuit from the skirt inductor 12 and crown inductor 14 between skirt terminal section 12a and crown terminal section 14a, which are connected to the outputs of a suitable single phase alternating  
5 current power source. Electrically connecting inner coil terminus 12c' to inner coil terminus 14c' can be accomplished by any suitable means, for example by brazing (that is, forming a brazed joint between the inner coil terminus of the skirt inductor 12 and the inner coil terminus of the crown inductor 14). Alternative means of electrically connecting the two inductor coils in series can be, for example, an electrical conductor suitably connected between the inner coil termini or  
10 other coil termini for other inductor coil arrangements.

[0050] Suitable middle electrical insulating material 94, for example formed from TEFLON®, is positioned as required between: (1) the skirt inductor foot 12a, skirt inductor leg 12b and skirt coil 12c; and (2) the crown inductor foot 14a, crown inductor leg 14b and crown coil 14c to provide a means of electrical isolation between skirt inductor 12 and crown inductor 14. Any  
15 other type of insulating material (dielectric), including air, can be used in other embodiments of the invention to provided electrical isolation between the skirt and crown inductor.

[0051] In this embodiment of the invention first 16 and second 18 inductor frames are each formed from a non-electrically conductive material such as a phenolic board or a GLASTIC® electrical insulating board.

[0052] FIG. 1(b) illustrates in cross section in this embodiment of the invention, inner skirt and crown concentrators 12d and 14d respectively; skirt and crown center plugs 12e and 14e respectively; and skirt and crown coils 12c and 14c respectively. The inner skirt and crown concentrators as shown in FIG. 1(b) provide maximum magnetic intensity on the respective inductor coil section when flush with the heating face ( $12c_{\text{face}}$  or  $14c_{\text{face}}$ ) of the respective  
25 inductor coil section's inner turn. If the inner face of a particular workpiece surface to be heat treated is too hot, the inner concentrators can be repositioned or re-sized to reduce the heating efficiency of the inner turn of the inductor coil section to provide a means of controlling the induction heating process that can rectify heating imbalance between the radial inner and outer workpiece faces. For example one or more of the L-shaped concentrators used in this  
30 embodiment can have the top of an L-shaped concentrator shortened adjacent to its respective heating face to selectively reduce the magnetic intensity for a particular induction heating application. In other embodiments of the invention the concentrators can be other than L-shaped to suit a particular induction heating application.

[0053] FIG. 3(b) illustrates in cross section in this embodiment of the invention, electrical insulating material 92a and 92b electrically separating skirt inductor foot 12a from crown inductor foot 14a. FIG. 9 and FIG. 10 also illustrate how in this embodiment of the invention crown inductor foot 14a is flush with the outer surface of skirt inductor foot 12a on the SKIRT side of the inductor assembly in FIG. 9 to facilitate connections to a single phase alternating current source either directly (not shown in the figure) or via an extraction assembly as described herein while skirt inductor foot 12a does not extend to the crown inductor side as indicated by open space 18b in crown inductor frame 18 in FIG. 10.

[0054] Assembly of the first and second workpiece inductors and the first and second inductor frames can be, for example, by bolted (or other suitable fastening means) construction.

[0055] In this embodiment of the invention FIG. 9 and FIG. 10 illustrate first (skirt) workpiece 90a in position over skirt coil 12c for induction heating of the first workpiece 90a simultaneously with the induction heating of the second (crown) workpiece 90b in position over crown coil 14c, and also in end view in FIG. 11 where the recessed skirt coil and crown coil are not visible.

[0056] In this embodiment of the invention skirt inductor coil 12c and crown inductor coil 14c are recessed respectively in skirt inductor frame 16 and crown inductor frame 18 as indicated by frame recess regions 16a and 18a, for example in FIG. 2 and FIG. 4 respectively.

[0057] In some applications of the present invention the geometry of either workpiece can be non-uniform and have substantial changes in mass at various radial quadrants of the workpiece.

These changes in mass create heat imbalances during heating. To compensate for this, the heating surfaces of the respective inductor coil section can be profiled in angular radial quadrants to form a profiled section or region correlating to the different workpiece quadrants of varying mass. The workpiece must then be placed in the induction heating position at a specified orientation to maintain the desired inductor coil section to workpiece relationship.

[0058] Inductor assembly 10 can be connected to actuator apparatus that moves the inductor assembly into the heat position between the first and second workpieces (shown in FIG. 11) and a retracted position downwards (in the negative Z-direction) so that facing skirt 90a and crown 90b heated surfaces can be simultaneously pushed together (in opposing X-directions) and twisted about the X-axis to join the skirt 90a and crown 90b. Alternatively in other embodiments one of the two workpieces can remain stationary and the other workpiece can be moved to push against the stationary workpiece.

[0059] The actuator apparatus is illustrated in one embodiment of the invention in FIG. 13(a) through FIG. 13(d) as double-sided inductor extraction assembly 30. Primary magnetic device 32a is suitably mounted to fixed structure such as primary mounting plate 81 that can be formed from a dielectric. Primary supply electrical conductors 86a and 86b are also mounted to primary mounting plate 81 (via standoff posts 81a in this embodiment). Primary supply electrical conductors are illustrated as bus bars in the example and can be any type of suitable electrical conductors. Power source cables 82a and 82b (three supply and three return cables in this embodiment) from a suitable single phase alternating current source are connected respectively to electrical conductors 86a and 86b. Power source cables can be any type of suitable power source electrical conductors such as bus bars.

[0060] Secondary magnetic device 32b is electrically connected to secondary output electrical conductors 88a and 88b. The secondary magnetic device and secondary output electrical conductors are connected to a suitable extraction actuator (not shown in the drawings) which in this embodiment moves the secondary magnetic device and secondary output electrical conductors linearly in the plus or minus Z direction as further described below. In other embodiments of the invention the extraction movement may be in another linear direction, a rotational direction or a combination of linear and rotational directions.

[0061] FIG. 14(a) through FIG. 14(e) illustrate one example of double-sided flat inductor assembly 10 electrically connected to the extraction assembly shown in FIG. 13(a) through FIG. 13(d). In this embodiment first inductor terminal section 12a and second inductor terminal section 14a are connected respectively to electrical conductors 88a and 88b on extraction assembly 30.

[0062] Optional cooling fluid medium cables 84a and 84b and 84c and 84d supply and return a cooling fluid medium to the skirt and crown inductors via the extraction assembly in this example.

[0063] In FIG. 13(a) through FIG. 14(e) extraction assembly 30 and attached double-sided flat inductor assembly 10 are shown in the induction heating position with the workpieces in place for induction heating as shown in FIG. 14(d) and 14(e) with the primary magnetic device aligned with the secondary magnetic device for flux transfer between the supply and return power magnetic devices and the inductor supply and return power magnetic devices. The inductor extraction actuator (not shown in the figures) moves the secondary magnetic device and secondary output electrical conductors with the attached double-sided flat inductor assembly 10 downwards to the inductor assembly (induction post-heat) extracted position where the double-

sided flat inductor assembly does not interfere with mating of the two workpieces in an industrial process after being induction heated, for example, when moving the two workpieces together.

[0064] FIG. 16 is one example of an electrical circuit for the components of the double-sided inductor extraction assembly shown in the figures. In this embodiment the primary and secondary magnetic devices each comprise two electrically isolated magnetic devices. When the extraction assembly is in the induction heating position and alternating current is supplied via power source cables 82a and 82b the supply and return electrical circuit to the double-sided flat inductor assembly is completed by flux coupling between the primary magnetic devices and the secondary magnetic devices. When the extraction assembly 30 moves inductor assembly 10 to the induction post-heat extracted position there is no magnetic flux coupling between the primary magnetic devices and the secondary magnetic devices while the inductor assembly is clear of the space between the two induction heated workpieces. This method of inductor assembly extraction provides a high speed method of clearing the space between the two induction heated workpieces while electromagnetically disconnecting a supply of power to the inductor assembly in comparison with mechanical movement of an entire inductor assembly, including, for example, bus work and power cables connected to a power source. When extraction assembly 30 begins to transition inductor assembly 10 from the induction heating position to the inductor assembly (induction post-heat) extracted position, alternating current output power from power source PS in FIG. 16 could be turned off and the extracted inductors 12 and 14 on inductor assembly 10 would be powerless during the transition between the two positions.

[0065] If the first or second workpiece has one or more coil facing protrusions that would prevent retraction of the inductor assembly, a depressed coil region in a coil planar face, such as V-notches 99 shown in FIG. 1(a), FIG. 1(b) and FIG. 2 can be provided in the coil for clearance as the inductor retracts. Depending upon the arc length of the V-notch the workpiece facing the coil can be rotated in the induction heating position during heating to ensure that workpiece surface region facing a V-notch region are sufficiently heated. In the embodiment with a relatively short V-notch region, such as region 99, when the V-notch is less than 90 degrees, the circumferential component of the induced eddy current could provide a sufficient heating effect of the workpiece region that corresponds to the V-notch location, and therefore eliminating a need for workpiece rotation during heating.

[0066] In this example first inductor coil section 12c has profiled regions, for example, at the top of the coil that are profiled (contoured) regions 99' in the X-direction (that is, the height of the induction coil section). Regions 99' are raised above the normal face heating plane of coil section 12c on either side of V-notches 99 to compensate for low induced heat in the regions of

the coil V-notches. Such profiling can be used to conform to the face of the coil section adjacent to the face of the workpiece being heated. In other examples of the invention the first and second coil sections may be of other shapes and contours to suit the shape of the corresponding first and second workpieces to heat each workpiece by proximity heating.

5    **[0067]** In this embodiment of the invention, in order to improve the heat uniformity in the transition regions 98 (FIG. 1(a) and FIG. 2) where there is a transition between the outer turn-to-middle turn and middle-turn-to-inner turn of the pair of three turn coils that provide simultaneous heating of the first and second workpieces, there are profiled regions 98'. In this example, regions 98' are profiled in the X-direction and raised above the normal face heating  
10   plane of the coil section to compensate for lower heat intensity due to a reduced heat generation.

**[0068]** In the above method electromagnetic coupling between primary magnetic device 32a and secondary magnetic device 32b allows the inductor to retract radially (Z-direction) away from the workpieces. For example, in this embodiment the secondary magnetic device may be slidably mounted adjacent to a stationary primary magnetic device so that the secondary magnetic device  
15   can be slid downwards relative to the primary magnetic device. There is no physical contact between the primary and secondary devices which allows the secondary half that forms an electrically closed-loop circuit, with the double-sided inductor attached, to be quickly extended to the induction heating position and retracted to the induction post-heat extraction position. This is diagrammatically illustrated in circuit FIG. 16 where the primary circuit is in bold and is  
20   connected to the non-bold secondary circuit when there is magnetic flux coupling between the primary and secondary magnetic devices. This motion allows the inductor assembly to be removed so that an industrial process, such as fusing the two workpieces together can occur in a fraction of a second after induction heating to minimize heat dissipation due to the combined effect of thermal conduction, thermal radiation and heat convection.

25   **[0069]** Each primary magnetic device can be any device that creates a magnetic flux from an alternating current flow through the device and each secondary magnetic device can be any device that magnetically couples the primary alternating magnetic flux for power transfer between the primary and secondary magnetic devices via transformer coupling without there being a physical connection between the primary magnetic devices and the secondary magnetic  
30   devices. For example in one embodiment of the invention each primary and secondary magnetic device can be two joined magnetic C-cores to form a rectangular closed magnetic core with a central opening in which a portion of electrical conductors 86a, 86b, 88a or 88b are placed so that when alternating current flows through primary supply electrical conductors 86a and 86b a magnetic flux field is created that couples with the corresponding secondary magnetic device

when extraction assembly 30 has positioned the inductors in the inductor assembly in the induction heating position. Each primary and secondary magnetic device may also be referred to as a coil wound core.

[0070] The terms skirt and crown are used interchangeably herein with other pairs of workpieces where it is advantageous to simultaneously induction heat the two workpieces. Further the process following the simultaneous heating may be joining the opposing faces of the workpieces together, but is not limited to that process as long as the process can benefit from the simultaneous induction heating.

[0071] The extraction assembly of the present invention may be used with other configurations and quantity of inductors in an induction assembly in industrial processes where high speed transfer of the inductor assembly from an induction heating position to a workpiece non-interference position where the workpiece can be further processed is desirable.

[0072] While the described embodiment of the present example uses a pair of three turn coils in series in other embodiments the number of coil turns can be singular or any multiple number of turns. In other embodiments the number of coil turns may be different for each coil in the pair of coils.

[0073] In the description above, for the purposes of explanation, numerous specific requirements and several specific details have been set forth in order to provide a thorough understanding of the example and embodiments. It will be apparent however, to one skilled in the art, that one or more other examples or embodiments may be practiced without some of these specific details. The particular embodiments described are not provided to limit the invention but to illustrate it.

[0074] Reference throughout this specification to "one example or embodiment," "an example or embodiment," "one or more examples or embodiments," or "different example or embodiments," for example, means that a particular feature may be included in the practice of the invention. In the description various features are sometimes grouped together in a single example, embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of various inventive aspects.

[0075] The present invention has been described in terms of preferred examples and embodiments. Equivalents, alternatives and modifications, aside from those expressly stated, are possible and within the scope of the invention.

1. A double-sided flat inductor assembly for simultaneous induction heating of complementary sides of a first workpiece and a second workpiece, the double-sided flat inductor assembly comprising:

5 a first workpiece inductor comprising:

a first planarly oriented inductor configured for induction heating a first workpiece face of the first workpiece; and

a first inductor terminal section electrically connected to the first planarly oriented inductor;

10 a second workpiece inductor comprising:

a second planarly oriented inductor planarly disposed opposing the first planarly oriented inductor, the second planarly oriented inductor configured for induction heating a second workpiece face of the second workpiece, the second workpiece face and the first workpiece face forming complementary sides of the first and the second workpieces; and

15 a second inductor terminal section electrically connected to the second workpiece inductor, the second planarly oriented inductor and the second inductor terminal section electrically isolated from the first planarly oriented inductor and the first inductor terminal section; and

20 a first and second workpiece inductor electrical connection means for connecting the first planarly oriented inductor and the second planarly oriented inductor in series electrical connection to form a series electrical circuit from the first inductor terminal section to the second inductor terminal section.

2. The double-sided flat inductor assembly of claim 1 wherein the first planarly oriented inductor comprises a first spiral inductor and the second planarly oriented inductor comprises a second spiral inductor.

3. The double-sided flat inductor assembly of claim 2 wherein the electrical connection means for connecting the first planarly oriented inductor and the second planarly oriented inductor in series comprises a brazed joint between a first inductor inner coil terminus of the first spiral inductor and a second inductor inner coil terminus of the second spiral inductor.

4. The double-sided flat inductor assembly of claim 1 further comprising at least one profiled section of the first or second planarly oriented inductor.

5. The double-sided flat inductor assembly of claim 1 further comprising an alternating current source connected between the first inductor terminal section and the second inductor terminal section.

6. The double-sided flat inductor assembly of claim 1 further comprising:  
a first inductor riser section electrically interconnecting the first planarly oriented inductor to the first inductor terminal section; and

a second inductor riser section electrically interconnecting the second planarly oriented inductor to the second inductor terminal section.

