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(54) Title: TRANSMISSION SENSOR WITH OVERMOLDING AND METHOD OF MANUFACTURING THE SAME

(57) Abstract: A sensor including a sensor core is disclosed. The sensor core includes a magnet, a pole piece, a bobbin, at least two terminals coupled to the bobbin, and a conductor wound about the bobbin and coupled to the terminals. At least a portion of the windings are disposed about at least a portion of the pole piece. The magnet is disposed substantially adjacent the pole piece. A support contacts at least a portion of the conductor. A supported portion of the conductor is located between the windings and the terminals. A sensor housing surrounds at least a portion of the sensor core. A method of manufacturing a sensor including providing a sensor core including a magnet, a pole piece, a bobbin, at least two terminals, and a conductor which is wound about the bobbin and coupled to the terminals is further disclosed. At least a portion of the windings surround at least a portion of the pole piece. The magnet is disposed substantially adjacent the pole piece. The method further includes adding support for a portion of conductor located in a region between windings, introducing the sensor core into a housing, and forming a seal between the sensor core and the housing. A manufacturing method including providing a magnetic circuit including a wire, the wire having a wound portion, a first portion conductively coupled to a first terminal, and second portion conductively coupled to a second terminal, the first terminal and the second terminal conductively coupled to a third terminal and a fourth terminal is also disclosed. The method further includes reinforcing a section of the wire located in a position between the wound portion and at least one of the first terminal and the second terminal, surrounding the magnetic circuit with a protective shell, and providing a seal effective to substantially seal the magnetic circuit within the shell.

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TRANSMISSION SENSOR WITH OVERMOLDING AND METHOD OF MANUFACTURING THE SAME

Cross Reference

This application claims priority to U.S. Patent Application No. 11/343,959, filed on January 31, 2006, entitled "TRANSMISSION SENSOR WITH OVERMOLDING AND METHOD OF MANUFACTURING THE SAME," and 11/358,603, filed on February 21, 2006, entitled "TRANSMISSION SENSOR WITH OVERMOLDING AND METHOD OF MANUFACTURING THE SAME," and U.S. Patent Application No. 11/431,895, filed on May 10, 2006, entitled "TRANSMISSION SENSOR WITH OVERMOLDING AND METHOD OF MANUFACTURING THE SAME"

Technical Field

The technical field relates to sensors for use in an automatic transmission of a motor vehicle, for example, and in particular, but not exclusively, to threaded transmission sensors for measuring the rotational speed of an input shaft or an output shaft.

Background

With the advance of improved controls for automatic transmission operation, the use of various electrical actuators and sensors has expanded greatly. Therefore, automotive electrical components such as transmission speed sensors have become high volume components within the automotive industry. Because such parts may experience failure within the operating life of the automobile, many of these components are offered through the aftermarket industry. Failure rates are generally affected by the type of part and the design. For example, the electromagnetic phenomenon of variable reluctance is commonly utilized in speed sensors. Typically, in such a sensor, a permanent magnet coupled with a wound coil is located in close proximity to a ferrous rotating member with teeth. As the magnetic field couples and decouples with each tooth on the member, an electrical signal is generated that varies in frequency depending on the angular speed of the member. Generally, this signal is remotely processed by a controller along with other inputs such as engine load, for controlling shifting of the transmission. U.S. Patent No. 4,586,401 describes one example of such an automatic transmission control scheme. Variable reluctance sensors are often used in these applications because of the reliability of the signal that they output (i.e., low signal noise). However, such transmission sensors, including threaded speed sensors, may become inoperative because of various failure modes. This can occur even prior to damage or decay to the external covering of the sensor. The present invention addresses these and other problems associated with prior art sensors.

