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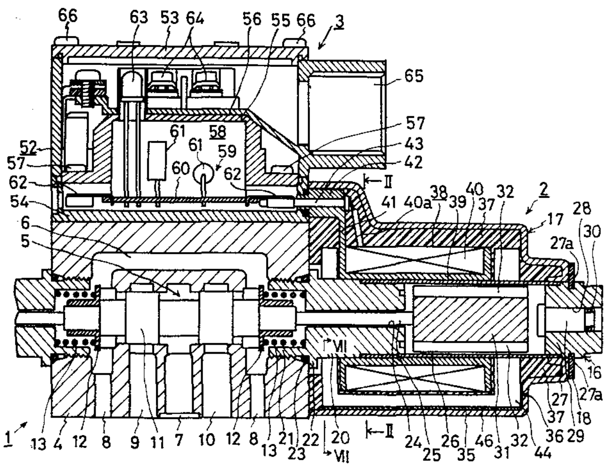
(54) An electromagnet and a method for manufacturing it.

(57) A cylindrical yoke of an electromagnet consists of two or more yoke elements, each of which is made of a number of yoke pieces made of magnetizable metal sheets and arranged radially around a cylindrical coil member of the electromagnet and of a filler member unifying the yoke pieces. The thickness of the yoke piece increases with increasing radial distance in order to improve the space factor of the yoke. The eddy current generated in the yoke is reduced due to the laminated construction of the yoke. The yoke disposed close to and coaxially with the coil member also contributes to the radial dispersion of the heat generated in the coil member and the yoke. The improved space factor results in the reduction of the leakage flux of the electromagnet and of the outermost size of the electromagnet for a certain available actuating power.



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"An electromagnet and a method for manufacturing it"

DESCRIPTION

1. Field of the Invention

This invention relates to an electromagent to operate a magnet valve apparatus and other mechanisms and more particularly to an electromagnet in which a circular cylindrical coil, a stator core and an armature core mounted about the axis of the coil and a yoke to lead the magnetic flux generated by feeding the coil with an alternate current to the stator core and the armature core are included and the armature core is pulled by the stator core under the electromagnetic force due to the magnetic flux.

2. Description of the Prior Art

In an electromagnet of the above described type, the yoke is made of laminated silicon steel sheets for the purpose of preventing the generation of eddy current. For the sake of easy manufacturing, the yoke is usually made in the form of a rectangular cylinder consisting of such a number of laminated silicon steel strips as is sufficient to obtain a cross-sectional area to pass satisfactorily the magnetic flux generated by the coil. However, since an air gap of a considerable thickness must be left between the circular cylindrical coil and the yoke, there is an undesirable and general tendency that the outermost dimension of the yoke is increased by an amount corresponding to the air gap and the electromagnet becomes relatively large-sized for the available electromagnetic performance as an electromagnet. Moreover, since the laminated silicon steel sheets are not radially arranged around the coil, there is also a disadvantageous tendency that the magnetic flux leaks out of the yoke and hence the electromagnetic force exerted on the armature core is relatively small for the electric power put into the coil.

Summary of the Invention

Now an object of the present invention is to provide an electromagnet in which eddy current is generated only to a very reduced degree due to a devised construction of many laminated yoke pieces.

Another object of the present invention is to provide an electromagnet construction which can be made small-sized despite the adopted laminated construction.

That is, if a number of yoke pieces constituting the yoke are arranged radially around the coil, each one of the many yoke pieces can be brought close to or even in contact with the outer side surface of the coil. In consequence of this, the outermost size as an electromagnet can be limited to the minimum value.

Still another object of the present invention is to provide an electromagnet in which the leakage magnetic flux of the coil is reduced and a relatively large electromagnetic force for the electric power put into the coil can be exerted on the armature core.

Namely, in the above yoke construction with a number of radially arranged yole pieces, most area of the outer side surface can be closely surrounded by the many core pieces and so almost all the magnetic flux generated by the coil can be brought to the stator core and the armature core through the yoke. Accordingly, a sufficiently large electromagnetic force can be applied on the armature core.

Still another object of the present invention is to provide a method of manufacturing an electromagnet of the above described construction with ease.

Other objects and advantages of the invention will become apparent during the following discussion of the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a longitudinal section of a magnet valve apparatus;

Fig. 2 is a section taken along the line II - II in Fig. 1;

Fig. 3 is a perspective view of a coil assembly;

Fig. 4 is an exploded perspective view showing the relationship between a coil member and yoke elements;

Fig. 5 is a perspective view of an outer frame;

Fig. 6 is a perspective view of a yoke piece;

Fig. 7 is an enlarged section taken along the line VII - VII in Fig. 1;

Fig. 8 is a plane view illustrating the setting up situation of yoke pieces with use of an assembling jig;

Fig. 9 is a section taken along the line IX - IX in Fig. 8;

Fig. 10 is a view showing the situation of the coil assembly before being filled up with a filler material;

Fig. 11 is a longitudinal section of the coil assembly filled up with synthetic resins;

Fig. 12 is an enlarged fragmental section taken along the line XII - XII in Fig. 11;

Fig. 13 is a plane view showing a different example of the assembling jig;

Fig. 14 is a section taken along the line XIV - XIV in Fig. 13;

Figs. 15 and 16 are longitudinal sections showing different examples of moulds;

Fig. 17 is a plane view showing a still different jig for assembling the yoke pieces;

Fig. 18 is a section taken along the line XVIII - XVIII in Fig. 17;

Fig. 19 is a plane view showing a still different example of the assembling jig for yoke elements;

Fig. 20 is a plane view showing yoke elements produced by dividing the yoke into a different number of parts;

Fig. 21 is a perspective view showing a different example of the yoke piece;

Fig. 22 is an enlarged fragmental view of the yoke piece of Fig. 21;

Fig. 23 is a view similar to Fig. 7 with the yoke piece therein replaced by that of Fig. 21;

Fig. 24 is a perspective view showing a still different example of the yoke piece;

Fig. 25 is an enlarged fragmental section of Fig. 24;

Fig. 26 is a view similar to Fig. 7 with the yoke piece therein replaced by that of Fig. 24;

Fig. 27 is a perspective view showing a still different example of the yoke piece;

Fig. 28 is an enlarged fragmental view of Fig. 27;

Fig. 29 is a view similar to Fig. 7 with the yoke piece therein replaced by that of Fig. 27;

Fig. 30 is a longitudinal section showing a different example of the actuator;

Fig. 31 is an enlarged side elevation of the stator core of Fig. 30;

Fig. 32 is an enlarged front elevation of the stator core of Fig. 30;

Fig. 33 is a section taken along the line XXXIII - XXXIII in Fig. 32;

Fig. 34 is a section taken along the line XXXIV - XXXIV in Fig. 32 and showing a construction to fix a shading coil in a core main portion;

Figs. 35 and 36 are perspective views of connection member elements;

Figs. 37 and 38 are perspective views of core pieces;

Fig. 39 is a view showing an assembling process of the stator core;

Fig. 40 is an enlarged side elevation of an armature core of Fig. 30;

Fig. 41 is an enlarged front elevation of said armature core; and

Fig. 42 is a section taken along the line XXXXII - XXXXII in Fig. 41.

Description of the Preferred Embodiments

In Figs. 1 to 12, a magnet valve apparatus comprises a valve device 1, an electromagnet 2 for actuating the valve device 1 and a terminal box 3 to which the ends of the power supply wires for the electromagnet is connected. For a start, an account is given of the valve device 1. A body 4 is provided interiorly with a space 5 for advance and retreat of a spool 11 and with an oil passage 6. The body is also provided with a port 7 for communication with a hydraulic pressure supply (for example, a pump), ports 8 for communication with a pressure-oil tank, and ports 9 and 10 for communication with a driven device, for example, a hydralulic cylinder and these ports are in communication as well with the aforesaid space 5 for advance and retreat of the spool 11 or with the oil passage 6. In the space 5, the well known spool 11 is mounted for right and left travel as viewed in Fig. 1. On either end of the spool 11, a spring seat 12 is capped and a spool restoring spring 13 is compressively inserted between the spring seat 12 and each of threaded connectors of an electromagnet to be described later on. These spool restoring springs 13 are mounted for keeping the spool 11 in a neutral position as shown in Fig. 1 and are both compressive.

In the next place, an account is given of the electromagnet 2. This electromagnet consists of an actuator 16 to operate mechanically the aforementioned valve device 1 and of a magnetizer 17 adapted to impart magnetic flux to the actuator 16. The actuator 16 has a stator core 20 which, at one end thereof, has an integral threaded connector 21 adapted threadedly in the body 4 of the valve device 1. The stator core 20 has also a flange portion 22 by which a ceiling O-ring 23 is pressed down. The stator core 20 has further a through hole 24 where a push rod 25 is inserted for the right and left displacement as viewed in Fig. 1. One end portion of a tube member 26 is capped on the other end portion of the stator core 20 and both the ends portions are hermetically welded to seal off the space inside the tube. The tube member 26 is made of a nonmagnetic material, defining a space for advance and retreat of the armature core 31. To the other end portion of the tube member 26 is hermetically welded a blocking member 27. The blocking member 27 is provided with a through hole 28 in which a push pin 29 for manual actuation is inserted for movement to the left of Fig. 1 and return to the shown position. The hermetic seal between the through hole 28 and the push pin 29 is maintained by an O-ring 30. In the space defined by the tube member 26 an armature core 31 is disposed for the right and left travel in Fig. 1. On a part of the cylindrical surface of this armature core 31 an oil passage groove 32 is cut over the full axial length of the armature core 31 so that oil may flow through the groove 32 between the left and the right ends of the armature core 31 as seen in Fig. 1. The actuator 16 goes by the name of a tube assembly. Next an account is given of the magnetizer 17. This magnetizer 17 is situated outside the actuator 16 and is prevented by a stop fitting 18 from departing the valve device 1. The magnetizer 17 is provided with a housing 35, which is made of synthetic resins in one case and is prepared as a die casting in another. Inside the housing 35 a coil assembly 36 is fitted and the space between the coil assembly 36 and the housing 35 is filled up with a filler member 37. As the material of the filler member 37, those synthetic resins are used which are highly electrically insulating and of sufficient heat conduction. Now an account is given of the coil assembly 36, which comprises a cylindrical coil member 38 and a yoke 44 formed so as to enclose the former. The coil member 38 consists of a cylindrical coil bobbin 39 with a flange at either end thereof and a coil wire 40 covoluted on the bobbin 39. From one of the flanges of the bobbin 39 is extending a tongue piece 41 whose tip is provided with a plug holder 42. A lead wire 40a of the aforesaid coil wire 40 is connected to a plug 43 held by the plug holder 42. As a matter of course, the coil bobbin 39 is made of a material of sufficient electrical insulation and the coil wire is a wire of little electrical resistance, for example, a copper wire. The yoke 44 consists of plural (two in the present embodiment) yoke elements 45. Each yoke element 45 comprises an auxiliary outer frame 46 and a plurality of similar yoke pieces 47 arranged radially towards the axis of the coil member 38. The outer frame 46 is preferably made of a magnetic material for the outer frame to be utilized as a part of a magnetic circuit but need not be so. The yoke pieces 47 are necessarily made of a magnetic material. Each yoke piece 47 formed of an intermediate member 48 to be positioned at the cylindrical surface of the coil member 38 and end members 49 extending integrally from both ends of the intermediate member 48 as shown in Fig. 6. The intermediate member 48 is substantially of the same length as the coil member 38 (slightly longer by a clearance for assembling to be described later). The width of the intermediate member of every yoke piece is selected to be sufficient to pass satisfactorily the magnetic flux generated by the coil member 38. The end member 49 has a length equal to the sum of the thickness of the coil member 38 and the width of the intermediate member 48. The width of the end member (the length thereof along the axis of the coil member 38) is selected to be sufficient to pass the magnetic flux of the coil member 38.