7. The double-sided flat inductor assembly of claim 1 further comprising:  
a first inductor frame for mounting the first workpiece inductor; and  
a second inductor frame for mounting the second workpiece inductor.

8. The double-sided flat inductor assembly of claim 1 further comprising a dielectric disposed between the first and second inductor frames to electrically isolate the first and second inductors from each other.

9. The double-sided flat inductor assembly of claim 1 further comprising:  
a double-sided inductor extraction assembly comprising:

a primary magnetic device mounted to a stationary primary mounting structure the primary magnetic device having a supply power magnetic device and a return power magnetic device, the supply power magnetic device and the return power magnetic device;

a secondary magnetic device having an inductor supply power magnetic device and an inductor return power magnetic device, the secondary magnetic device slidably mounted relative to the primary magnetic device between: an induction heating position when the supply power magnetic device is aligned with the inductor supply power magnetic device, and the return power magnetic device is aligned with the inductor return power magnetic device when an alternating current is supplied to the supply power magnetic device and the return power magnetic device to transfer flux respectively to the inductor supply power magnetic device and the inductor return power magnetic device; and an induction post-heat extracted position when the supply power magnetic device is not aligned with the inductor supply power magnetic device and the return power magnetic device is not aligned with the inductor return power magnetic device to isolate the inductor supply power magnetic device and the inductor return power magnetic device from the alternating current by sliding the secondary magnetic device;

an extraction assembly inductor supply terminal connected to the inductor supply power magnetic device, the first inductor terminal section electrically connected to the inductor supply power magnetic device; and



an extraction assembly inductor return terminal connected to the inductor return power magnetic device, the second inductor terminal section electrically connected to the inductor return power magnetic device.

10. The double-sided flat inductor assembly of claim 9 wherein each of the supply and return power magnetic devices and each of the inductor supply and return power magnetic devices comprises a coil wound core.

11. The double-sided flat inductor assembly of claim 9 further comprising at least one depressed coil region in either the first planarly oriented inductor or the second planarly oriented inductor to allow transition of the first planarly oriented inductor or the second planarly oriented inductor from the induction heating position to the induction post-heat extracted position.

12. The double-sided flat inductor assembly of claim 9 further comprising an alternating current source having an output for supplying the alternating current to the supply power magnetic device and the return power magnetic device.

13. A method of simultaneous induction heating complementary sides of a first workpiece and a second workpiece with a double-sided flat inductor assembly comprising:

a first workpiece inductor comprising:

a first planarly oriented inductor configured for induction heating a first workpiece face of the first workpiece; and

a first inductor terminal section electrically connected to the first planarly oriented inductor;

a second workpiece inductor comprising:

a second planarly oriented inductor planarly disposed opposing the first planarly oriented inductor, the second planarly oriented inductor configured for induction heating the second workpiece face of the second workpiece, the second workpiece face and the first workpiece face forming complementary sides of the first and the second workpieces; and

a second inductor terminal section electrically connected to the second planarly oriented inductor, the second planarly oriented inductor and the second inductor terminal section electrically isolated from the first planarly oriented inductor and the first inductor terminal section; and

a first and second workpiece inductor electrical connection means for connecting the first planarly oriented inductor and the second planarly oriented inductor in series electrical connection to form a series electrical circuit from the first inductor terminal section to the second inductor terminal section; the method comprising:

connecting an inductor power supply and an inductor power return to the series electrical circuit to a secondary magnetic power circuit;

magnetically coupling the secondary magnetic power circuit to a primary magnetic power circuit connected to an alternating current power source by a supply magnetic flux field coupling and a return magnetic flux field coupling without physical connection between the secondary magnetic power circuit and the primary magnetic power circuit to simultaneously induction heat the complementary sides of the first and the second workpiece; and

simultaneously separating the secondary magnetic power circuit from the primary magnetic power circuit and extracting the double-sided flat inductor assembly from between the first and second workpieces complementary sides by keeping the primary magnetic power circuit stationary while moving the secondary magnetic power circuit with attached inductor assembly to create an unobstructed space between the complementary sides of the first and second workpieces.

14. An extraction assembly for an inductor assembly, the extraction assembly comprising:

a stationary primary magnetic device mounted to a stationary primary mounting structure the primary magnetic device having a supply power magnetic device and a return power magnetic device;

a secondary magnetic device having an inductor supply power magnetic device and an inductor return power magnetic device, the secondary magnetic device slidably mounted relative to the stationary primary magnetic device between: an induction heating position when the supply power magnetic device is aligned with the inductor supply power magnetic device, and the return power magnetic device is aligned with the inductor return power magnetic device when an alternating current is supplied to the supply power magnetic device and the return power magnetic device to transfer flux respectively to the inductor supply power magnetic device and the inductor return power magnetic device; and a workpiece non-interference position when the supply of the power magnetic device is not aligned with the inductor supply power magnetic device and the return power magnetic device is not aligned with the inductor return power magnetic device to isolate the inductor supply power magnetic device and the inductor return power magnetic device from the alternating current by sliding the secondary magnetic device;

an extraction assembly inductor supply terminal connected to the inductor supply power magnetic device, a first inductor terminal section of the inductor assembly electrically connected to the inductor supply power magnetic device;

an extraction assembly inductor return terminal connected to the inductor return power magnetic device, the second inductor terminal section of the inductor assembly electrically connected to the inductor return power magnetic device to form an attached inductor assembly; and

5 an extraction actuator connected to the secondary magnetic device with the attached inductor assembly to move the secondary magnetic device and attached inductor assembly between the induction heating position and the workpiece non-interference position.

15. The inductor extraction assembly of claim 14 wherein each of the supply and return  
10 power magnetic devices and the inductor supply and return magnetic devices comprises a coil wound core.

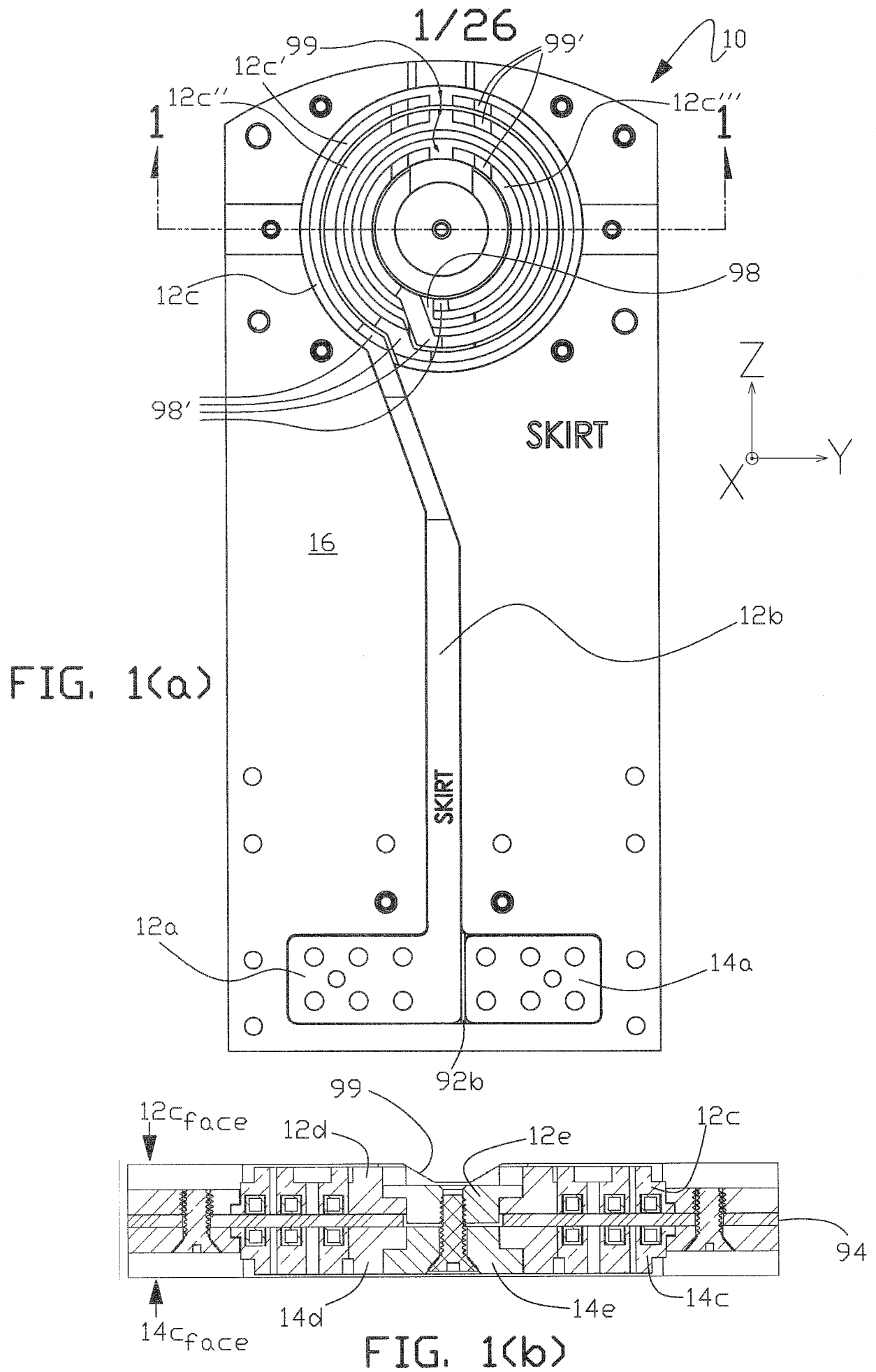
16. The inductor extraction assembly of claim 14 wherein:

the supply power magnetic device comprises a supply power rectangular open magnetic core with a supply electrical conductor disposed within the supply power rectangular open  
15 magnetic core, the supply electrical conductor connected to the supply alternating current source output;

the return power magnetic device comprises a return power rectangular open magnetic core with a return electrical conductor disposed within the return power rectangular open magnetic core, the return electrical conductor connected to the return alternating current source  
20 output;

the supply inductor magnetic device comprises a supply inductor rectangular open magnetic core with a supply inductor electrical conductor disposed within the supply inductor rectangular open magnetic core, the supply inductor electrical conductor connected to the inductor supply alternating current source output; and

25 the return inductor magnetic device comprises a return inductor rectangular open magnetic core with a return inductor electrical conductor disposed within the return inductor rectangular open magnetic core, the return inductor electrical conductor connected to the inductor return alternating current source output.



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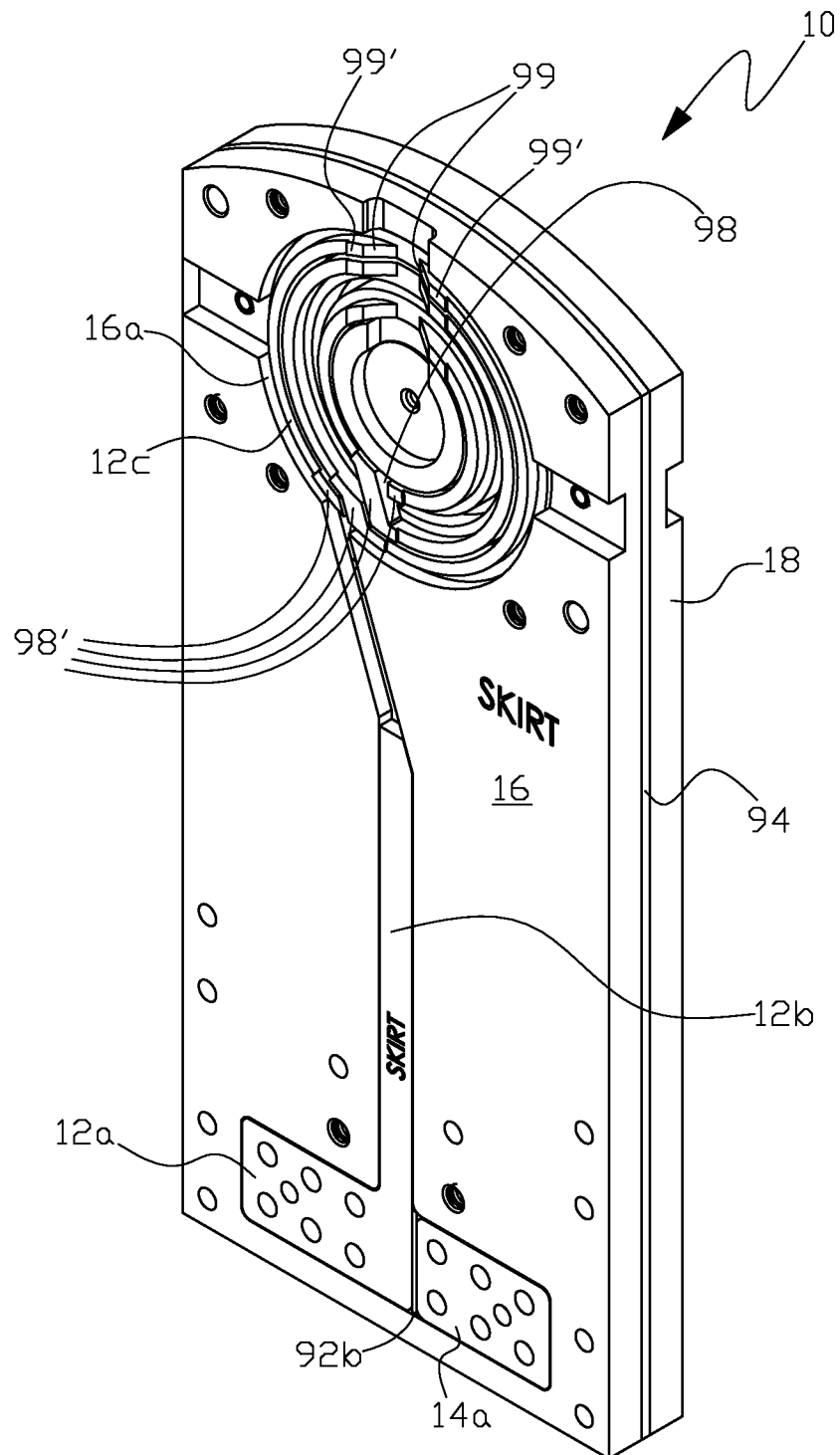
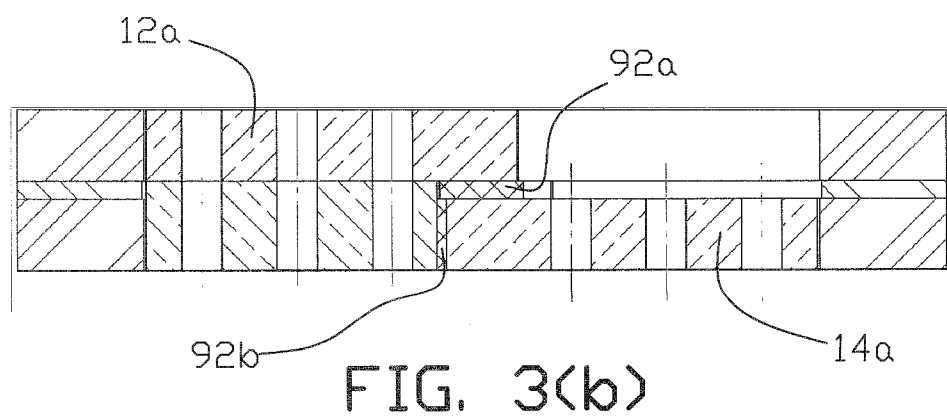
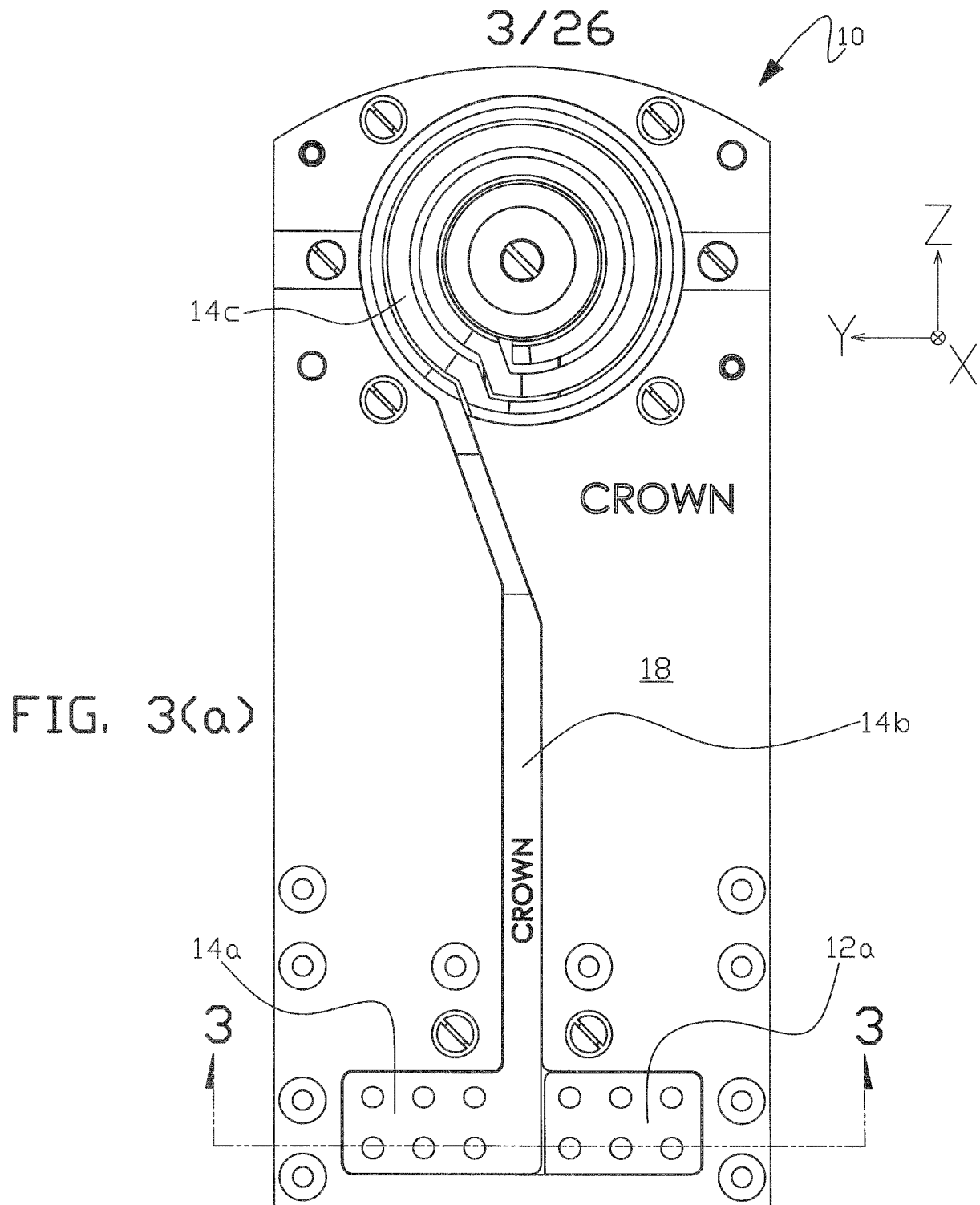