One example of such a sensor is the output speed sensor (P/N 0400879) used in several Chrysler transmissions including the A604. This prior art sensor 39 is shown in an exploded view in Fig. 11. Sensor 39 includes shell 40 having threads 41, stopping flange 42, and tip 46. Sensor 39 further includes bobbin assembly 50 having magnet 54, pole piece 53, wound copper wire 52, bobbin 51, and pins 55. Sensor 39 is assembled as follows. Shell 40 is independently formed as a single piece using injection molding. Wire 52 is wound on bobbin 51 and the ends of wire 52 are soldered to pins 55. Pole piece 53 is inserted into the bobbin assembly 50 and magnet 54 is placed at the end of pole piece 53. Bobbin assembly 50 is then advanced into shell 40 in the direction indicated by arrow I so that magnet 54 pole piece 53, wire 42 and pins 55 are positioned inside a cylindrical cavity formed inside shell 40. Assembly is completed by bending a holding flange over the inserted bobbin assembly. Bending of the holding flange may be accomplished by using heat and pressure to bend the thin holding flange without breaking the plastic. The heat can be applied using convection, conduction or ultrasound. A similar prior art sensor is the input speed sensor (P/N 0400878) also used in several Chrysler transmissions including the A604.

With reference to Fig. 12 there is shown a top view of shell 40. Identical reference numerals are used to indicate portions of shell 40 described above. Additionally, there is shown cylindrical cavity 43 including side surface 44 and tip cavity 45. As described above, bobbin assembly 50 is advanced into cavity 43 during assembly of sensor 39. In the assembled state, magnet 54 and an end portion of pole piece 53 are positioned in tip cavity 45, and the rest of pole piece 53, wire 52, pins 55 and a portion of bobbin 51 are positioned in cavity 43.

Summary

One embodiment according to the present invention includes a sensor including a bobbin including a first region adapted to receive windings and a second region defining a cavity formed in the bobbin is disclosed. A first electrical terminal is coupled to the bobbin and disposed in the cavity and a second electrical terminal is coupled to the bobbin and disposed in the cavity. A wire including a wound portion wound about the first region of the wire is conductively coupled to the first terminal and the second terminal to provide an electrically conductive pathway from the first terminal to the second terminal. A magnetizable core is disposed at least partially within the wound portion and a magnet is positioned adjacent the magnetizable core. An overmolded shell defining an exterior surface of the sensor encapsulates at least the first region and the wound portion and contacting at least the wound portion.

In one refinement of the sensor the overmolded shell includes threads formed on the outermost surface of the shell. In another refinement of the sensor the overmolded shell is formed of a polyamide resin. In another refinement of the sensor the wire further comprises a first and second lead portions extending from the wound portion and the overmolded shell encapsulates and contacts the first and second lead portions. In another refinement of the sensor the overmolded shell encapsulates a region of the second portion but does not encapsulate or obstruct the cavity. In another refinement of the sensor the first region and the second region are spaced apart along a longitudinal axis of the bobbin.

Another embodiment according to the present invention includes a method of manufacturing a sensor. The method includes providing an assembly. The assembly includes a bobbin having a cavity, a wire including a wound portion wound about the bobbin, a magnetizable core disposed at least partially within the wound portion, and a magnet positioned adjacent the magnetizable core. The method further includes inserting a plug into the cavity, positioning the plug and the assembly into a mold, introducing resin into the mold effective to encapsulate the sensor assembly, first removing the plug and the assembly from the mold, and second removing the plug.

In one refinement of the method the mold is a book mold and further comprising closing the book mold about the plug and the assembly. In another refinement of the

method the resin is a polyamide resin. In another refinement of the method the wire is a polyurethane coated wire. In another refinement of the method the introducing utilizes injection molding. In another refinement of the method the injection molding includes rotating the mold relative to a resin injector effective to inject resin through a plurality of ports defined in the mold.

A further embodiment according to the present invention includes a method of overmolding a resin shell about a variable reluctance sensor assembly. The assembly includes a bobbin, a conductor wound about the bobbin, and an aperture defined at an end of the bobbin. The method includes connecting a positioning tool to the assembly at the aperture, placing the assembly and the positioning tool in a mold, maintaining the position of the assembly using the tool, introducing resin into the mold, and allowing the resin to set. The introducing is effective to substantially hermetically encapsulate a portion of the assembly excluding the aperture and is further effective to form an outermost surface of the sensor.

In one refinement of the method the resin is a polyamide resin. In another refinement of the method the introducing is effective to define threads on the outermost surface. In another refinement of the method the introducing is effective to define a stopping flange on the outermost surface. In another refinement of the method the conductor is a polyurethane coated wire. In another refinement of the method the resin introduced into the mold is heated resin and the allowing the resin to set includes cooling the resin. In another refinement of the method the introducing resin into the mold utilizes injection molding. In another refinement of the method the mold is a book mold and further comprising closing the book mold about the assembly and the tool.