The intermediate members 48 of all the yoke pieces 47 form a substantially cylindrical yoke portion enclosing the coil member 38. (In effect, the cylindrical yoke portion has longitudinal cuts but the cuts of such width as that of the present embodiment interfere in no way with the function to conduct magnetic flux.) The end members 49 of many yoke pieces 47 all together form two flange-shaped yoke portions, one connecting magnetically the cylindrical surface of the space for advance and retreat of the armature core 31 to one end of the aforementioned cylindrical yoke portion, and the other connecting similarly the cylindrical surface of the stator core to the other end of the cylindrical yoke portion.

Further, an account is given of the terminal box 3. This terminal box comprises a main box 52 and a lid 53 put on it, and both are made of an electrically insulating material such as synthetic resins. The main box 52 consists of a base member 54 and partition wall members 55 and 56, and the base member 54 together with the partition wall member 55 is fixed on the body 4 of the valve device 1 with fastening screws 57. Between the base member 54 and the partition wall member 55 is prepared a disposition space 58 where a control circuit 59 is disposed. This circuit 59 includes a plurality of circuit components 61, a socket 62, pilot lump 63 and so on all mounted on a printed-circuit board 60. To the socket 62 the plug 45 is connected detachably as shown clearly in Fig. 1. The partition wall member 56 is provided with terminals 64 and as well with an integral wire inlet 65 through which power supply wires are taken in to be connected to the terminals 64. The lid 53 is secured on the main box 52 with mounting screws 66.

Although not shown, the other electromagnet similar to the aforementioned electromagnet 2 is mounted at the left side of the vlave device 1 as seen in Fig. 1 (only a part of the stator core of the other electromagnet being shown), and a plug of the other electromagnet is connected to a socket 62 provided to the left hand side of the control circuit 59.

When electric power is supplied to the terminals 64 through the wires taken in from outside in the magnet valve apparatus of the aforementioned construction, the electric power is sent to the coil wire 40 through the control circuit 59 and further through the plug 43. In this instance, the pilot lamp 63 is lighted in a well known manner. When the electric power is supplied as described above to establish a current in the coil wire 40, a certain amount of magnetic flux passes through a magnetic circuit consisting of the cylindrical yoke portion of the yoke 44, one of the flange-shaped yoke portion, armature core 31, the stator core 20 and the other flange-shaped yoke portion of the yoke 44. Consequently, the armature core 31 is pulled towards and moves to the stator core 20. This movement of the armature core is transmitted to the spool 11 by way of the push rod 25 and the spool 11 is displaced to the left hand side as seen in Fig. 1. In consequence of this, the port 7 communicates with the port 9 and the port 10 with the port 8.

Now, on interruption of the above current, the generation of magnetic flux by the coil 38 stops and so the armature core 31 ceases to be pulled by the stator core 20. Then, the spool 11 returns to the neutral position as shown in Fig. 1 under the bias of the spool restoring spring 13 provided at the left of the spool 11. Also, the armature core 31 is returned to the position as shown in Fig. 1 by the push rod actuated by the spool 11.

When an electric current is turned on in the coil wire 40 to actuate the armature core 31 in the aforementioned manner, the eddy current loss in the yoke 44 can be decreased and the energy of the electric current can be used effectively for the operation of the armature core 31 even if the current is alternating. Namely, when a certain amount of magnetic flux passes through the yoke as the result of the power feed to the coil wire 40, it is difficult for an eddy current of considerable strength to flow in the yoke 44, which consists of many yoke pieces 47 arranged radially, and the eddy current loss in the yoke is small. Thus, electric energy can be used effectively as described above.

Furthermore, when a current is turned on in the coil wire 40 to operate the electromagnet, the heat generated by the coil wire 40, if any, can be given off effectively to outer regions of the apparatus. That is, in the yoke 44 enclosing the peripheral surface of the coil member 38, a number of yoke pieces 47 are radially arranged. Consequently, the heat generated by the coil wire 40 is first transmitted from the outer peripheral surface of the coil member 38 to the inner peripheral edges of the yoke pieces 47 and is directly conducted outwards along the radially disposed yoke pieces 47 to be conveyed to the outer peripheral edges of the yoke pieces 47. Accordingly, the heat generated by the coil can be released from whole the broad outer peripheral surface of the yoke 44. In this manner, the heat in the coil member 38 can be released effectively. The heat conducted to the outer peripheral edge of each yoke piece 47 can be brought further to and released at the outer peripheral surface of the housing 35 by more direct heat conduction due to the outerframe 46, the filler member 37 and the housing 35.

In the next place, the manufacturing process of the aforesaid magnetizer 17 is described. Firstly, the housing 35 and the coil assembly are manufactured separately. The coil assembly 36 is manufactured in the following manner. Namely, the coil wire 40 is fist covolted on the coil bobbin 39 and the lead wire 40a for the coil wire 40 is connected to the plug 43, the coil member 38 as shown in Fig. 4 being formed. On the other hand, the plural yoke elements 45 are made in a separate process other than that for the coil member 38. For the manufacture of the yoke elements, a necessary number of outer frames 46 as shown in Fig. 5 are prepared and at the same time a number of yoke pieces 47 as shown in Fig. 6 are also prepared. Furthermore, an assembling jig is prepared which consists of an enclosing member 71 as shown in Figs. 8 and 9 and of a center column 72 adapted in it dismountably along its axis. The diameter of the center column 72 is made equal to that of the aforementioned actuator 16. When such a jig has been prepared, the outer frame 46 is first adapted between the enclosing member 71 and the center column 72. Then, a number of yoke pieces 47 are inserted between the outer frame 46 and center column 72 from the upside towards the downside of Fig. 9. After a prescribed number of yoke pieces 47 have been inserted, the enclosing member 71 is divided into two along the partition line 73 of Fig. 8, and the outer frame 46 and a plurality of yoke pieces 47 having been adapted therein are taken out so that the yoke pieces may not be in bits. Then, the yoke elements 45, having been taken out, are put on the coil 38 prepared beforehand in the form as shown in Fig. 4 and the form as shown in Fig. 3 is constructed. By the step thus far the assembling of the coil assembly 36 is completed. In the next place, the aforementioned coil assembly 36 is inserted into the housing 35. Then, a positioning jig 74 is set in the coil assembly 36. This positioning jig 74 consists of a setting portion adaptable to the outer periphery of the opening side of the housing 35 and of a rod member 76 adapted to be inserted in the coil assembly 36 and positions the coil assembly 36 against the housing 35. The rod member 76 is formed to be as thick as the aforementioned actuator 16. Next, a suitable type of liquid filler material is poured into the housing 35 through an injection port 77 formed in the jig 74. This filler material is made to stream in among the coil member 38, respective yoke pieces 47 and the outer frame 46 in the coil assembly 36 as well as between the housing 35 and the coil assembly 36. Having been poured, the filler material is solidified. In this solidifying process, the liquid filler material is prevented from streaming out, since the housing 35 is shut up a forehand with a bottom plate 35a as shown in Fig. 11. After the filler material has been solidified, the jig 74 as well as the bottom plate 35a is removed. By the step to this point the magnetizer 17 is completed.

If, in pouring the filler material, the rod member 76 in the positioning jig 74 is made of a magnetizable material and an electric current is turned on in the coil member 38 of the coil assembly 36 through plugs 43, the following effects can be obtained. That is, as the result of the aforementioned energization of the coil member 38, the rod member 76 is magnetized to become an electromagnet. Consequently, the internal peripheral edges 49a of the end members 49 in many yoke pieces 47 are pulled by the rod member 76 as shown in Fig. 12. In this manner, the internal peripheral edges 49a of the end members 49 in many yoke pieces 47 are in alignment in good order around the outer peripheral surface of the rod member 76. Moreover, the external peripheral edges 49b of the end members 49 are repelling one another to be arranged side by side at regular intervals as shown in Fig. 12, since all of the external peripheral edges 49b are magnetized to be of the same polarity (for example, N pole). Therefore, if the filler material is poured among the yoke pieces 47 in such an alignment and is solidified there, many yoke pieces 47 can be fixed in good order at substantially regular intervals. Furthermore, since the internal peripheral edges 49a in the coil assembly 36 formed in the aforementioned manner are arranged in good order as described above, the internal peripheral edges 49a in the assembled electromagnet 2 come to positions very close to the stator core 20 or the armature core 31 of the actuator 16. Subsequently, the reluctance of the aforementioned magnetic circuit is decreased and a powerful actuating force can be generated in the armature core 31. Furthermore, the heat generated by the coil member 38 on energization thereof can be utilized to quicken the solidification of the filler material.

On the other hand, the actuator 16 is manufactured separately from the magnetizer 17. Namely, the tube member 26 is put on the stator core 20, both are fixed to each other by welding and the armature core 31 is insertedly mounted in the tube member 26. Further, the push pin 29 is inserted in the through hole 28 of the blocking member 27, which is then fixed to the tube member 26 by welding. The actuator 16 is thus completed. Next, an account is given of the assembling process of the magnet valve apparatus. First, the actuator 16 is connected to the valve body 4 by screwing the threaded connector 21 into the threaded hole of the valve body 4. Then, the magnetizer 17 is put on the outer peripheral surface of the actuator 16. A stopper member 18, for example a C-shaped ring, is put in a peripheral groove 27a formed on the blocking member 27, transversely to the axis of the blocking member 27. Thus, also the magnetizer 17 is fixed relative to the valve device 1, and the magnet valve apparatus is completed.