FIG. 2



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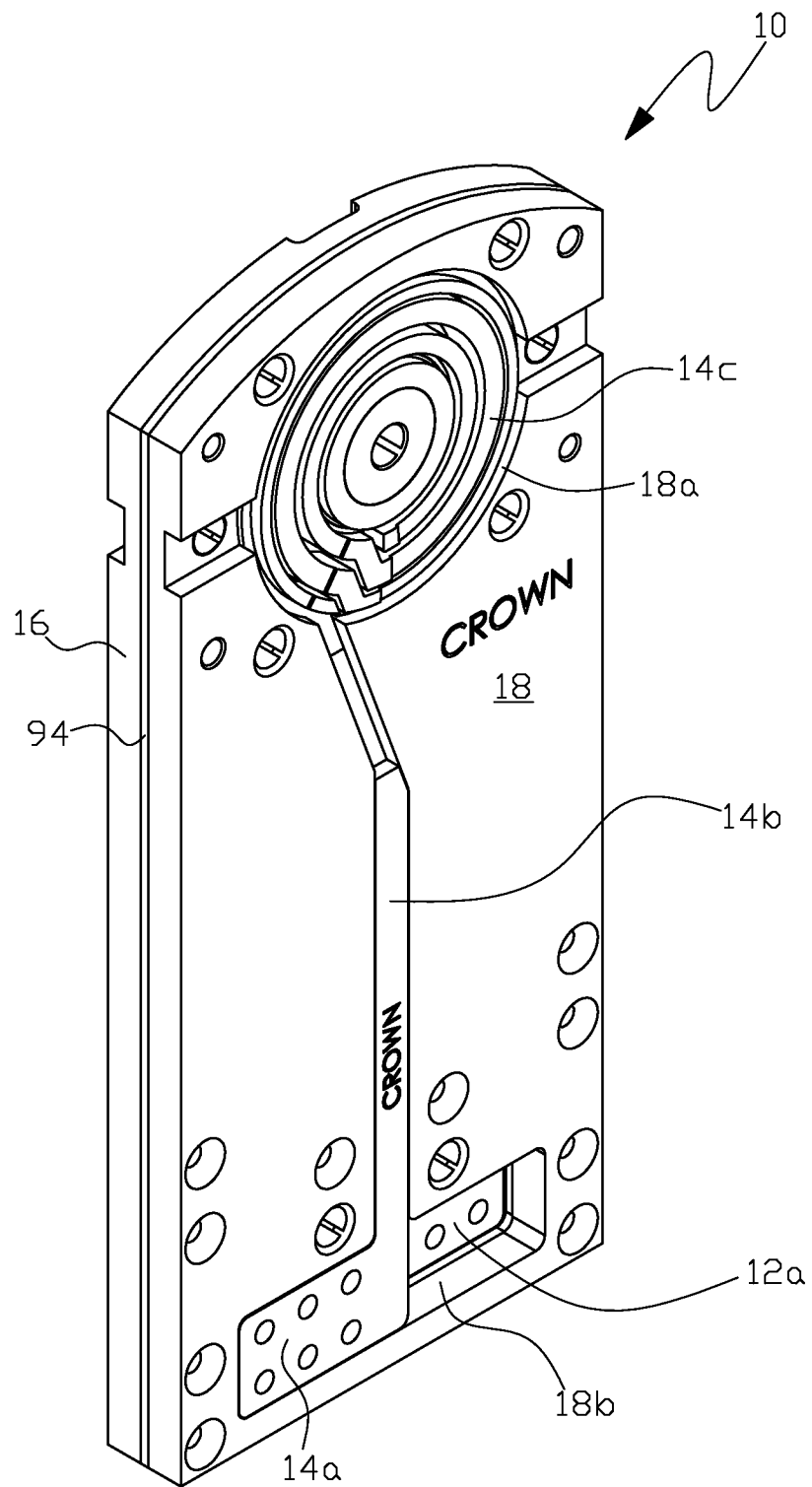


FIG. 4

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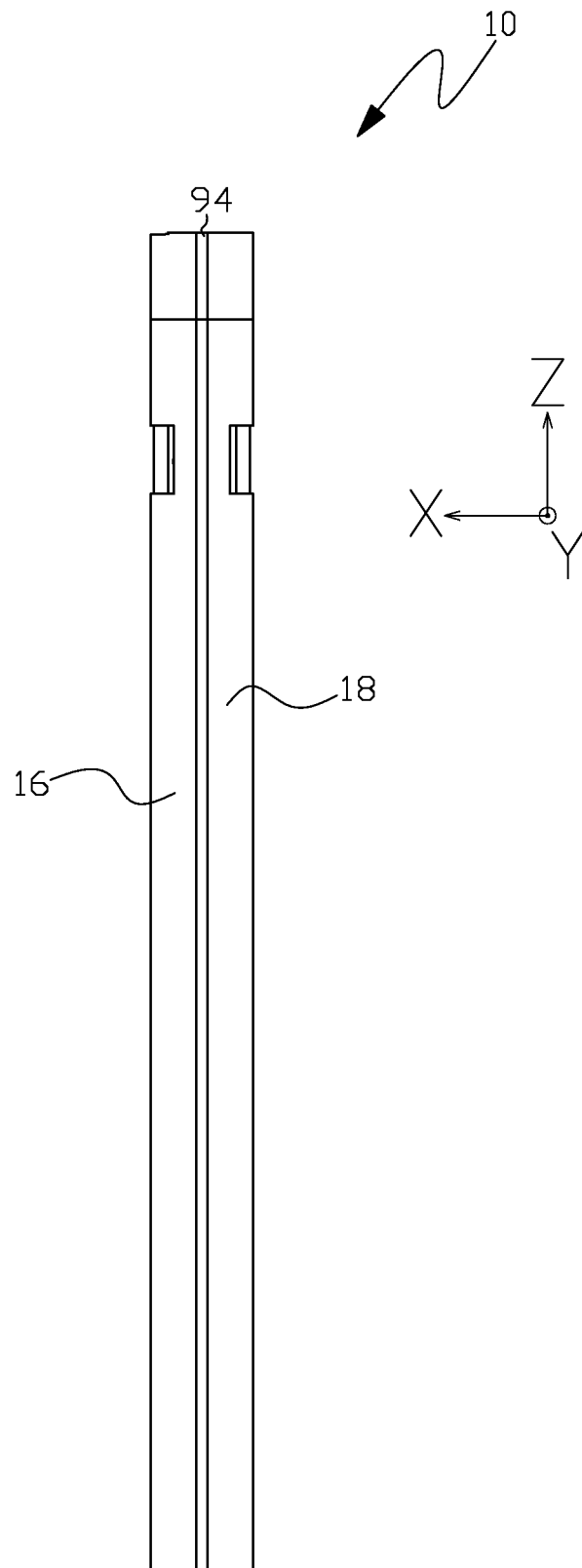


FIG. 5



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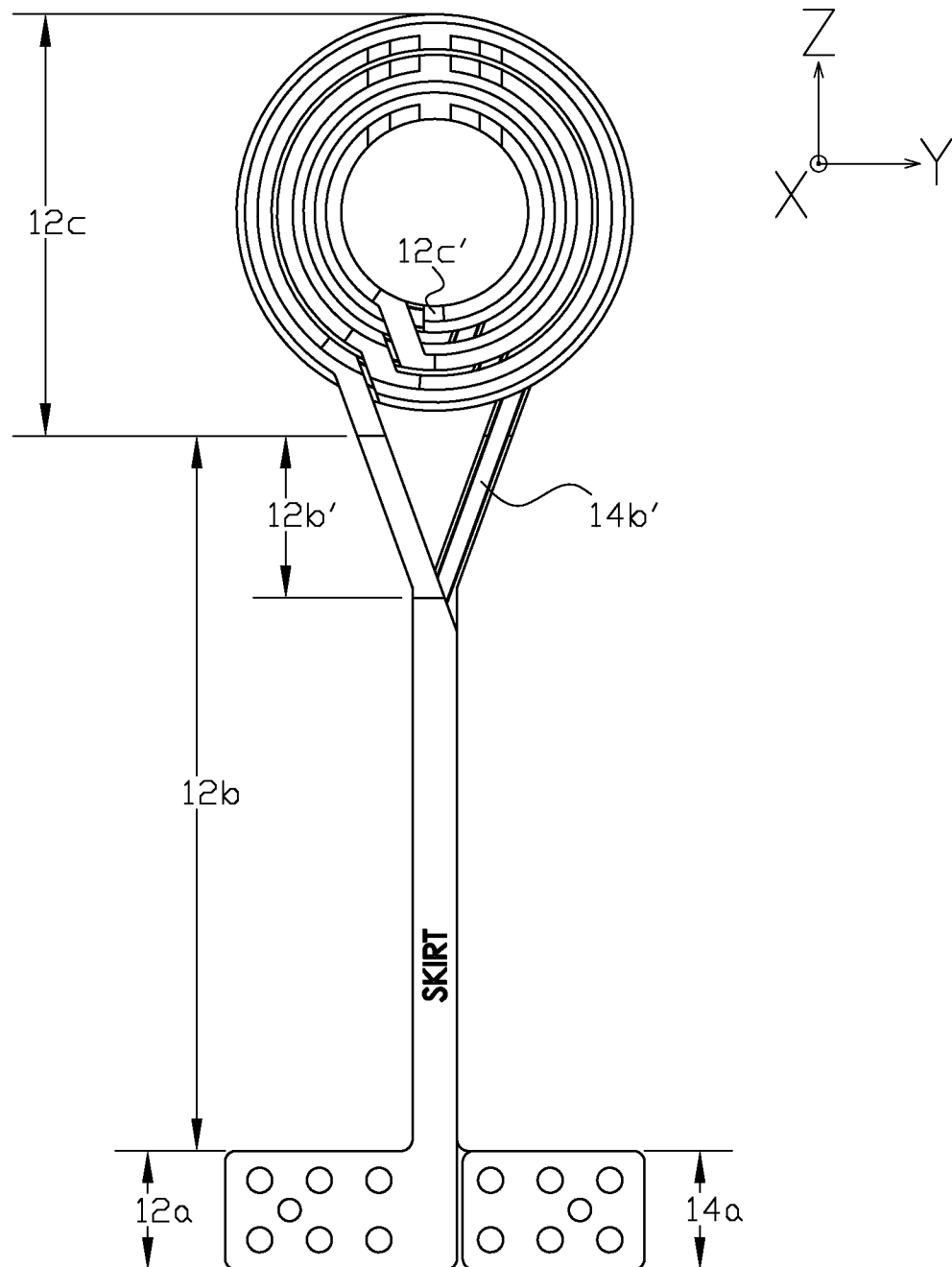