A further embodiment according to the present invention includes an apparatus comprising a variable reluctance sensor element including a wound wire, a magnet, and a pole piece. The sensor element includes a first end. The apparatus further comprises a cap positioned about the first end of the sensor element, the cap including at least one groove defined in the cap. The apparatus also comprises an overmolded shell encapsulating at least a portion of the sensor element and, contacting the groove effective to provide a seal between the shell and the cap.

In one refinement of the apparatus the cap is formed of polyamide resin. In another refinement of the apparatus the cap is at least partially formed of at least partially electrically conductive resin. In another refinement of the apparatus the magnet and a portion of the pole piece are positioned within the cap. In another refinement of the apparatus further comprising a cavity defined at a second end of the sensor element and two electrical terminals positioned within the cavity. In another refinement of the apparatus the cap further includes a second groove, the overmolded shell contacts the second groove, and the first groove and the second groove are ring shaped. In another refinement of the apparatus the cap is formed of polyamide resin, the magnet and a portion of the pole piece are positioned within the cap, and the groove is defined in a flange of the cap.

A further embodiment according to the present invention includes a method of overmolding a resin shell about a variable reluctance sensor element including a pole piece, a magnet, and a wound wire. The method comprising positioning a cap at one end of the element. The method further comprising placing the element and the cap in a mold. The method further comprising maintaining the position of the element within the mold using at least the cap and introducing resin into the mold effective to encapsulate the element.

In one refinement of the method the positioning is effective to introduce the magnet into the cap. In another refinement of the method the mold is a book mold and further comprising closing the book mold about the element and the cap. In another refinement of the method the cap includes a groove and the introducing is effective to substantially fill the groove. In another refinement of the method the positioning is effective to introduce the magnet into the cap, the cap includes a groove and the introducing is effective to substantially fill the groove, and the introducing is effective to encapsulate a portion of the cap. In another refinement of the method the maintaining also uses a positioning plug and the maintaining is effective to substantially center the element within the mold.

A further embodiment according to the present invention includes a method comprising providing an assembly including a bobbin, a wire wound about the bobbin, a magnetizable core disposed at least partially within the wound portion, and a magnet positioned adjacent the magnetizable core. The method further comprises positioning a cap over at least a portion of the magnet. The method further comprises placing the assembly and the cap into a mold. The method further comprises introducing resin into the mold effective to encapsulate at least a portion of the assembly.

In one refinement of the method the positioning includes positioning the cap over the magnet and a portion of the core. In another refinement of the method the introducing includes injection molding. In another refinement of the method the mold is a book mold. In another refinement of the method the cap includes a flange, the flange includes at least one groove formed in the flange, and the introducing is effective to fill the groove with resin. In another refinement of the method the resin is a polyamide resin, the positioning includes positioning the cap over the magnet and a portion of the core, and the mold is a book mold. In another refinement of the method comprising first forming the cap from an at least partially conductive resin material.

Another embodiment according to the present invention includes a sensor including a sensor core. The sensor core includes a magnet, a pole piece, a bobbin, at least two terminals coupled to the bobbin, and a conductor wound about the bobbin and coupled to the terminals. At least a portion of the windings are disposed about at least a portion of the pole piece. The magnet is disposed substantially adjacent the pole piece. A support contacts at least a portion of the conductor. A supported portion of the conductor is located between the windings and the terminals. A sensor housing surrounds at least a portion of the sensor core.

In one refinement of the sensor the support is an epoxy or a thermosetting resin. In another refinement of the sensor further comprising a seal between the housing and the core formed after introduction of the core, including the support, into the housing. In another refinement of the sensor the support is resin occupying a region located between the windings and at least one of the terminals. In another refinement of the sensor the resin further extends to contact a portion of the housing adjacent said region and to substantially encapsulate both of the terminals. In another refinement of the sensor further comprising threads integrally formed with the housing and located on the exterior of the housing. In another refinement of the sensor the conductor is a wire and the resin is a thermosetting resin which encapsulates substantially the entire portion of the wire intermediate the terminals and the bobbin, and further comprising threads integrally formed with the housing and located on the exterior of the housing.