Now, Figs. 13 and 14 show a different example of the assembling jig for the yoke elements 46 (unlike that shown in Figs. 8 and 9). In the assembling jig shown in Figs. 13 and 14, an enclosing member 71e is formed integral with a center column 72e. If a member in these figures is considered to be the same as or alike to the corresponding one in previous figures, it is given a numeral same as in the previous figures but with an alphabet e and repeated description has been omitted. (In any of the following figures, an alphabet f, g, ----- or so on is successively affixed to a numeral according to the same idea and the repeated description is again omitted.)

Next, Fig. 15 shows a different example of the method for injecting the filler material. In this figure a mould consists of two members 78 and 79 and the latter is provided with a rod member 76f. When the jig of this construction is used, a housing 35f containing a coil assembly therein is adapted between the elements 79 and 78. Then, the filler material is poured between the housing 35f and the coil assembly 36f through an injection port 77f and the filler material is solidified. In this case, it is preferable to energize the coil member 38f through plugs 43 as in the previous case. After the filler material has been solidified, the elements 78 and 79 are separated from each other. Thus, a magnetizer 17f is completed. In the case of the example shown in Fig. 15, it is unnecessary to shut the housing 35f with the aforementioned bottom plate.

In the next place, Fig. 16 shows a still different example of the moulding method of a magnetizer 17g. The moulding according to this Fig. 16 is performed with the mould as shown in Fig. 15. In the case of this example, the moulding is done without using the housing. Namely, a coil member 38g and a yoke 44g are positioned around a center column 76g of an element 79g and, with these kept there, elements 78g and 79g are combined. Then, the filler material is injected through an injection port 77g to be solidified. According to such a method for moulding, the injected filler material, on solidification thereof, becomes a member which functions as a housing. It is preferable as well in this example to energize the coil member 38g through plugs 43g as in the previous case.

Next, Figs. 17 and 18 show a different example of the jig used for the assembling of yoke elements 45h. This jig consists of an outer frame 81, an inner frame 82 divisible into two sections and a core 83. The assembling of the yoke element 45h with use of such a jig is performed as follows. First, a number of yoke pieces 47h are arranged and fixed around the core as shown in Fig. 17, and the pieces 47h together with the core 83 are inserted into the inner frame 82 which has been set in the outer frame 81. Then, a bonding agent, for example liquid resins or adhesives, is poured through an injection port 84 formed between the inner frame 82 and the core 83. After the bonding agent has settled, the outer frame 81 is first taken off, then the inner frame 82 is divided into two sections and lastly the finished yoke element 45h is detached from the core 83. Since all the many yoke pieces 47h in the yoke element 45h finished in this manner are unified rigidly, the works in the next step, i.e. setting the yoke element around the coil member and inserting them into the housing, can be carried out easily. If the core 83 of the present example is made of a permanent magnet, the work to arrange and fix the many yoke pieces around the core 83 and to insert them into the inner frame 82 is made easy. Namely, it becomes possible to join (to keep) the plural yoke pieces 47h around the core 83 under the magnetic force thereof and the many yoke pieces can be prevented from dispersing. Moreover, with use of such a magnetized core, the many yoke pieces can be arranged in good order as in the case described in reference to Fig. 12.

In the next place, Fig. 19 shows a still different example of the assembling jig. This example of the assembling jig differs from that shown in Figs. 17 and 18 in the partition position of an inner frame 82i.

Next, Fig. 20 shows a different embodiment of the present invention. In this embodiment of Fig. 20, a yoke 44j is designed to consists of four yoke elements 45j. Generally speaking, the number of the yoke elements is not limited to 2 of the previous embodiment or 4 of the present embodiment but may be 3 or an arbitrary number more than 3.

In the next place, a different example of the form of the yoke pieces is shown in Figs. 21 and 22. A yoke piece 47k shown in these figures is so formed that its thickness is decreasing towards the internal peripheral edge, i.e. increasing towards the external peripheral edge. In a finished yoke element 44k as shown in Fig. 28, a plurality of the yoke elements 47k made in this form can be arranged closely without any air gaps. Consequently, a magnetic circuit of a large cross section can be provided and hence the reluctance of it is lowered. Conversely speaking, the radial dimension of the magnetic circuit can be reduced to obtain a magnetic circuit cross section of a certain area and hence it is possible to promote the miniaturization of an electromagnet. In the present example, it is preferable that a silicon steel plate or an ordinary magnetizable steel plate, on which a suitable surface processing is performed for reduction of eddy current, is used as the material of the yoke piece 47k.

Next, in Figs. 24 and 25 is shown an example of the yoke element of still different forms. In these figures, a yoke piece 47ℓ is formed with space securing projections 86. This projection can be made by protruding a small part of a yoke piece 47ℓ simultaneously when it is died from a metal sheet material (magnetic sheet material). The yoke pieces, each having such a projection 86, can be arranged systematically at regular intervals.

In Figs. 27 and 28 showing a still different example of the yoke piece, an engage projection 87 is formed on the top of a space securing projection 86m, whereas the rear side of the space securing projection 86m is shaped to present an engage recess 88. When a yoke element 46m is assembled from these yoke pieces 47m, they can be unified just by arranging them in such a manner that the engage projection 87 of one of the yoke pieces 47m may engage with the engage recess 88 of another of the yoke pieces 47m. Accordingly, the yoke element 46m can be assembled without using the aforementioned outer frame as shown in Fig. 29.

Now, referring to Fig. 30, where a different example of the actuator is shown, an actuator 98 includes a hollow container 92, which consists of a connector 93 for connection to the body of the valve apparatus and of a receiver 94 for receipt of an armature core to be described later. The connector 93 is generally made of a magnetic material such as iron but may be made of a non-magnetic metalic material. The receiver 94 consists of a cylindrical member 97 adapted to guide the advancing or retreating armature core and of an end member 98 integral with the cylindrical member 97. These members 97 and 98 are made of magnetic materials but may be made of nonmagnetic materials. One end of an intermediate cylinder 99 is fixed to one end of the cylindrical member 97 by welding all over the peripheries of both ends. This intermediate cylinder 99 is situated inside the coil member and that outside the space for the advance and retreat of the armature core. Subsequently, this intermediate cylinder 99 is made of a nonmagnetic material in order to prevent that magnetic flux from passing through the structure of the intermediate cylinder 99 which should pass through the armature core and stator core. The other end of the cylinder 99 is fixed to a cylindrical portion 96 by welding all over their peripheries. Thus, the hollow container 92 is hermetically sealed. In the hollow container 92, a stator 101 is fixedly provided close to the connector 93 and an armature core 102 is arranged for advance and retreat to the left and the right in Fig. 30.

Now, a detail account is given of the stator core 101 referring to Figs. 31 to 38. The stator core 101 consists of a central connection member 103 and a core main portion 104 disposed therearound. The connection member 103 consists of two elements 105 and 106 joined together. The connection member 103 is made of a high strength material such as S10C or S45C. Each of the elements 105 and 106 has, at its periphery, an annular joint portion 107, the cross section of which has a form suitable to constitute a dovetail groove. The element 105 is provided, in its central portion, with a through hole 108 in which the aforementioned push rod 25 is inserted. The core main portion 104 is constructed by assembling a plurality of such core elements 109 and 110 respectively as shown in Figs. 37 and 38. These many core elements 109 and 110 are arranged alternately as clearly shown in Fig. 32 and each of them is radially disposed around the central connection member 103. The core element 109 is made, for example, of a silicon steel sheet and the core element 110 of a magnetic steel sheet so that it may be difficult for eddy current to flow in the core main portion 104. The core piece 110 is made thicker towards the outer peripheral side, i.e. thinner towards the inner peripheral side. Consequently, when the core pieces 109 and 110 are laminated one upon another, they can be arranged in the form of an annulus around the connection member 103. Both the core pieces 109 and 110 may be made either of silicon steel sheets or magnetic steel sheets on which a surface treatment of arbitrary type is preferably applied to increase the superficial electric resistivity. When the core pieces of both the above types are made of a single kind of material as in the above case, they need not be different in shapes from each other as shown in Figs. 37 and 38 but those core pieces of one type are suffice which have such a thickness as is suitable for the radially close arrangement of a plurality of them. The inner peripheral portion of each of the core pieces 109 and 110 is so formed as to present a joint member 111 having a shape conformable to the joint member 107 of the connection member 103. The above inner peripheral portion of the core pieces 109 and 110 is provided also with a recess 112. A number of the recesses 112 of all the core pieces 109 and 110 are disposed in succession to define an annular groove 113 as shown in Fig. 31. The core pieces 109 and 110 are further provided with a gain 114 for putting a shading coil therein. These gains 114 as well define an annular groove 115 as shown in Fig. 32. In the groove 115 is embeded a shading coil 116, which is made of a good electrically conducting material such as copper and formed by an arbitrary method such as machining or stamping out.

Now, the armature core 102 is described referring to Figs. 40 to 42. This armature core 102 is constructed equivalently to the aforementioned stator core 101. That is, a connection member 117 consists of two elements 118 and 119 each of which has a joint portion 120. On the other hand, a core main portion 121 around the connection member 117 is formed of a plurality of those core pieces 122, each being made of a silicon steel sheet and those core pieces, each being made of a magnetic steel sheet, which are assembled radially about the axis of the connection member 117. Furthermore, each of the core pieces 122 and 123 has a joint portion 124, which is coupled with the joint portion 120 of the connection member 117. The core main portion 121 of the armature core 102 is provided, on its side surface, with an oil passage slot 125 which is cut lengthwise in the longitudinal direction of the armature core, i.e. in the direction of advance or retreat of the armature core. The slot 125 is formed by sandwiching several core pieces 122' and 123' of smaller radial size between the core pieces 122 and 123. An oil passage slot 126 is formed on that end surface of the core main portion 121 which is opposite to the stator core 101. This slot 126 is prepared by reducing the axial length of the core piece 122', i.e. by reducing locally the axial length of the armature core 102 at the slot 126 as clearly shwon in Fig. 42. Furthermore, on the element 118 of the connection member 117 in the armature core 102 is formed an oil passage slot 127 which communicates with the aforementioned oil passage slot 126. The distance L between the inner ends of a pair of opposting slots 127 is made smaller than the diameter of the push rod 25. Accordingly, even when the armature core 102 has been pulled by the stator core 101, a part of the slot 127 can communicate with the through hole 108 where the working oil flows.