FIG. 6

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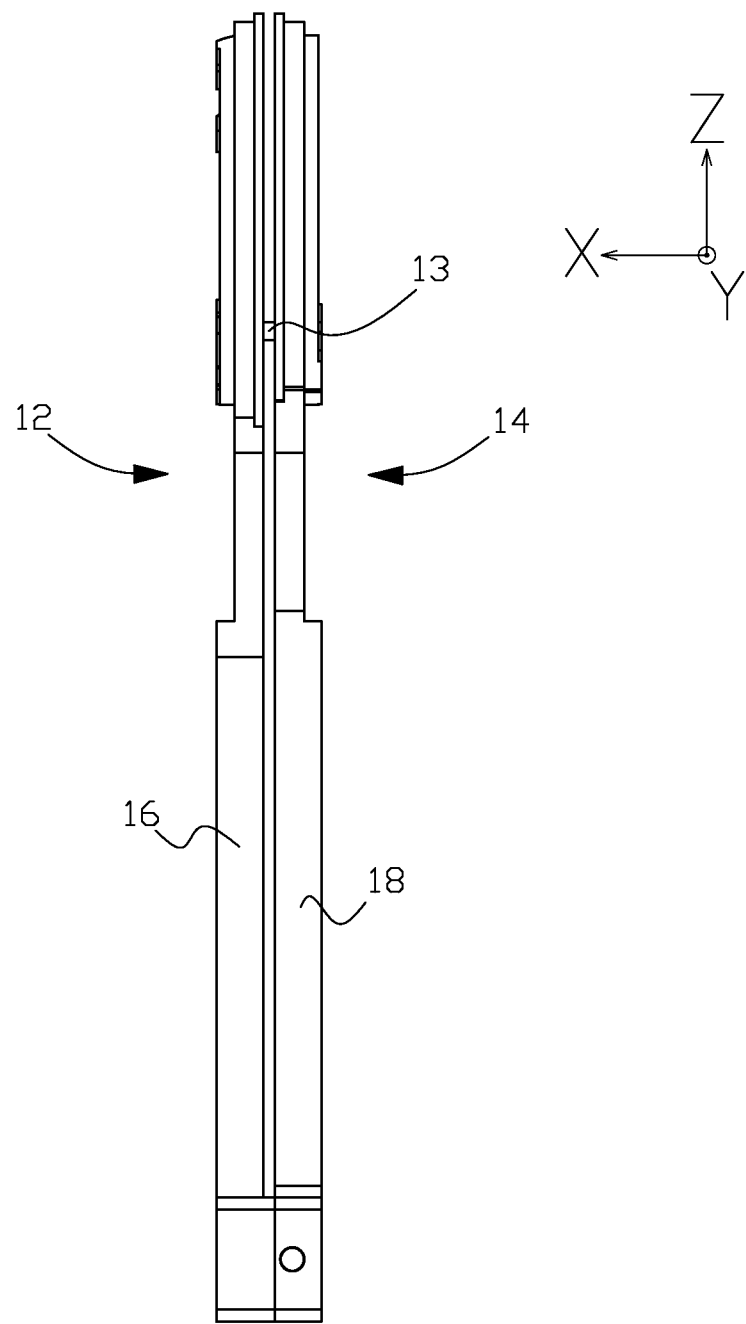


FIG. 7

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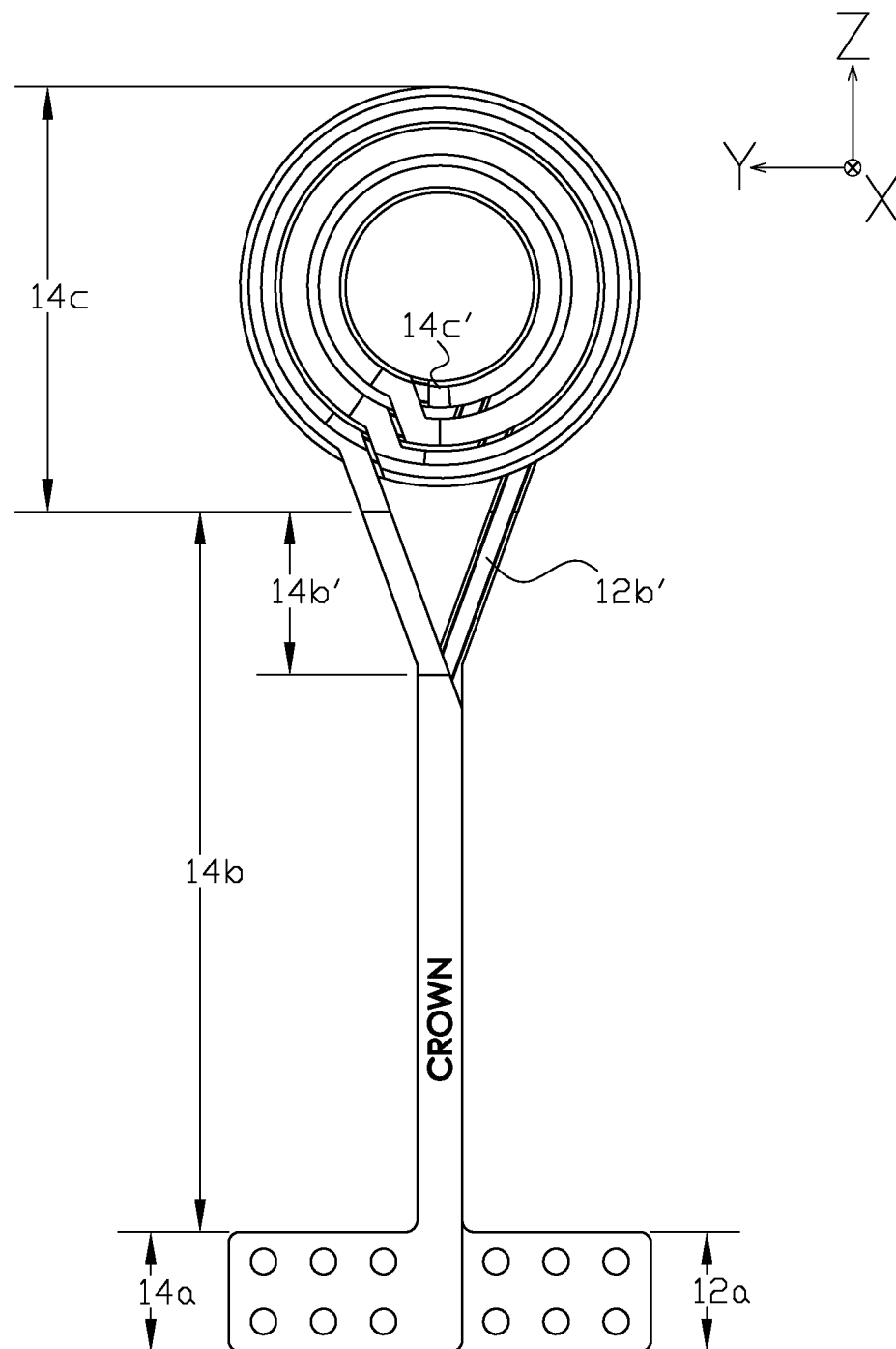


FIG. 8

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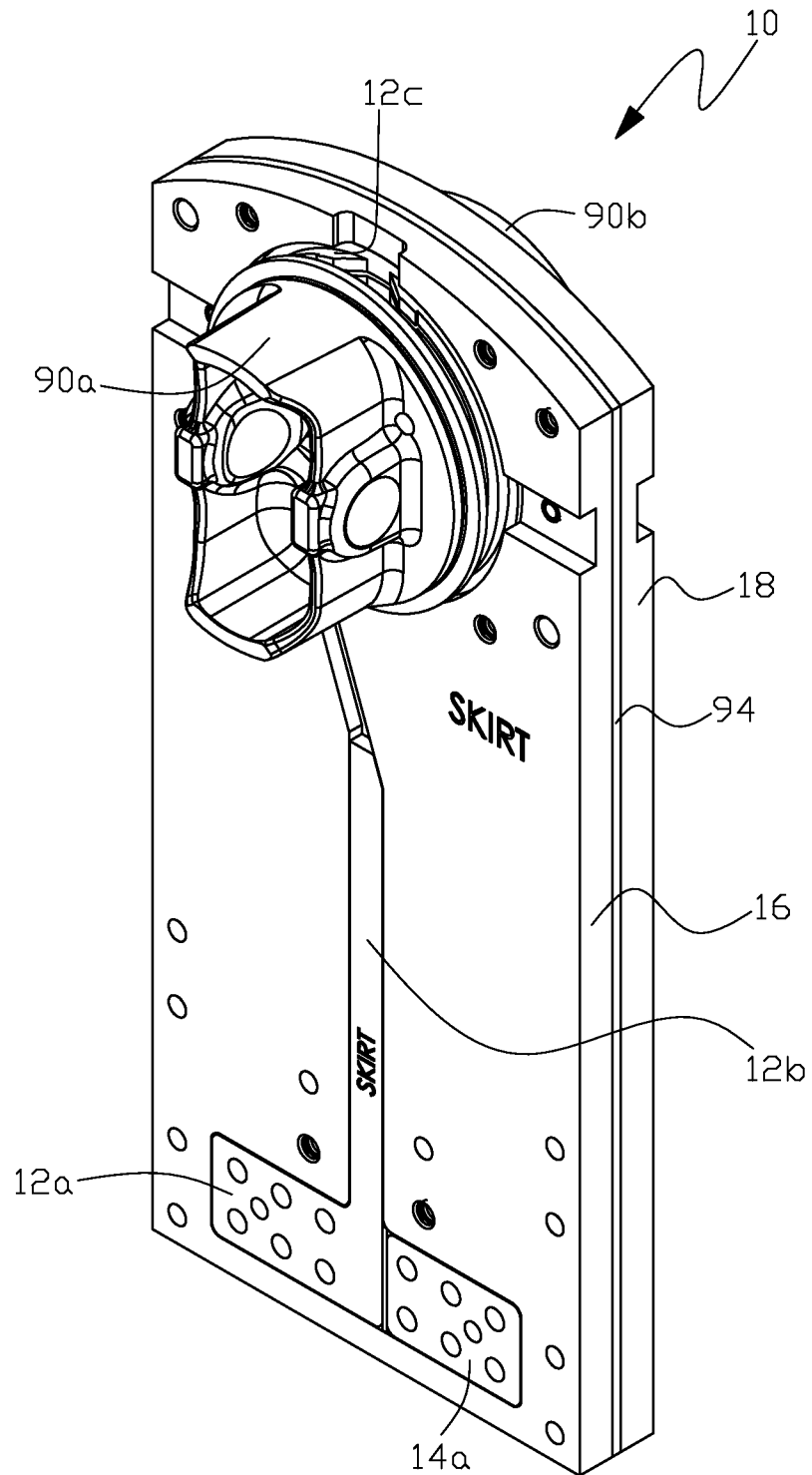


FIG. 9

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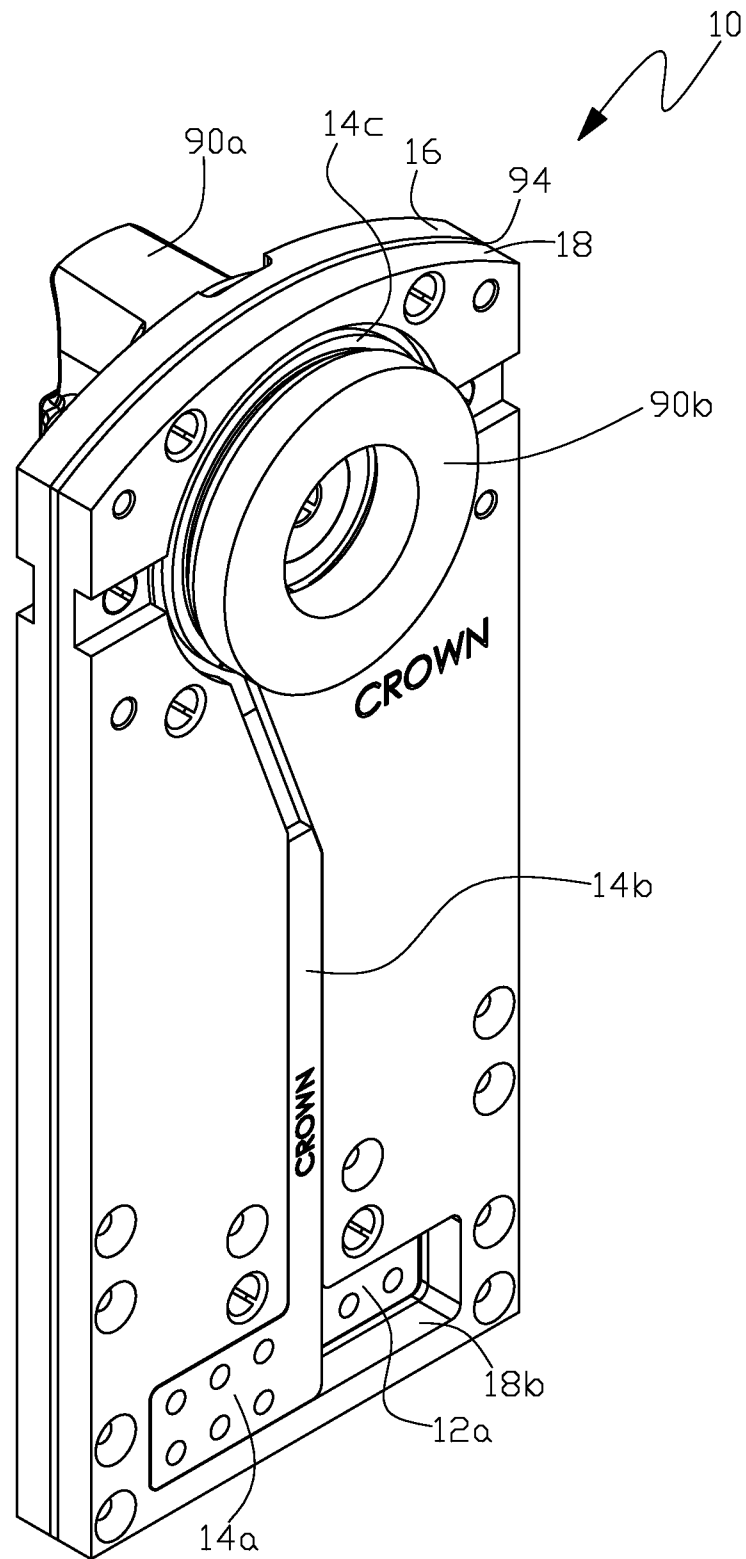