Another embodiment according to the present invention includes a method of manufacturing a sensor including providing a sensor core including a magnet, a pole piece, a bobbin, at least two terminals, and a conductor which is wound about the bobbin and coupled to the terminals. At least a portion of the windings surround at least a portion of the pole piece. The magnet is disposed substantially adjacent the pole piece. The method further includes adding support for a portion of conductor located in a region between windings and at least one of the terminals, introducing the sensor core into a housing, and forming a seal between the sensor core and the housing.

In one refinement of the method the region is a volume adjacent the conductor and the adding support includes adding resin to said area. In another refinement of the method the conductor is a wire and said providing a sensor core includes injection molding a bobbin, winding the wire about the bobbin, soldering one end of the wire to one of the terminals, and soldering the other end of the wire to the other of the terminals. In another refinement of the method the adding support includes encapsulating a portion of the wire extending from the windings to the terminal with resin. In another refinement of the method the resin is thermosetting resin and further comprising setting the thermosetting resin. In another refinement of the method the providing a sensor core includes placing the pole piece within the bobbin and placing the magnet at the end of the pole piece, the adding support occurs before the introducing, and the support is resin contacting at least a portion of the conductor intermediate the windings and the terminal. In another refinement of the method said providing a sensor core includes placing the pole piece within the bobbin and placing the magnet at the end of the pole piece, the adding support occurs after the introducing, and the support is resin which substantially encapsulates at least a portion of the conductor located between the windings and the terminal. In another refinement of the method the resin is epoxy, the conductor is wire, the shell is threaded on a part of its exterior surface and the resin is deposited such that it extends to contact the shell.

A further embodiment according to the present invention includes a manufacturing method including providing a magnetic circuit including a wire, the wire having a wound portion, a first portion conductively coupled to a first terminal, and second portion conductively coupled to a second terminal, the first terminal and the second terminal conductively coupled to a third terminal and a fourth terminal. The method further includes reinforcing a section of the wire located in a position between the wound portion and at least one of the first terminal and the second terminal, surrounding the magnetic circuit with a protective shell, and providing a seal effective to substantially seal the magnetic circuit within the shell.

In one refinement of the method the reinforcing includes injecting resin into an area between the windings and the first terminal or the second terminal. In another refinement of the method the resin is thermosetting resin and the reinforcing includes encapsulating substantially the entire exterior of the wire with the resin, said method further comprising temperature setting the resin. In another refinement of the method resin is an epoxy or a thermosetting resin, the reinforcing occurs prior to the surrounding, and the injecting includes flowing epoxy. In another refinement of the method the reinforcing occurs after the surrounding, and the reinforcing includes adding resin to contact a portion of the wire.

It is one object of the present invention to provide an improved transmission sensor.

Additional embodiments, aspects, objects, and advantages of the present invention will be apparent from the following description and claims.

Brief Description of the Figures

Fig. 1 is a side view of an embodiment of an output sensor of the present invention.

Fig. 2 is an enlarged detail view of Section 2 of Fig. 1.

Fig. 3 is a side view of the embodiment of Fig. 1 rotated 90°.

Fig. 4 is a top view of the embodiment of Fig. 3.

Fig. 5 is an enlarged detail view of Section 5 of Fig. 3.

Fig. 6 is an enlarged detail view of Section 6 of the embodiment of Fig. 3.

Fig. 7 is a top view of the embodiment of Fig. 6.

Fig. 8 is a cross-sectional view of the embodiment of Fig. 1 along the lines 8-8.

Fig. 9 is an enlarged detail view of Section 9 of Fig. 8.

Fig. 10 is a rotated perspective view of the embodiment of the invention illustrated in Fig. 1.

Fig. 11 is an exploded view of a prior art sensor.

Fig. 12 is a top view of the shell of the sensor of Fig. 11.

Fig. 13 is a top view of an embodiment of an input sensor of the present invention.

Fig. 14 is a top view of another embodiment of a locating cap of the present invention.

Fig. 15 is a cross-sectional view of the embodiment of Fig. 14 along the lines 15-15.