When an electric current is turned on in the coil to actuate the armature core 102 in the above mentioned construction, the eddy current loss in the stator core 101 and the armature core 102 due to the electric current, even though an alternate current, can be reduced and the energy of the electric current is used effectively for actuation of the armature core 102. The reason is as follows. The respective core main portions 104 and 121 of the stator core 101 and the armature core 102 are both of laminated construction, in which it is difficult for the eddy current to flow. On the other hand, since either the connection member 103 or 117 is of solid construction, there is a possibility that the eddy current will be generated. However, either the connection member 103 or 117 is used in the central region of the respective core 101 or 102 and so its cross-sectional area is much smaller compared with that of the core 101 or 102. For example, if the radius of the connection member is 1/3 of that of the core, the cross-sectional area of the connection member is reduced to 1/9, and if the radius 1/5, the cross-sectional area 1/25. If the cross-sectional area of the connection member is so much smaller, the generated eddy current is proportionately smaller. For this reason, the eddy current loss in the cores 101 and 102 is small.

Moreover, in the above mentioned operation, when the load bearing surface of the armature core 102, i.e. the surface thereof to abut on the push rod 25, strikes against the push rod 25, the reaction force of an impact is exerted on the connection member 117 by the push rod 25 in the axial direction (the left and right direction in Fig. 30). The reaction force is applied through the joint portion 120 and the joint portion 124 jointed thereto equally on all the pieces 122, 123, 122' and 123'. Consequently, relative displacements are rarely brought about among the many pieces 122, 123, 122' and 123' even if the above striking operation takes place repeatedly.

Furthermore, in the above operation of the armature core, the push rod 25 advances and retreats repeatedly in the through hole 108 bored through the central portion of the stator core 101. However, any of the core pieces

109 and 110 does not touch the advancing or retreating push rod 25, since the through hole 108 is formed in the connection member 103. Thus, the operation of the apparatus over a long period does not result in relative displacements among the many core pieces 109 and 110.

In the next place, the manufacturing process of the actuator 90 is described. First the stator core 101 of the actuator 90 is manufactured as follows. One element 105 of the connection member as shown in Fig. 36, one element 106 of the connection member as shown in Fig. 36 and a number of core pieces 109 as shown in Fig. 37 and core pieces 110 as shown in Fig. 38 are prepared. The element 105 is fixed on the jig 128, prepared in advance, by an arbitrary method as shown in Fig. 9(A). For example, it is fixed by inserting a positioning rod 129 of the jig 128 into the through hole 108. Then, many pieces 109 and 110 are arranged radially around the element 105 in succession one or several at a time so that the order of arrangment as shown in Fig. 32 may be established. In this case, the joint member 111 of each core piece is brought into engagement with the joint member 107 of the element 105. In the next step, after the prescribed number of the core pieces have been arranged, the element 106 is thrusted against the element 105 by a suitable pressing in method so that the joint member 107 may engage the joint member 111. After the foregoing procedure, each core piece is prevented from slipping away out of the connection member 103 by the engagement of the joint member 111 of each core piece with the joint member 107 of the connection member 103. The element 106 is securely fixed to the element 105 by caulking a part indicated by the numeral 130 and the reliable unification between the elements 105 and 106 and between these elements and core pieces 109 and 110 is obtained by welding a part indicated by the numeral 131. Thereafter, the outer surface of the core main portion 104 is processed by polishing (for example by centerless polishing) to be finished to a diameter suitable for tightly fitting in the cylindrical portion 96 of the hollow container 92 and inside the intermediate cylinder 99. Moreover, both the end surfaces of the stator core 101 (the left and the right end surfaces in Fig. 33) are respectively finished to smooth planes by cutting. After or before the polishing and the cutting processes, the shading coil 116 is fitted in the groove 115. This fitting procedure consists of inserting the coil 116 into the groove 115 and deforming a part indicated by a numeral 132 of Fig. 32 to the form as shown in Fig. 34 to make the coil 116 abut the side surface of the groove 115 and be fixed therein. In this manner, the stator core 101 is completed.

The assembling of the armature core is performed similarly as in the case of the aforementioned stator core

101. That is, after the core main portion 121 has been combined with the connection member 117, the elements 118 and 119 are fixed to each other by caulking a part indicated by a numeral 133 and then the reliable unification between the elements 118 and 119 and between them and the pieces 122, 123, 122' and 123' is obtained by welding such parts, as indicated by numerals 134 and 135, respectively. The outer surface of core main portion 121 is processed by polishing and the armature core 102 is completed.

On the other hand, the connection member 93 and the receiver 94 of the hollow container 92 are formed independently of the above manufacturing work. In forming the receiver 94, the cylindrical member 97 and the intermediate cylinder 99 are welded together in advance and their internal surfaces are porcessed by polishing so that they may not interfere with the advance and retreat movement of the armature core 102.

As a next procedure, the stator core 101, the armature core 102, push pins and so on are filled together in the hollow container 62 and thereby the actuator 90 is completed. The first step of this procedure is to fit the stator core 101 into the cylindrical member 96 of the connector 93. Meanwhile the push pins are inserted into the through holes of the receiver 94 and besides the armature core 102 is contained inside the receiver 94. Then, one end portion of the intermediate cylinder 99 of the receiver 94 is made to cover the stator core 101. Next, one end edges of the cylindrical portion 96 and the intermediate cylinder 99 of the receiver 94 are met to each other and welded together all over the periphery. In this case, the groove 113 of the stator core 101 is situated just inside the contacting edges of the cylindrical portion 96 and the intermediate cylinder 99. Accordingly, when the contacting edges are welded and hence heated, the heat due to welding scarecely diverges from there (the contacting edges are hard to be cooled) and as result of that, the contacting ends can be welded with ease and in addition with good work efficiency. In consequence of the above welding work, a raised stripe 136 is formed which rises from the contacting edges towards the bottom of the groove 113 as shown in Fig. 33. This raised stripe 136, as a matter of cource, is formed all over the circumference of the groove 113 and thereby that situation is realized where the displacement of the stator core 101 relative to the hollow container 92 is prevented. By the work as proceeds in the foregoing manner, the cylindrical portion 96 and the intermediate cylinder 99 are connected mutually to complete the hermetically sealed hollow container 92 to which, at the same time, is secured the armature core 101 to complete the actuator 90.

As many apparently widely different embodiments of the present invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.

CLAIMS

1. In an electromagent comprising a cylindrical coil member, a stator core and an armature core both being mounted about the center axis of said coil member and a yoke disposed around said coil member and adapted to conduct that magnetic flux to said stator and armature cores which is generated by and passes outside of said coil member, the improvement characterized by that said yoke is made of a number of similar yoke pieces arranged radially around said coil member.

2. In the electromagnet as set forth in claim 1, the improvement characterized by that each of said yoke pieces is made thinner towards the inner peripheral edge thereof and thicker towarts the outer peripheral edge thereof and the side surfaces of said each yoke piece is in close vicinity of the side surfaces of adjacent yoke pieces.

3 In the electromagnet as set forth in claim 1, the improvement characterized by that said stator core consists of a connection member and of a number of core pieces arranged radially around said connection member.

4. In the electromagnet as set forth in claim 1, the improvement characterized by that said armature core consists of a connection member and a number of core pieces arranged radially around said connection member.

5. In a method for manufacturing an electromagnet comprising a cylindrical coil member, a stator core and an armature core both being mounted about the center axis of said coil member and a yoke disposed around said coil member and adapted to conduct that magnetic flux to said stator and armature cores which is generated by and passes outside of said coil member, said yoke consisting of a number of similar yoke pieces arranged radially around said coil member, an electromagnet manufacturing method including the following steps (a) to (d):

(a) a step to form said cylindrical coil member,

(b) a step to form plural yoke elements, each including a number of yoke pieces which are arranged radially with inner peripheral edges thereof placed on a cylindrical surface coaxial with the outer side surface of said coil member,

(c) a step to arrange said plural yoke elements around said cylindrical coil member so that said elements may sorround said coil member, and

(d) a step to connect said cylindrical coil member and plural yoke elements together.

6. A method as set forth in claim 5 wherein the step to form said yoke element consists of setting an outer frame between an annular enclosing member and a center column of a jig with the outer side surface of said outer frame conforming with the inner surface of said enclosing member, assembling said many yoke pieces radially into the inner side of said outer frame with the center column as the center axis, and taking out said outer frame together with a number of said assembled core pieces from between said enclosing member and said center column.

7. A method as set forth in claim 6 wherein the step to connect said cylindrical coil member and plural yoke elements together consists of putting said coil member together with plural yoke elements surrounding said coil member into a housing for said electromagnet and inserting a rod member into the inside space of said coil member in order to prevent a filler material from streaming in there, and connecting said coil member and said yoke elements together by pouring said liquid filler material between said housing and said rod member and by solidifying said filler material.

8. A method as set forth in claim 7 wherein the step to insert said rod member into the inside space

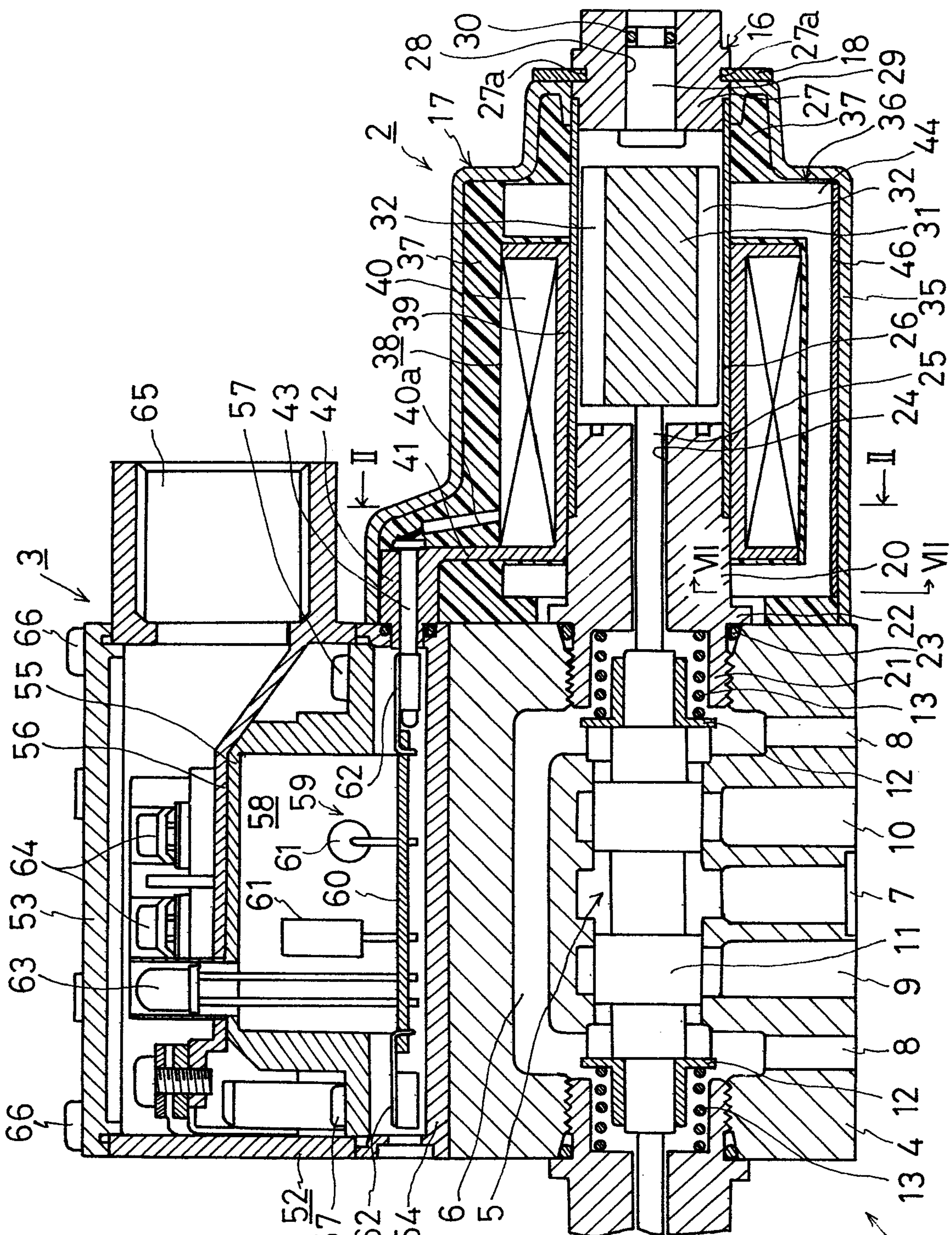
of said coil member is, in effect, a step to insert a rod member made of a magnetic material, and besides a step is included in which said rod member is magnetized by energyzing said coil member while solidifying said filler material.