FIG. 10

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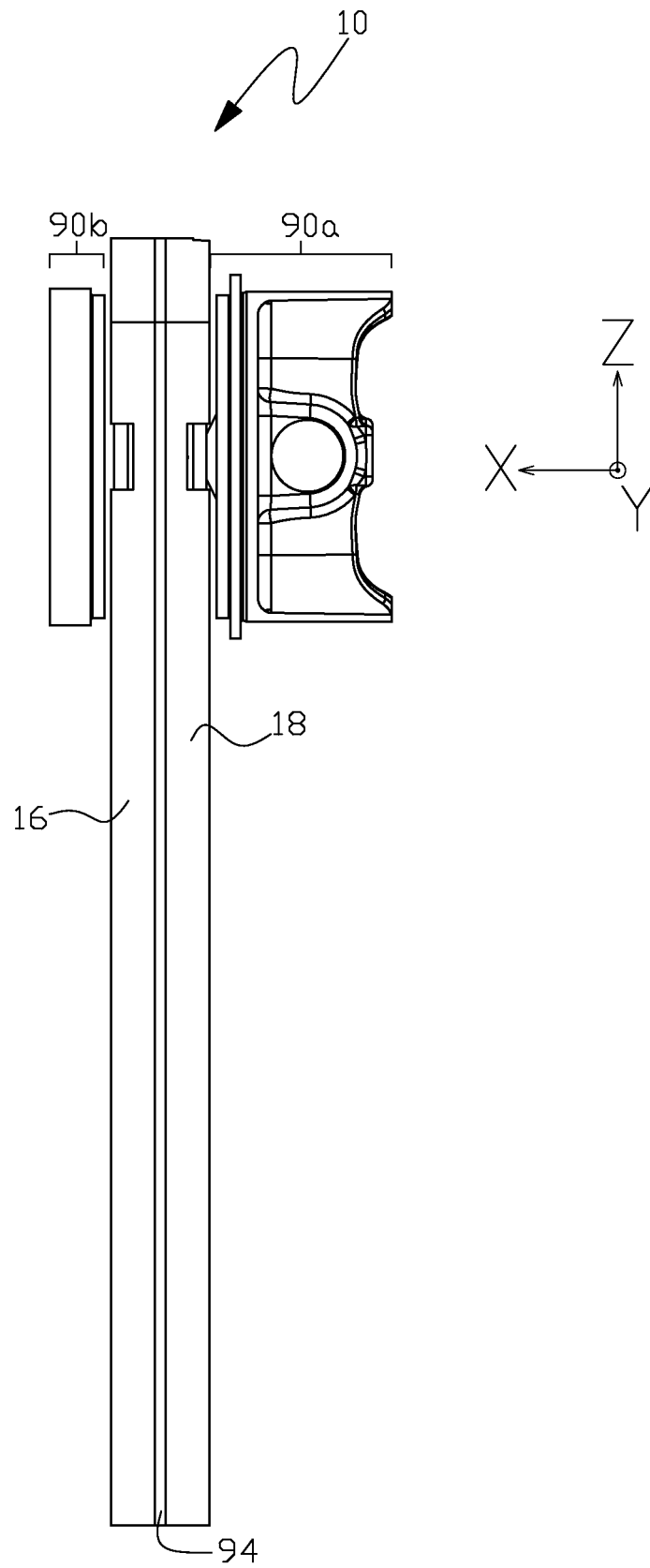


FIG. 11

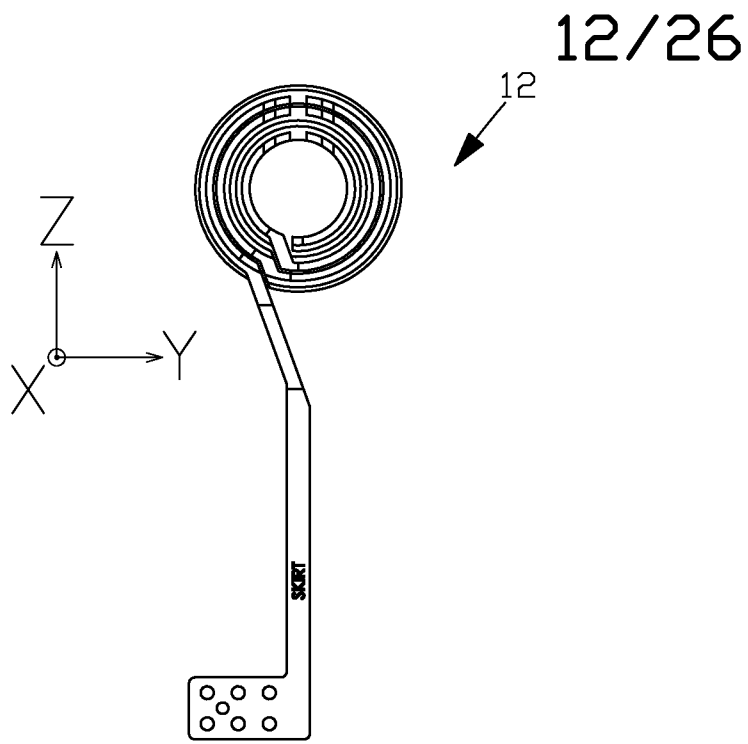


FIG. 12(a)

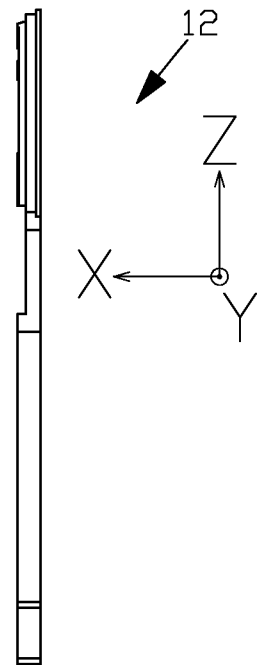


FIG. 12(b)

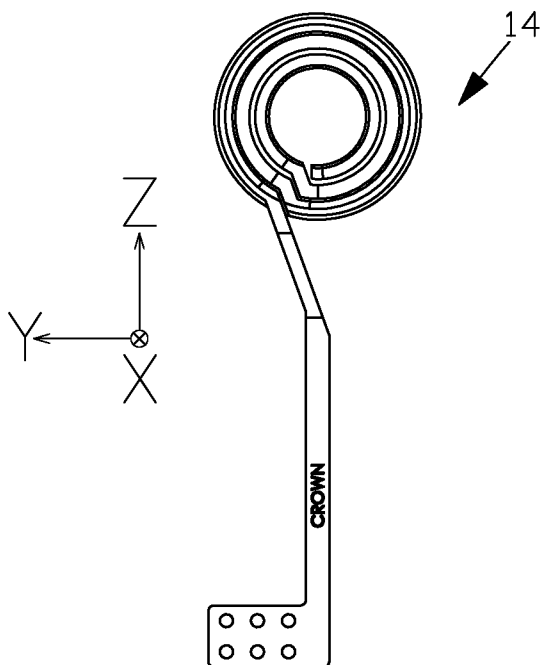


FIG. 12(c)

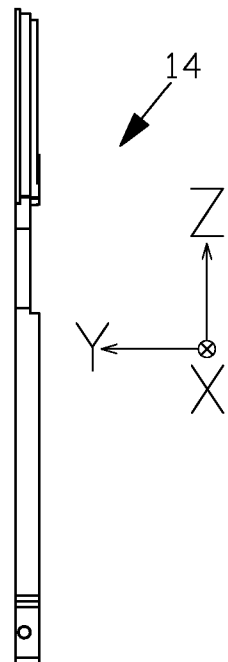
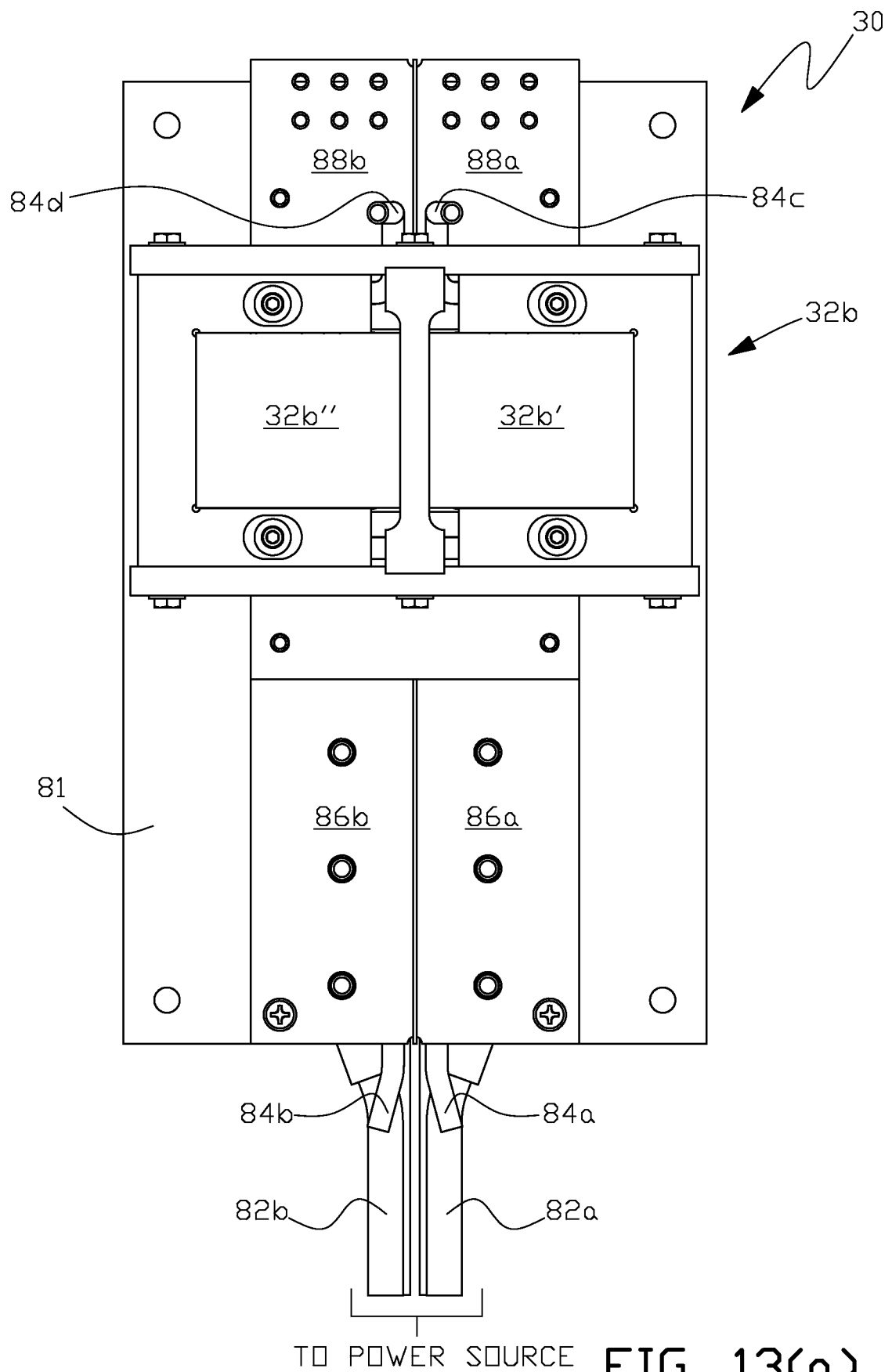


FIG. 12(d)

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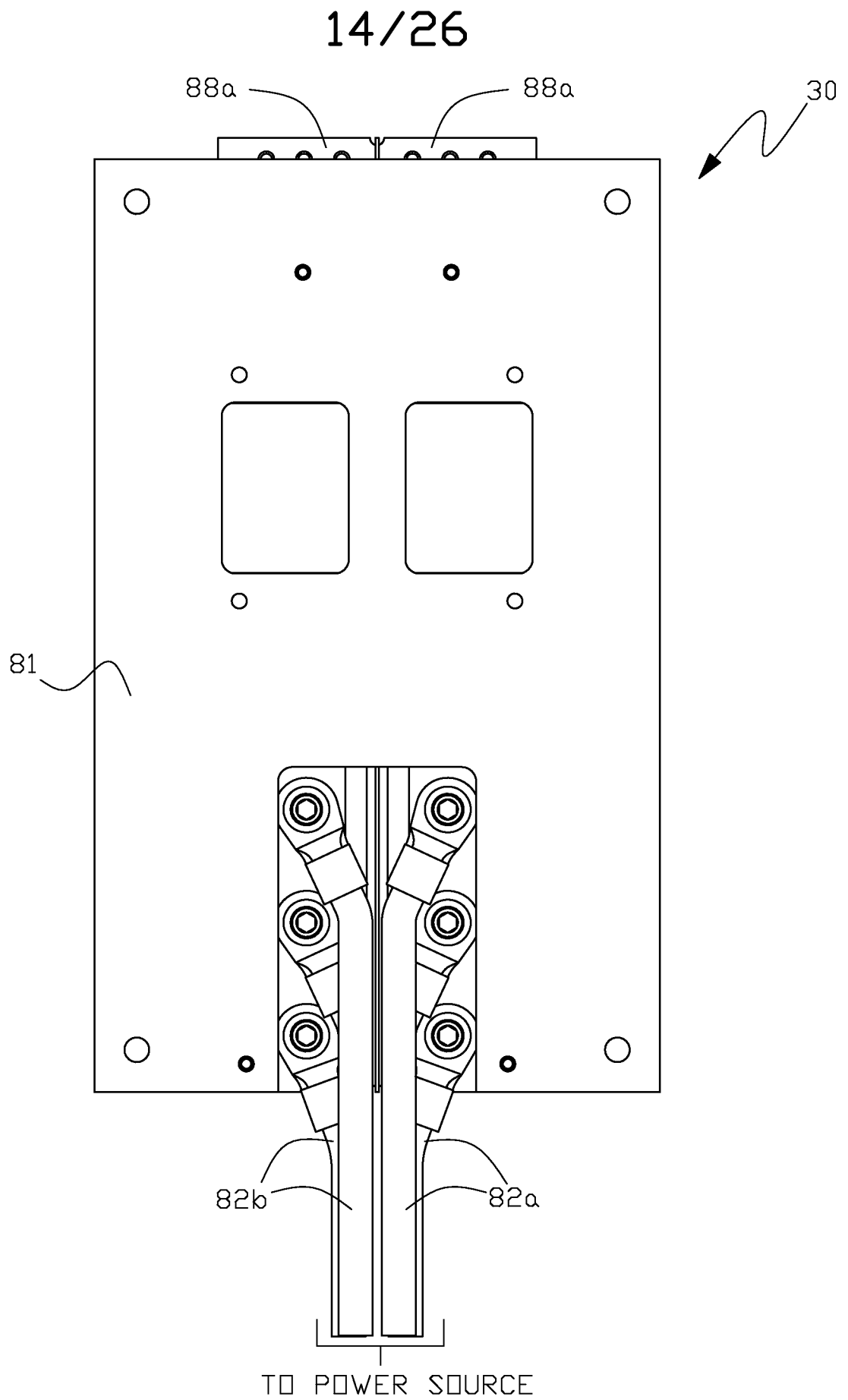
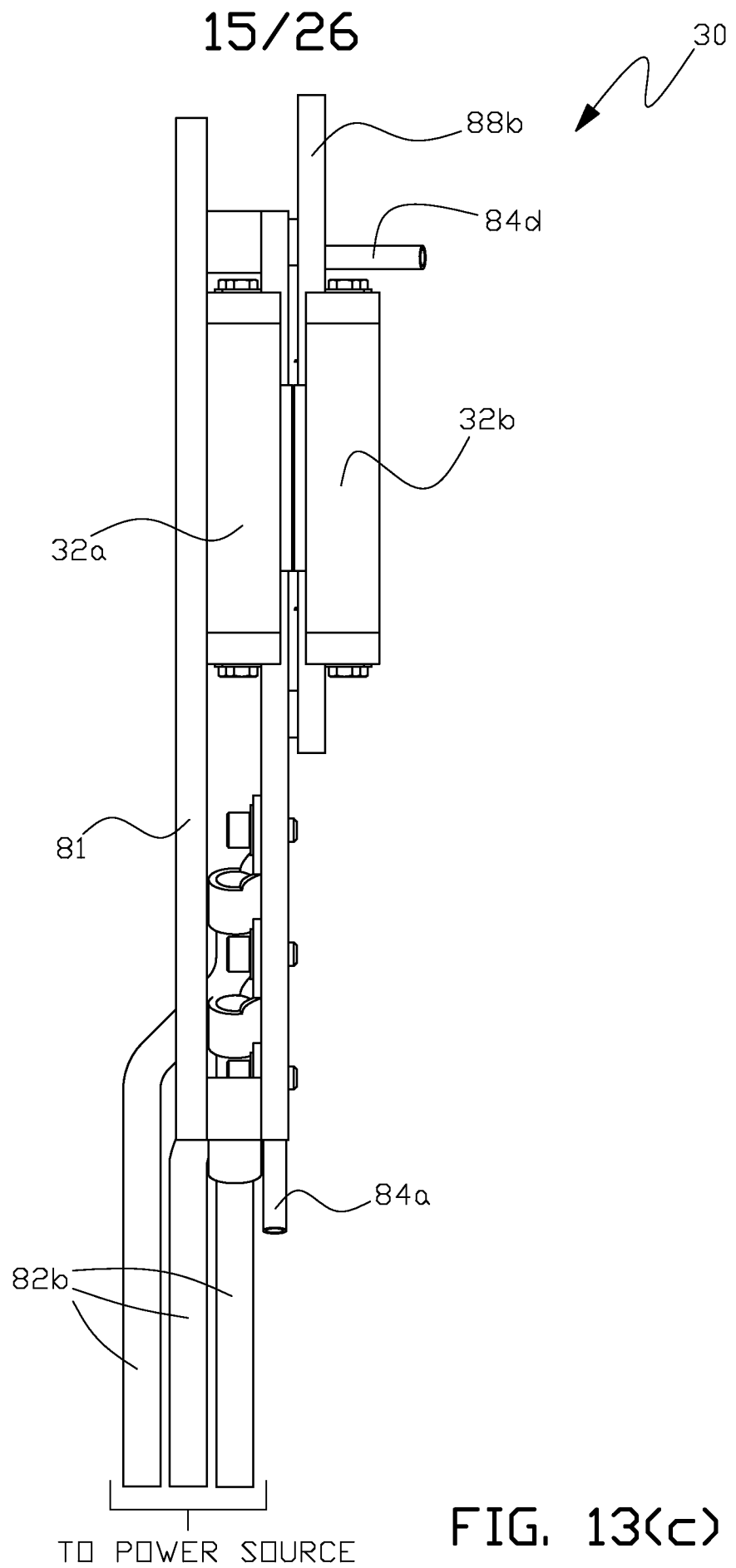