9. A method as set forth in claim 5 wherein the step to connect said cylindrical coil member and said plural coil elements together consists of putting said coil member and said plural yoke elements arranged around said coil member into an inner mould and inserting a rod member into the space inside said coil member in order to prevent a liquid filler material from streaming into said space, and connecting said coil member and said yoke elements together and forming simultanously a housing by pouring said liquid filler material for formations of said housing inside said mould and by solifying said filler material.

10. The method as set forth in claim 5 wherein the step to from said yoke elements consists of arranging radially a number of yoke pieces around a core, putting them into a shaping frame, and connecting said yoke pieces to one another by pouring a binder material for unifying said yoke elements between said shaping frame and said core and by solidifying said binder material.

11. A method as set forth in claim 10 wherein the step to arrange radially a number of yoke pieces around a core is, in effect, a step to arrange a number of said yoke pieces one by one around a core made of a magnet under the attracting force due to said magnetized core.

FIG.1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II
VII

FIG. 2

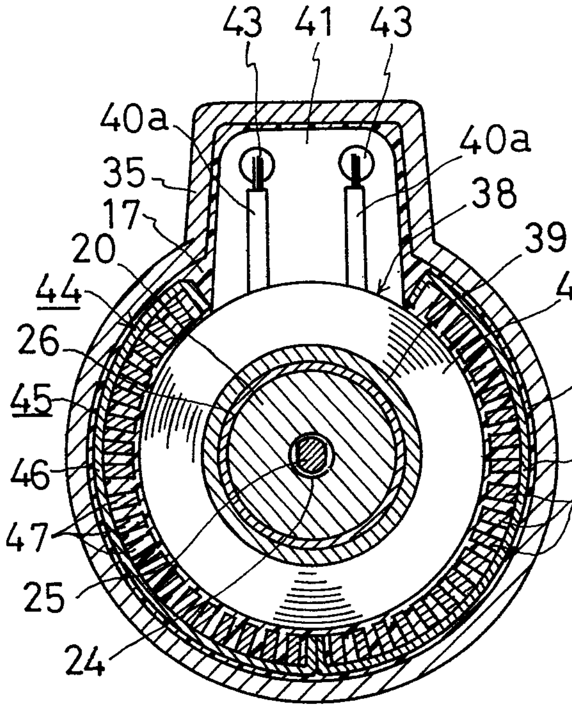
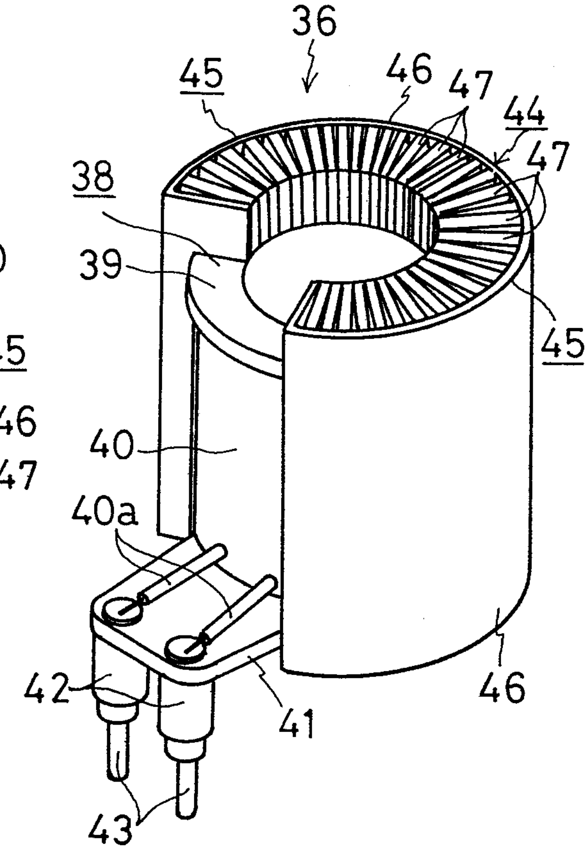


FIG. 3



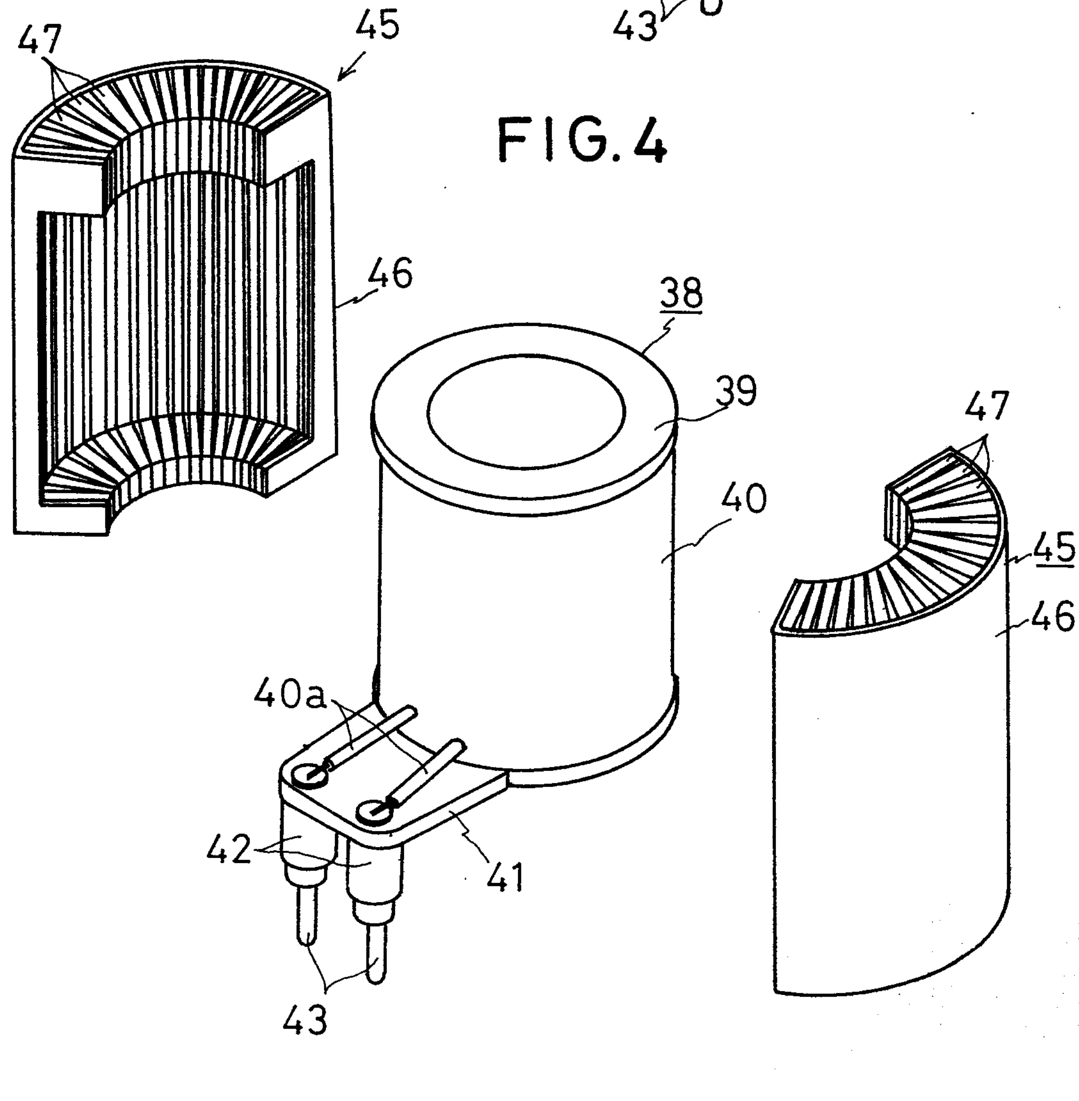


FIG. 4

FIG. 5

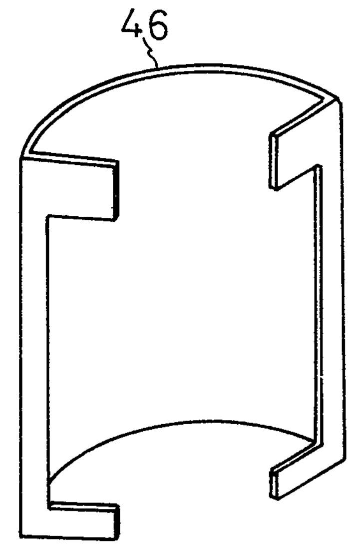


FIG. 8

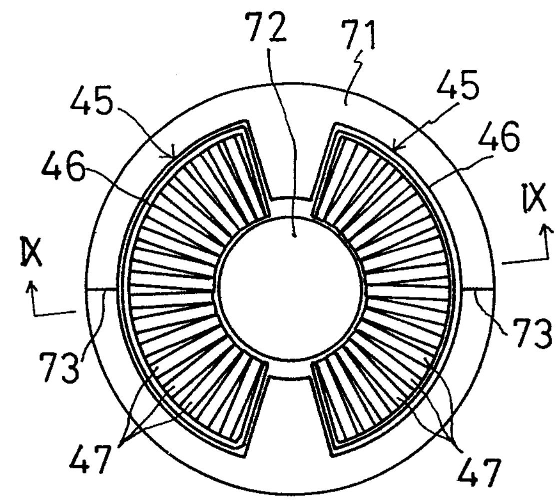


FIG. 6

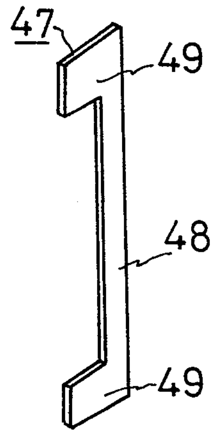


FIG. 9

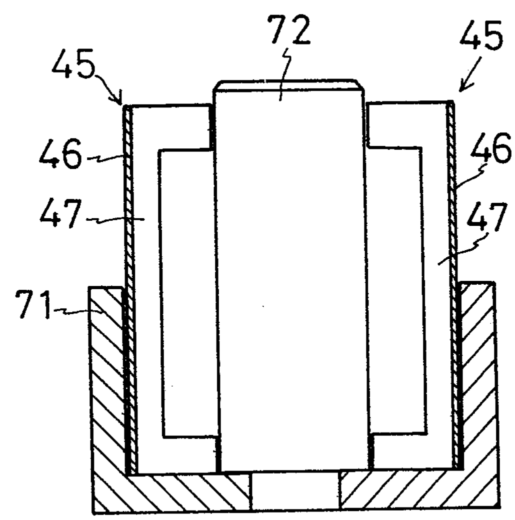


FIG. 7

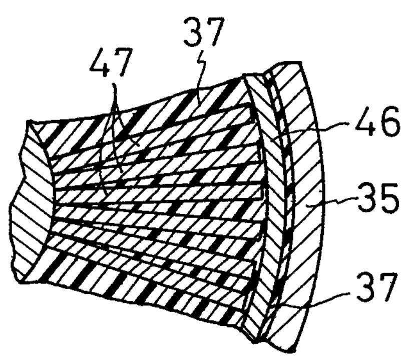


FIG.11

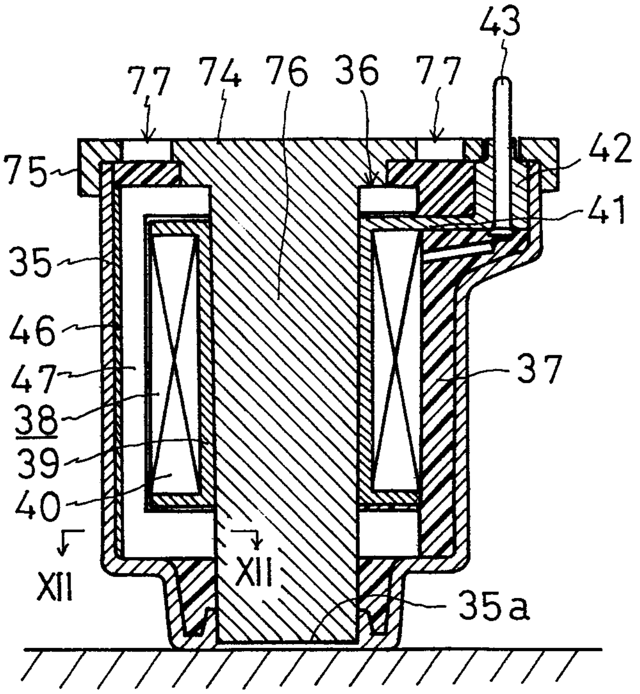


FIG.13