FIG. 13(b)



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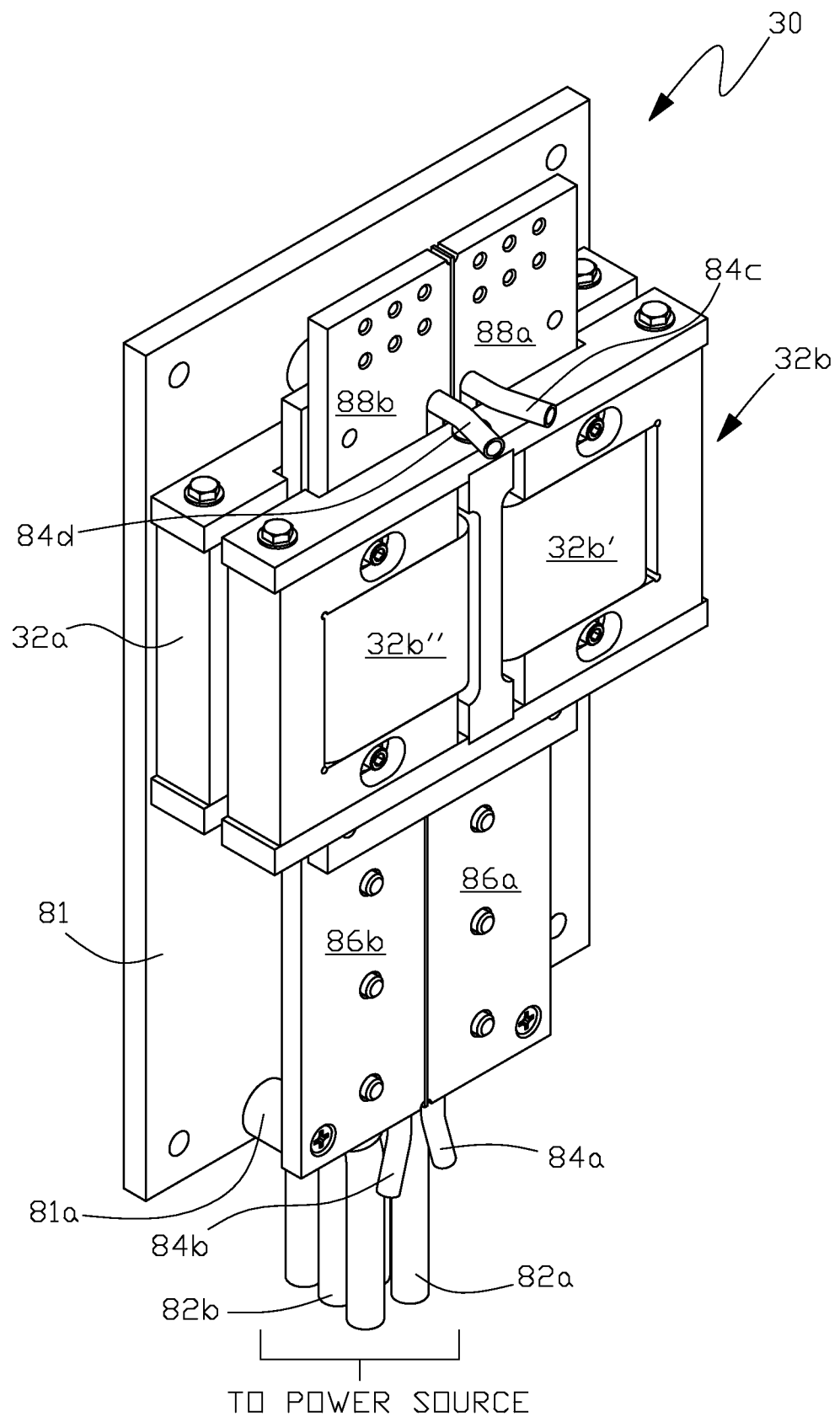


FIG. 13(d)

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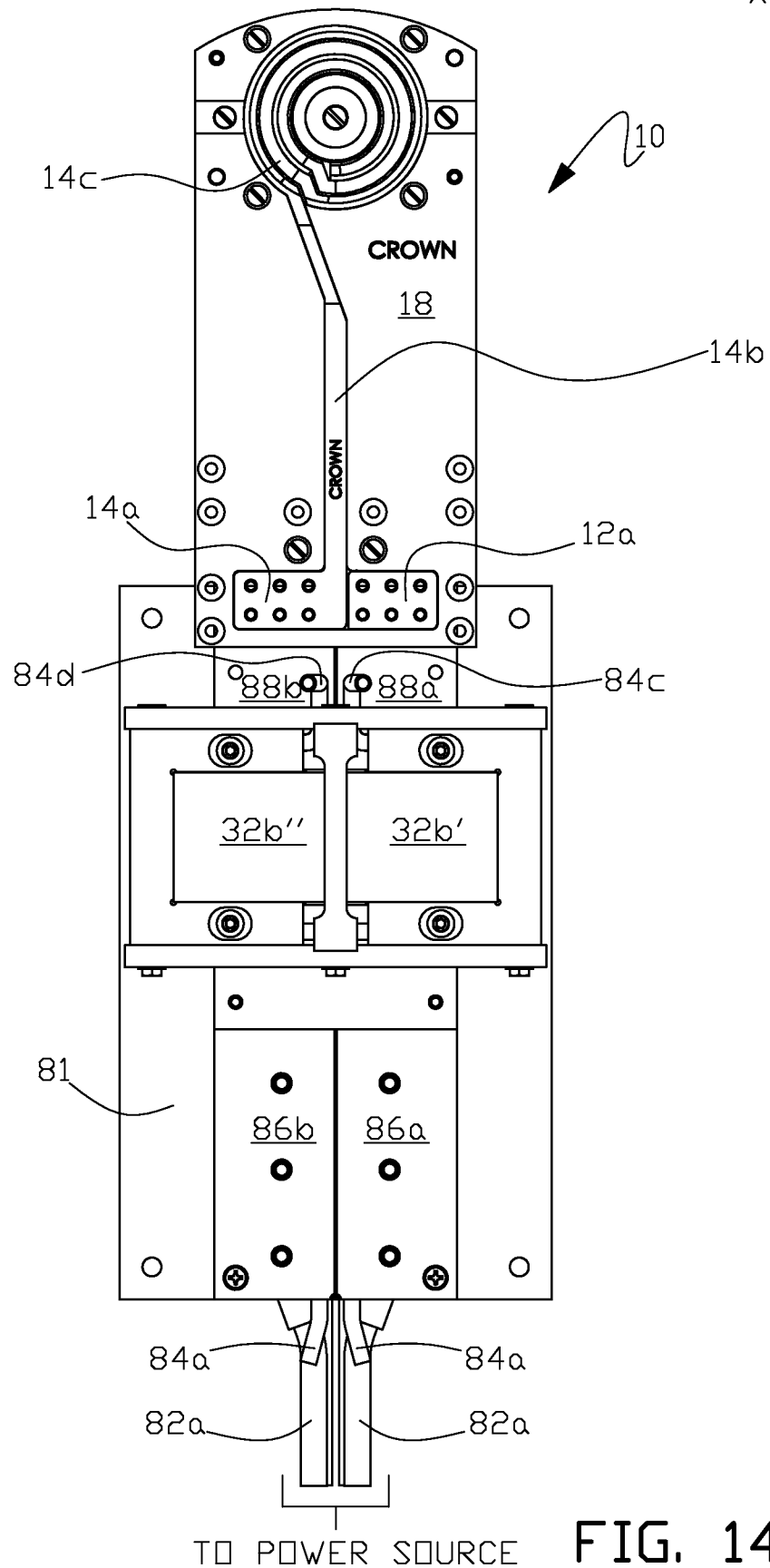
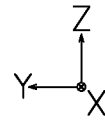
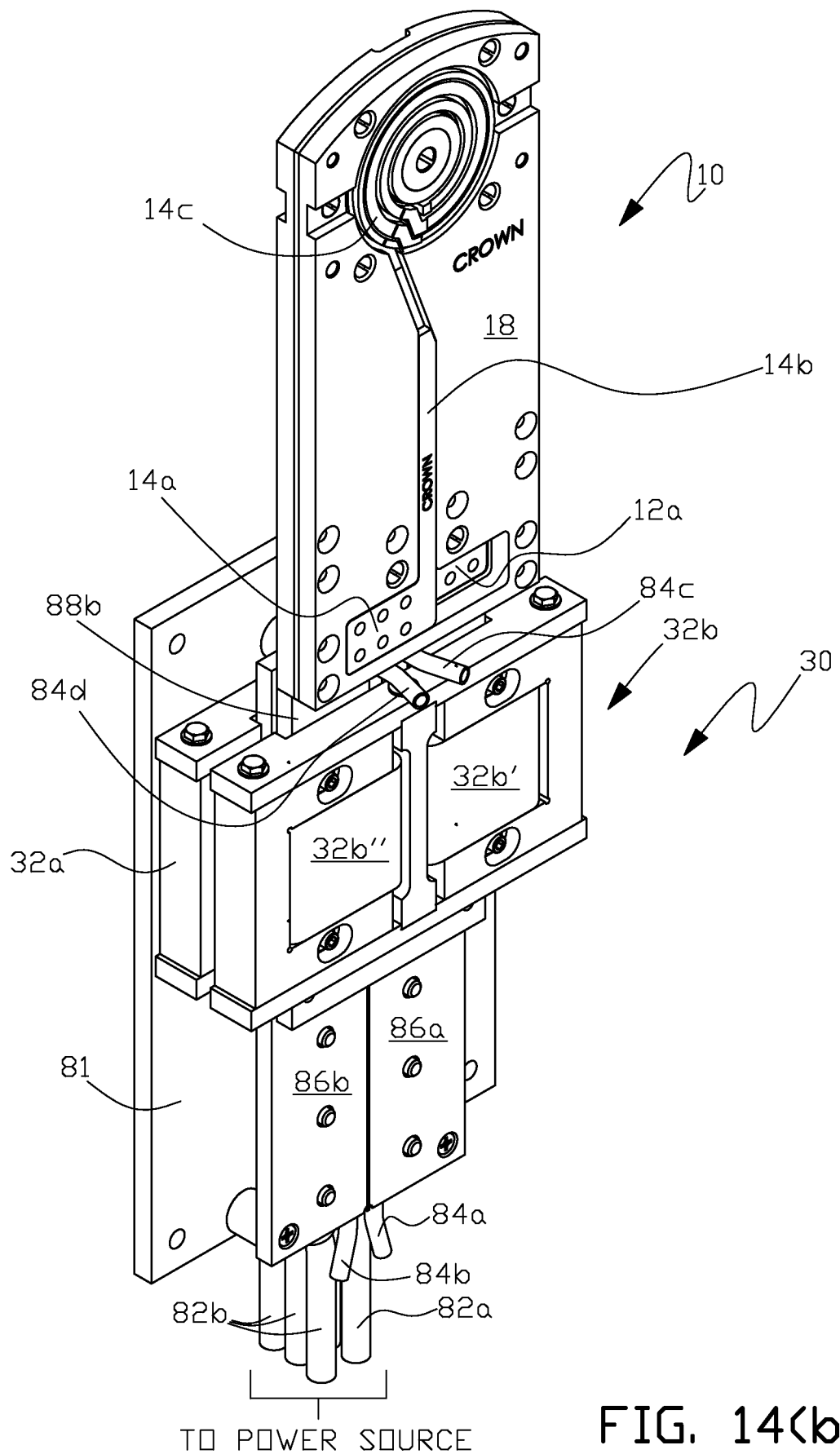


FIG. 14(a)