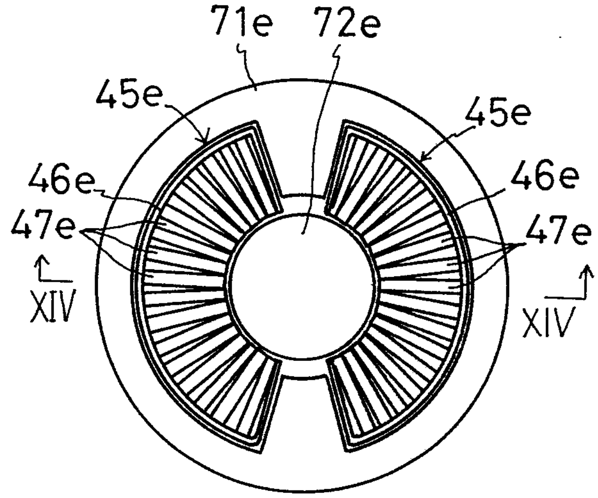


FIG.12

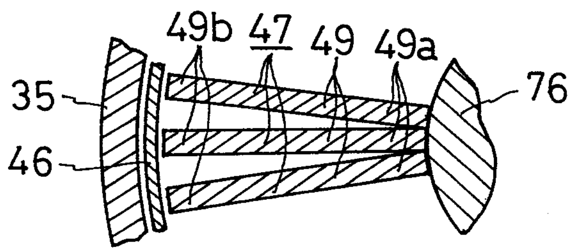


FIG.10

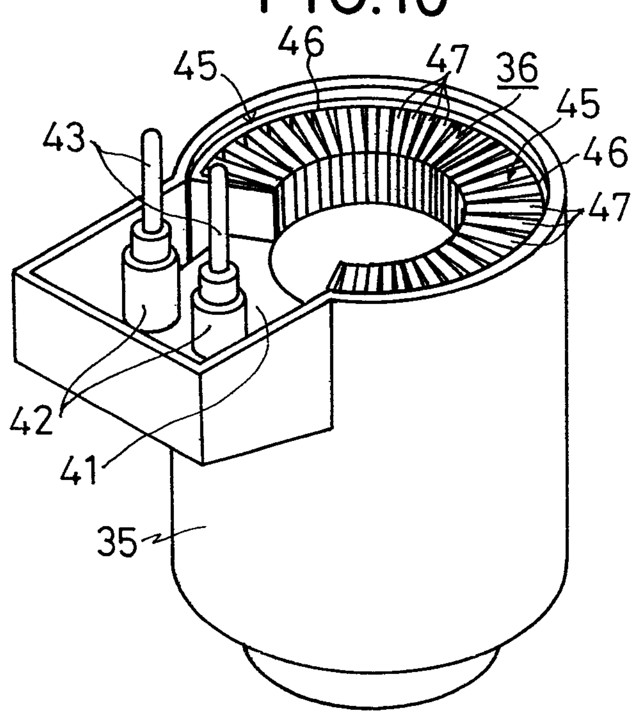


FIG.14

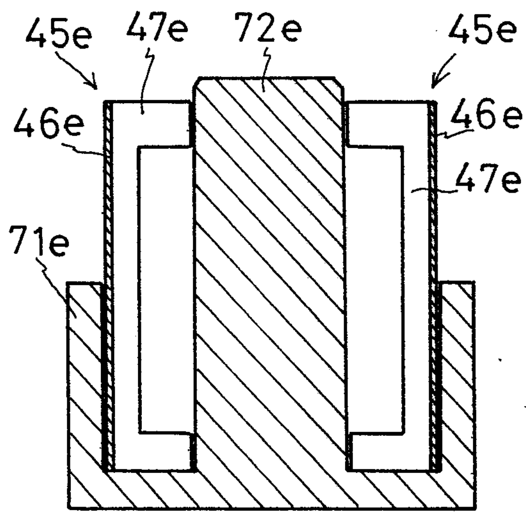


FIG. 15

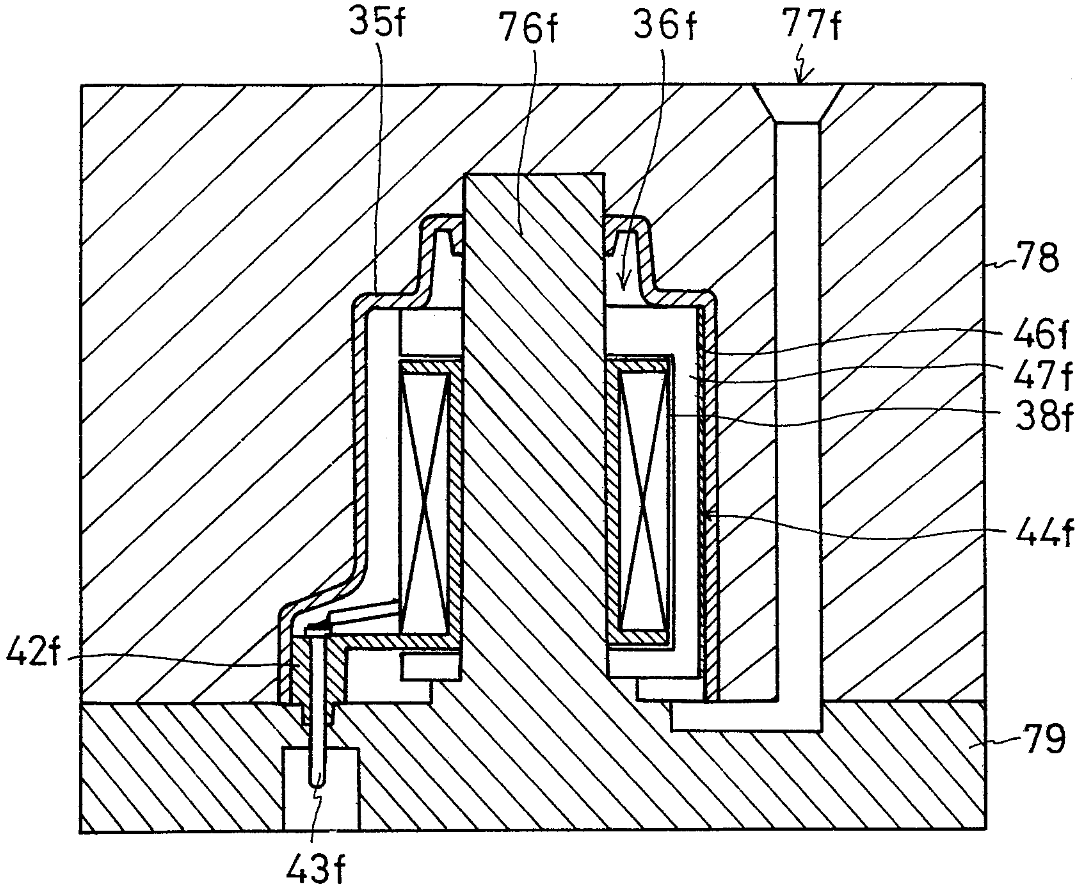

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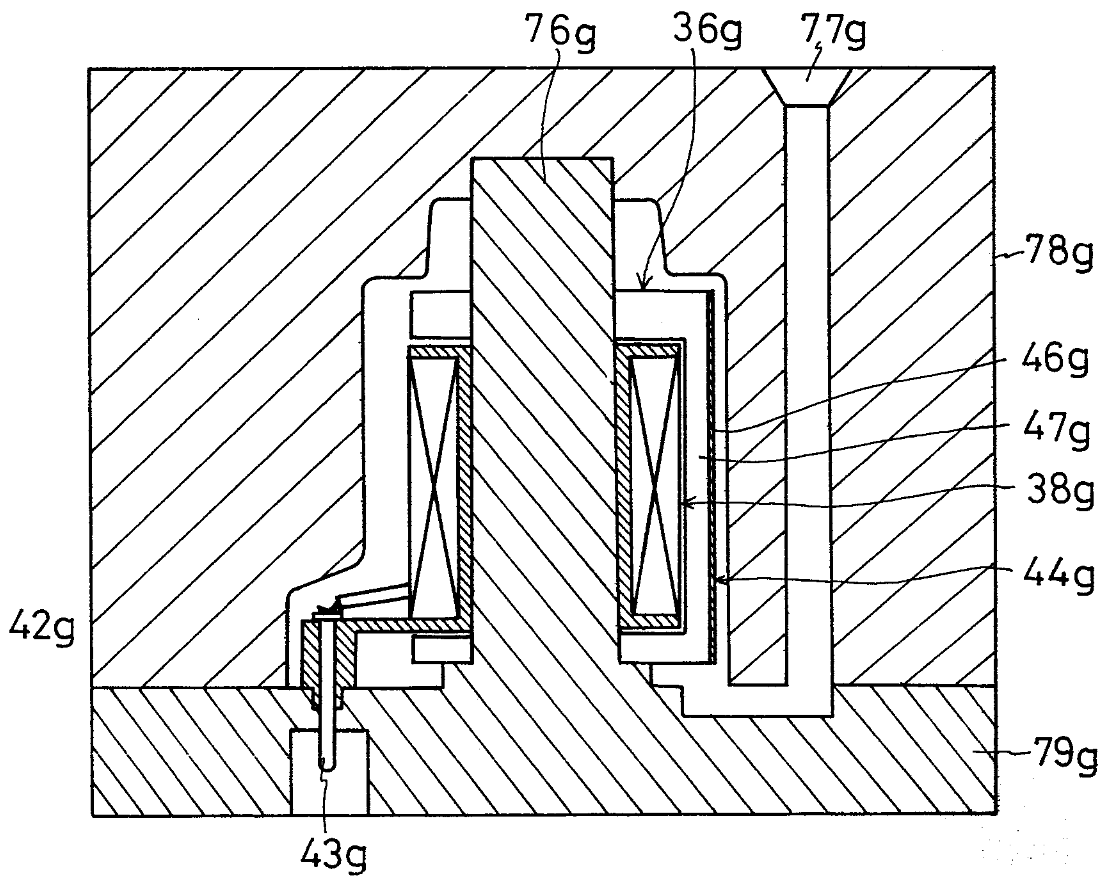
FIG. 16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0138408