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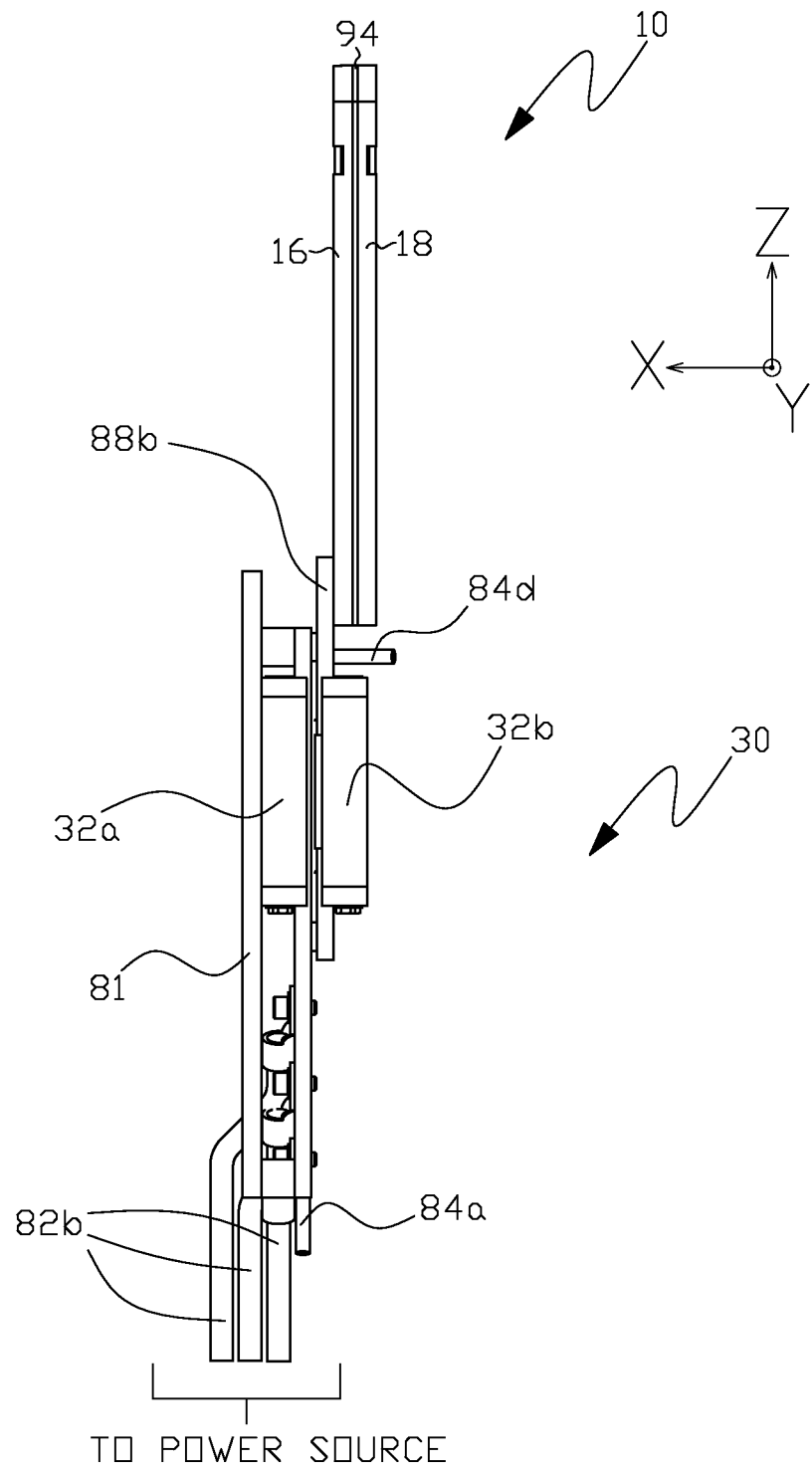


FIG. 14(c)

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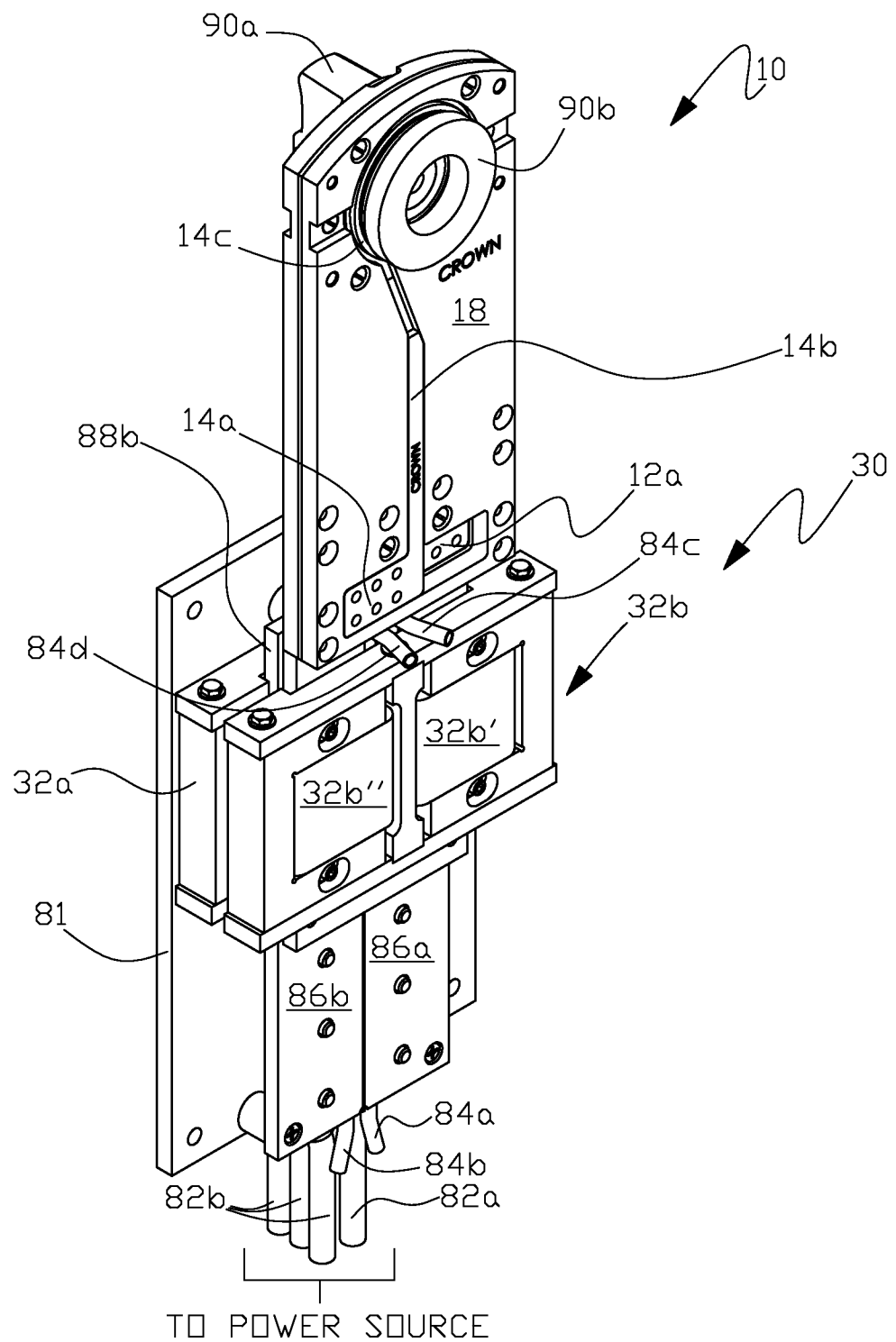


FIG. 14(d)

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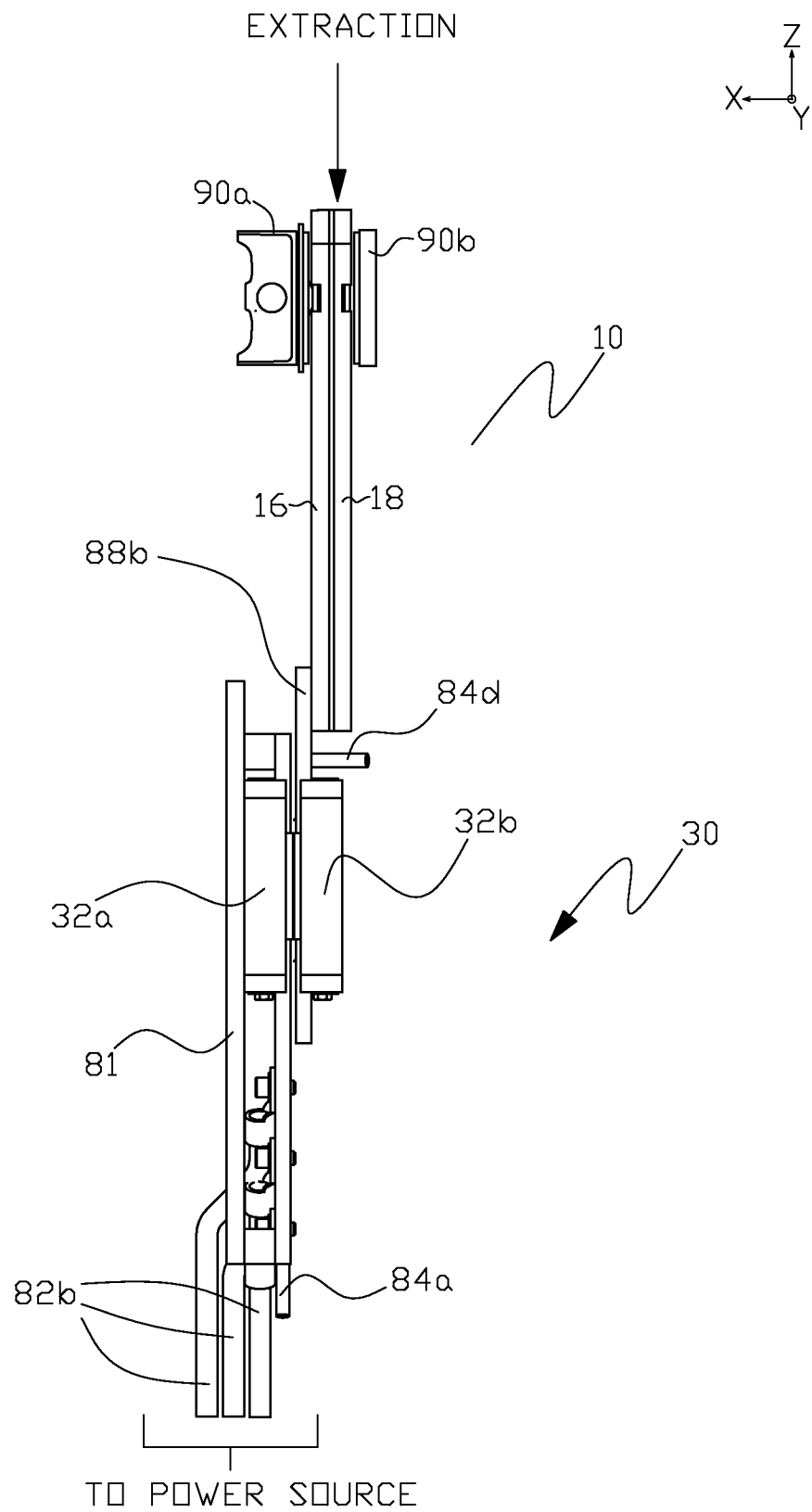
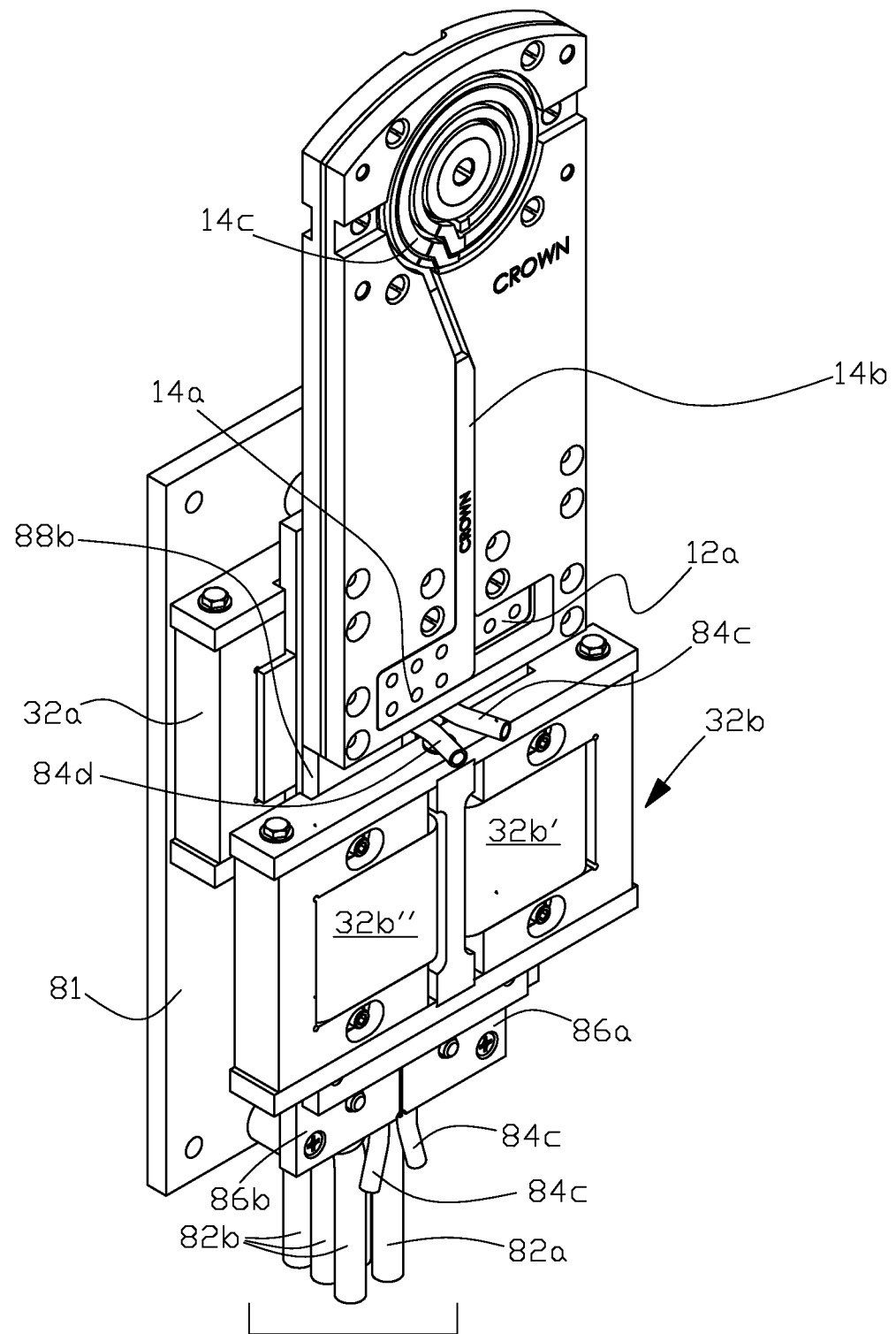


FIG. 14(e)



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TO POWER SOURCE

FIG. 15(a)

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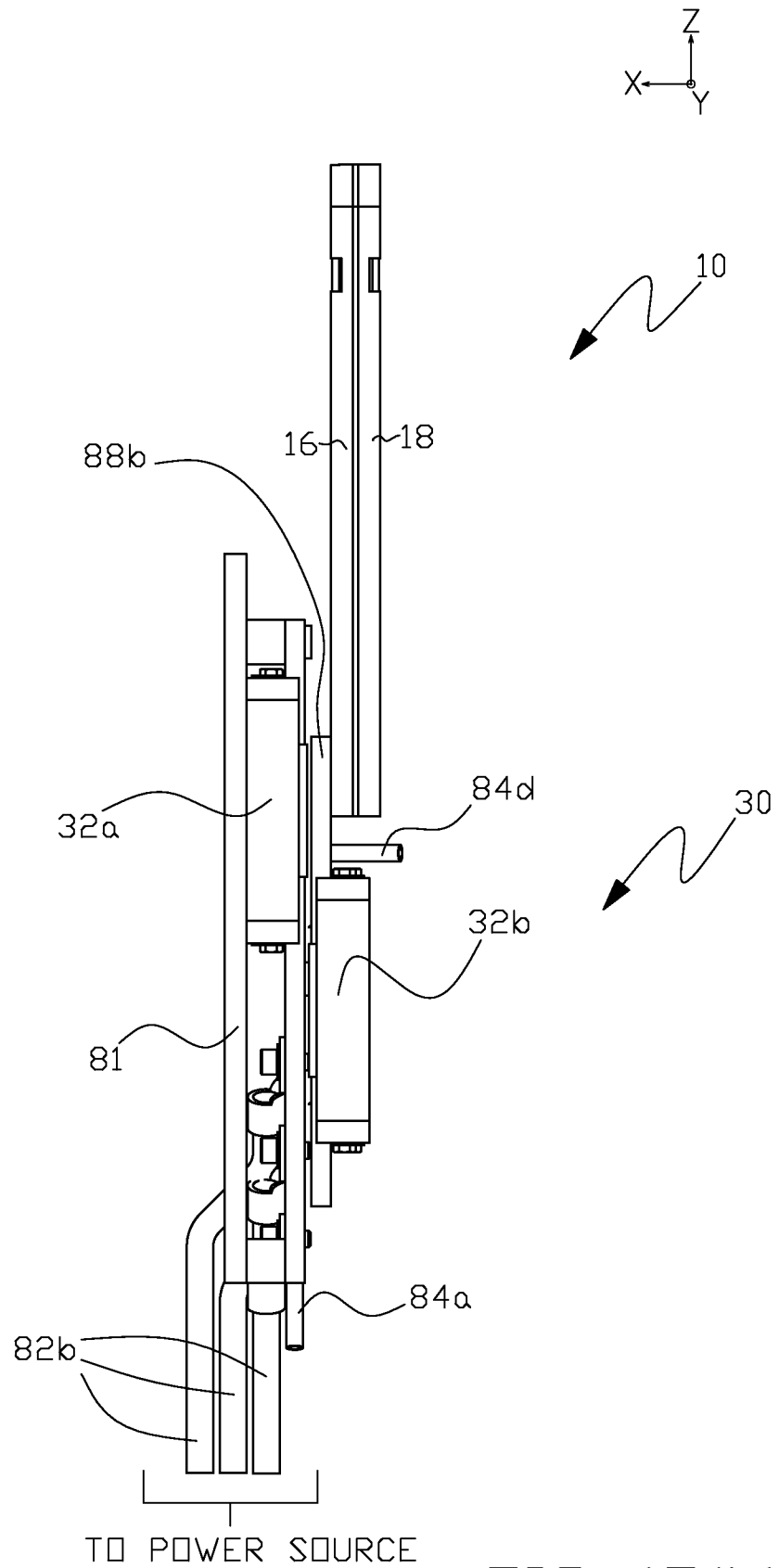


FIG. 15(b)

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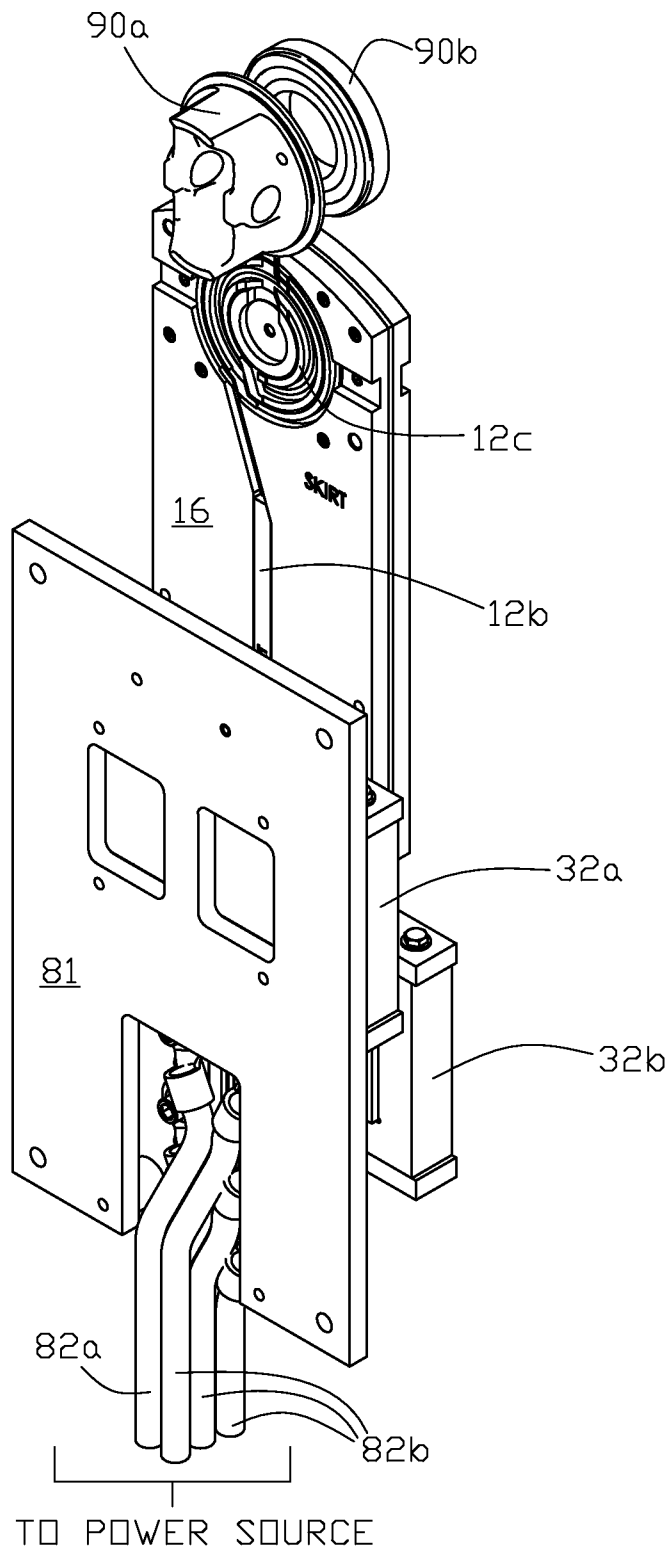


FIG. 15(c)

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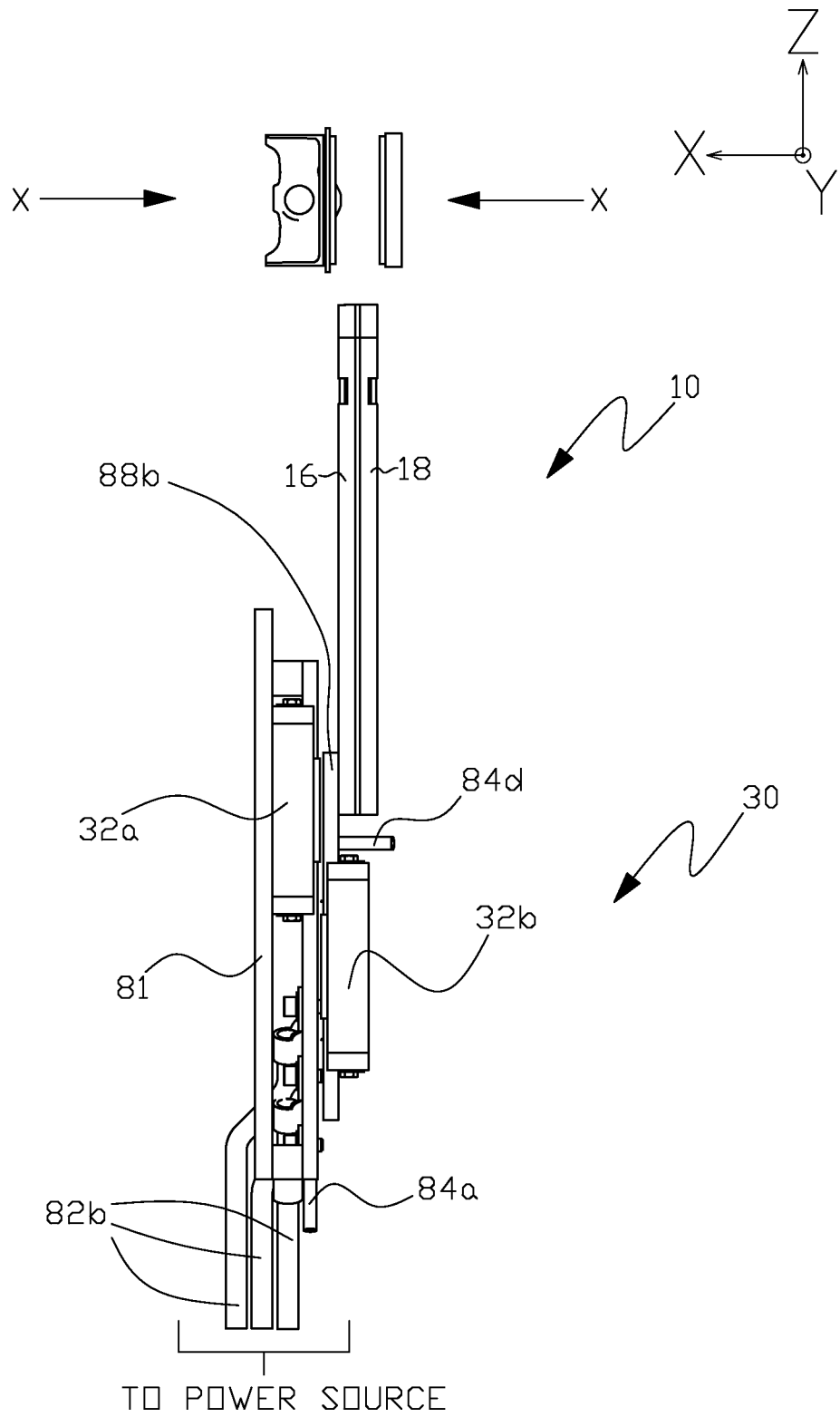


FIG. 15(d)

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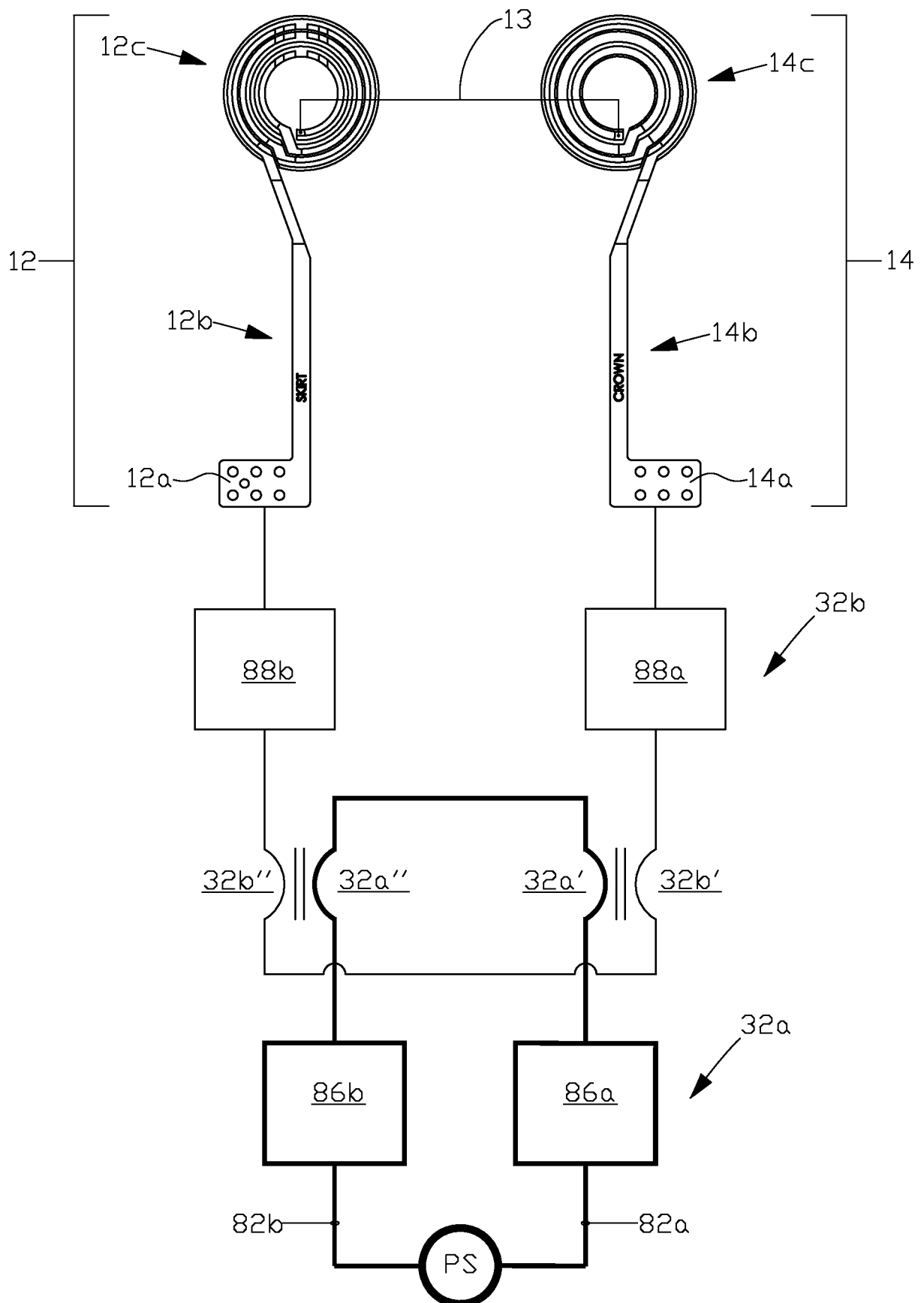


FIG. 16

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2015/021297****A. CLASSIFICATION OF SUBJECT MATTER****H05B 6/02(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H05B 6/02; H05B 6/36; H05B 6/10; H05B 6/06; H05B 6/38; H05B 6/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) &amp; Keywords:flat, double-sided, inductor, second, magnetic, primary, workpiece, power, supply

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014-0042151 A1 (TORU TONOMURA et al.) 13 February 2014 See paragraphs [0007]-[0008], [0013]; and figure 2.	1-13
A	US 2004-0149739 A1 (CARMO RIBEIRO et al.) 05 August 2004 See paragraph [0033]; and figures 3-4.	1-13
A	KR 10-2007-0107731 A (E.G.O. ELEKTRO-GERATEBAU GMBH) 07 November 2007 See paragraphs [0008], [0013]; and figure 4.	1-13
A	US 2006-0124632 A1 (WILLIAM I. STUEHR et al.) 15 June 2006 See paragraph [0011]; claim 1; and figure 1.	14-16
A	US 2006-0289493 A1 (JEFFREY R. THOMAS et al.) 28 December 2006 See paragraphs [0025]-[0026]; and figures 1-2.	14-16
A	US 5523546 A (ROBERT LAKE) 04 June 1996 See column 2; and figure 1.	14-16



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

28 May 2015 (28.05.2015)

Date of mailing of the international search report

**29 May 2015 (29.05.2015)**

Name and mailing address of the ISA/KR

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**INTERNATIONAL SEARCH REPORT**International application No.  
**PCT/US2015/021297****Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Group I, Claims 1-13 relate to a double-sided flat inductor assembly for simultaneous induction heating of complementary sides.

Group II, Claims 14-16 relate to an extraction assembly for an inductor assembly.

The invention listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons; they are separate inventions with distinct fields of search.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

**PCT/US2015/021297**

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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KR 10-2007-0107731 A	07/11/2007	AT 451818 T CN 1943274 A CN 1943274 B DE 102005005527 A1 DE 502006005577 D1 EP 1844630 A1 EP 1844630 B1 ES 2337922 T3	15/12/2009 04/04/2007 14/11/2012 03/08/2006 21/01/2010 17/10/2007 09/12/2009 30/04/2010



**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2015/021297**

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		JP 04925343 B2	25/04/2012
		JP 2008-528918 A	31/07/2008
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