FIG.17

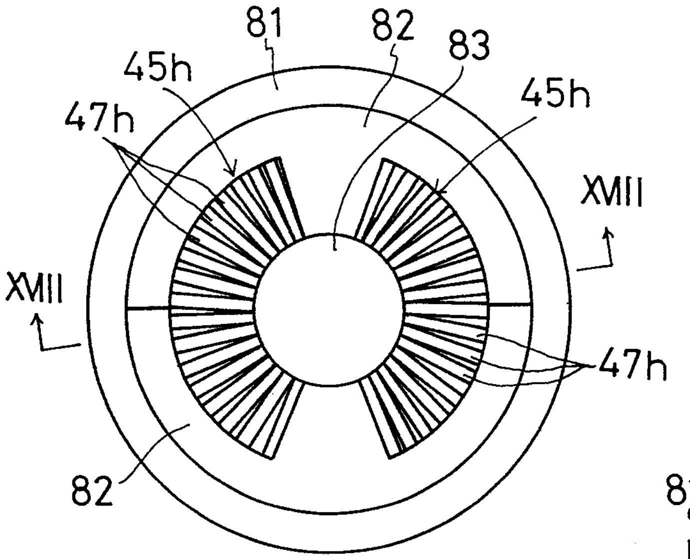

FIG.18

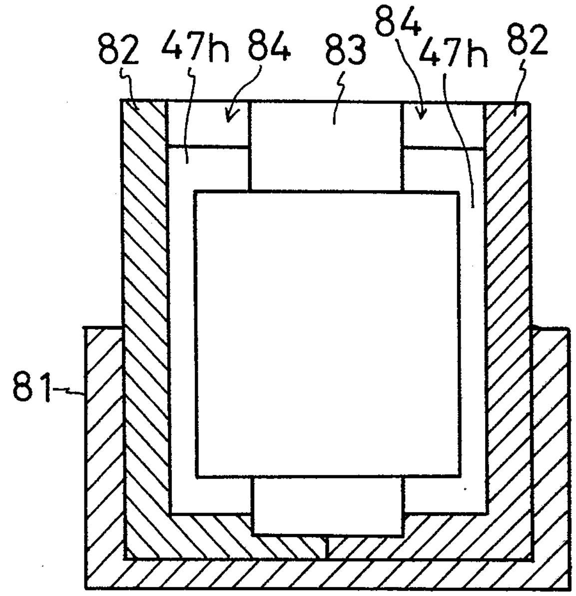

FIG.19

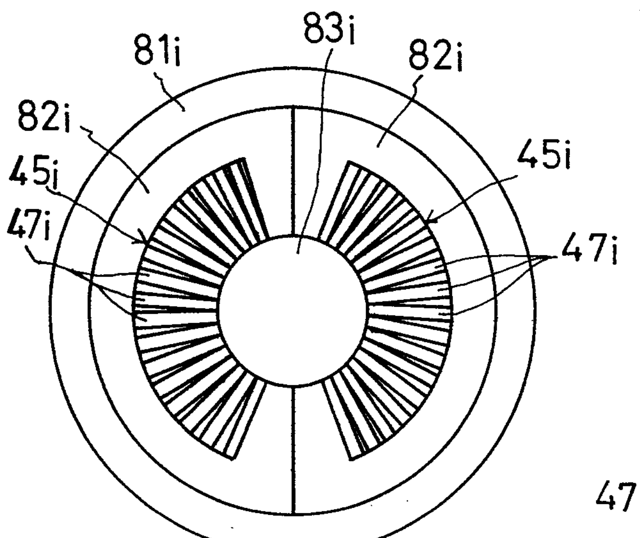

FIG. 20

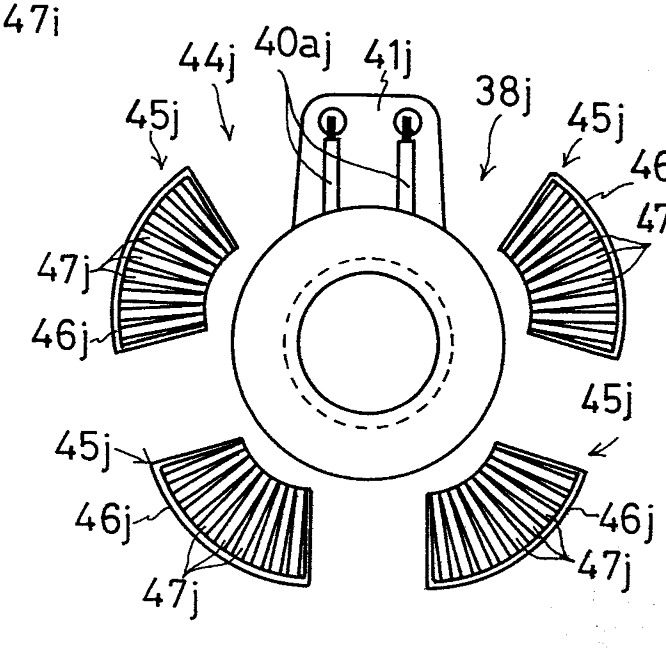

FIG. 21

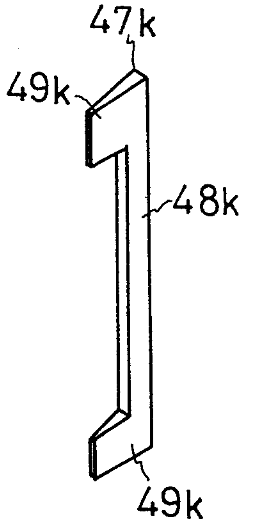

FIG. 22

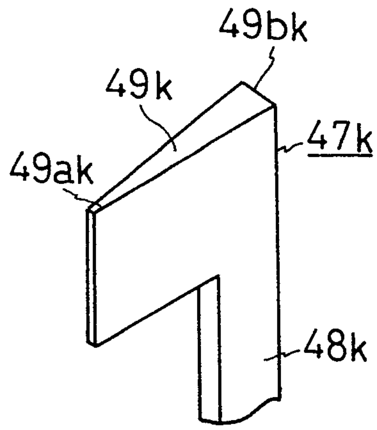

FIG. 23

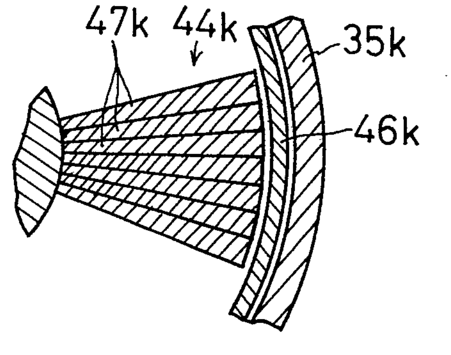

FIG. 24

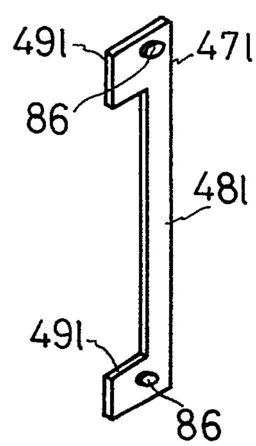

FIG. 25

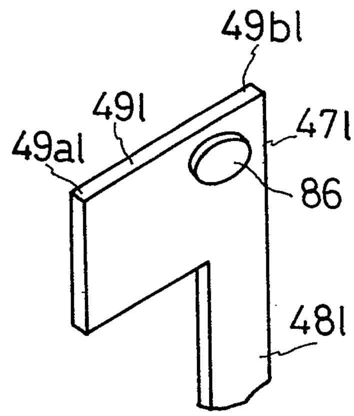

FIG. 26

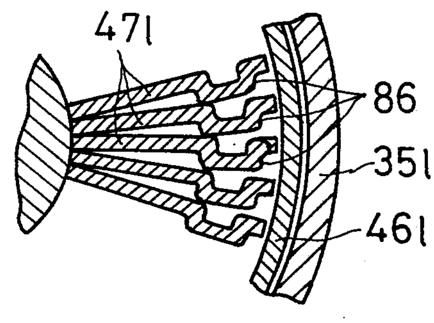

FIG. 27

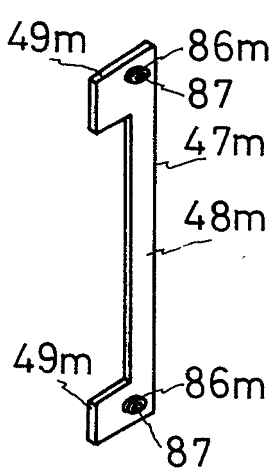

FIG. 28

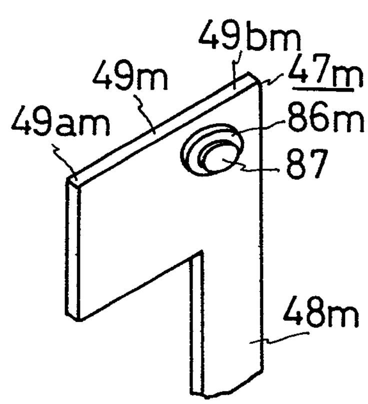

FIG. 29

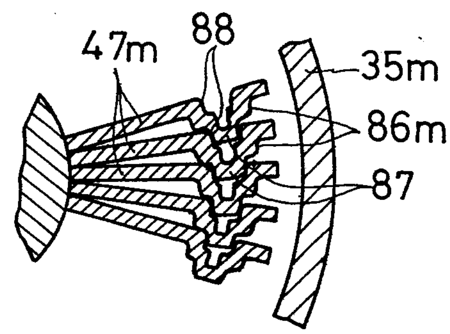

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FIG.30

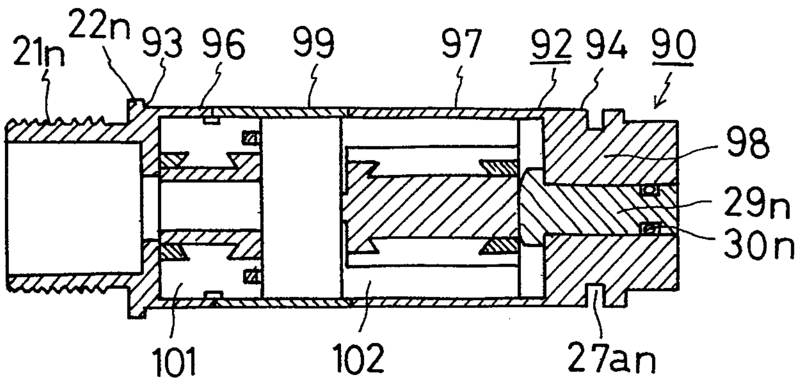

FIG.31

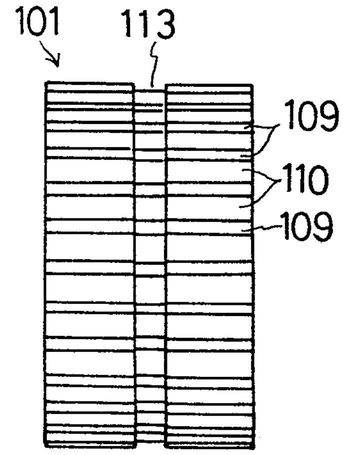

FIG.32

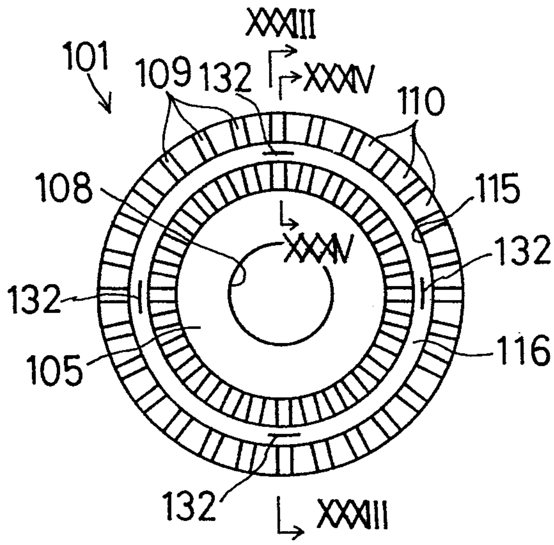

FIG.33

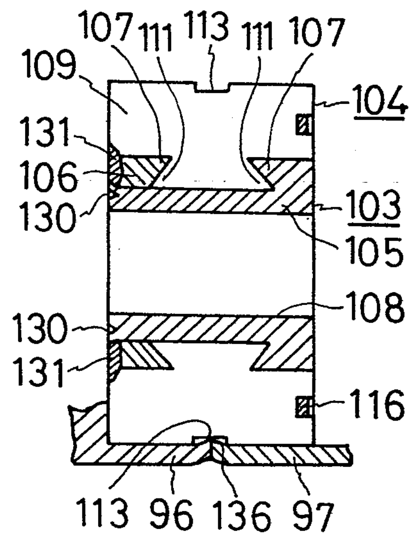

FIG.34

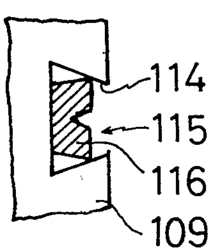

FIG.36

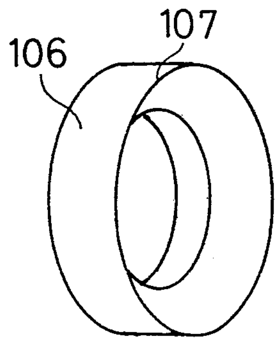

FIG.35

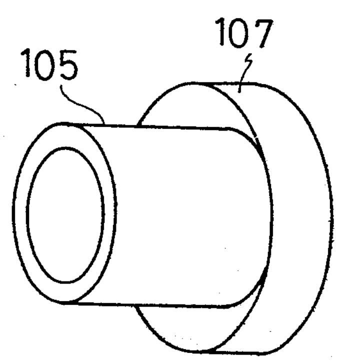

FIG. 39

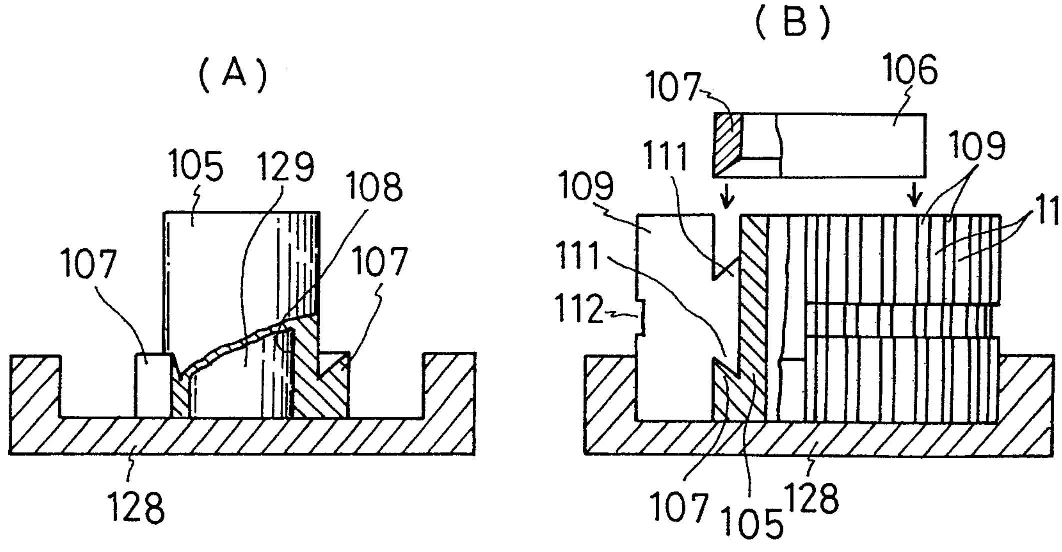

FIG. 37

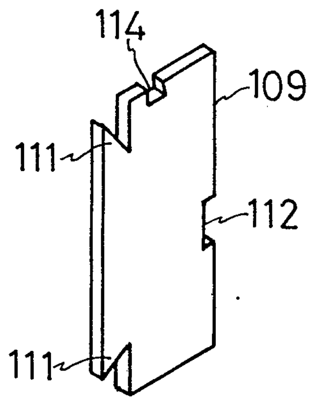

FIG. 38

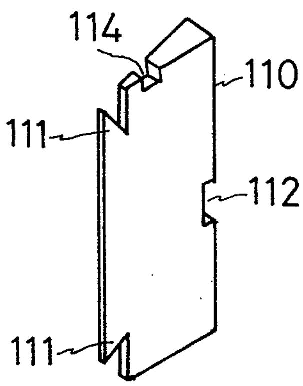

FIG. 40

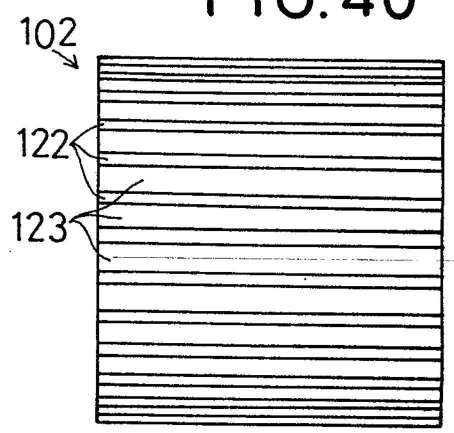

FIG. 41

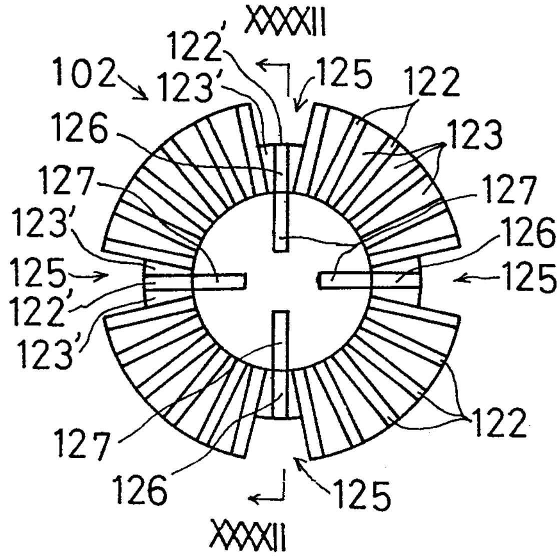

FIG. 42