Fig. 16 is an enlarged detail view of Section 16 of the embodiment of Fig. 15.

Fig. 17 is a side view of the embodiment of Fig. 14.

Fig. 18 is an elevated side perspective view of the embodiment of Fig. 14.

Fig. 19 is a side view of one embodiment of the locator plug for holding the sensor in the mold.

Fig. 20 is the side view of the embodiment of Fig. 19 with added detail concerning various dimensions of this embodiment of the locator plug.

Fig. 21 is an enlarged end view of the embodiment of Fig. 20.

Fig. 22 is a flow diagram according to an embodiment of the present invention.

Fig. 23 is a side sectional view of a sensor according to one embodiment of the present invention.

Fig. 24 is an exploded side sectional view of a sensor according to one embodiment of the present invention.

Fig. 25 is a side sectional view of a sensor according to one embodiment of the present invention showing the addition of resin.

Fig. 26 is a side sectional view of a sensor according to one embodiment of the present invention showing the addition of resin.

Fig. 27 is a side view of a portion of a sensor according to one embodiment of the present invention.

Fig. 28 is a side view of a portion of a sensor according to one embodiment of the present invention.

Fig. 29 is a side view of a portion of a sensor according to one embodiment of the present invention.

Fig. 30 is a flowchart according to one embodiment of the present invention.

Detailed Description

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated device, and such further applications of the principles of the invention as illustrated therein being contemplated as would normally occur to one skilled in the art to which the invention relates.

The inventor has determined that the design and assembly of sensors such as prior art sensor 39 contributes to a high failure rate in the field. The inventor has determined that approximately 90% of the failure rate is due to wire failure. In prior art sensors some or all of the wire is unsupported and exposed after insertion in to the shell cavity within the sensor. Heat, vibration and/or corrosion can lead to fatigue failure of the wire. This creates an open circuit coil that will not generate a signal. Such a failure will create shifting problems in the transmission, as the controller has to default to open-loop control of the unit.

With reference to Figs. 1-10 there are shown multiple views of an output transmission sensor according to a preferred embodiment of the present invention. Fig. 1 shows output sensor 99 which is a threaded variable reluctance sensor for sensing the rotational speed of the output shaft of an automatic transmission. Output sensor 99 includes bobbin 120 and centering cap 140 which are partially encapsulated by overmolded resin shell 100. Shell 100 includes threads 101, stopping flange 102, hexagonal section 103, and top section 104. Output sensor 99 also preferably includes O-ring 180.

Sensor 99 is preferably adapted to be installed in a threaded bore formed in the housing of an automatic transmission near a toothed ferrous rotating ring associated with the output shaft of an automatic transmission. Installation of Sensor 99 can be accomplished by advancing sensor 99 into the bore until threads 101 contact threads formed on the interior of the bore. A tool can then be used to engage hexagonal section 103 and rotate sensor 99 to cause threads 101 to engage the threads of the bore and advance sensor 99 into the bore. Sensor 99 is preferably rotated until a stopping flange 102 contacts the outside of the transmission housing and a seal is formed between sensor 99 and the housing by stopping flange 102 and O-ring 180. Sensor 99 is then preferably torqued down to a particular force to prevent back out.

With reference to Figs. 2-10 there are shown additional views of sensor 99. Identical reference numerals are used to indicate aspects of sensor 99 described above. Additional aspects of sensor 99 are as follows. Fig. 2 shows a detailed view of the portion of output sensor 99 indicated by arrows 2 in Fig. 1. A portion of the terminal connection end of bobbin 120 is shown in Fig. 2 which includes fastener 121. Fastener 121 is adapted to releasably engage a clip of a plug of an electrical cable that connects to terminal connection end of bobbin 120.

Fig. 3 shows sensor 99 with O-ring 180 removed and O-ring seat 181 visible. Fig. 4 shows cavity 170 formed in the terminal connection end of sensor 99. Terminals 171 and 172 are disposed within cavity 170 and are electrically interconnected to a wire wound around a portion of the bobbin 120 within sensor 99 as shown and described below in connection with Figs. 8 and 9. During operation a plug of an electrical cable can be inserted into terminal cavity 170 to establish electrical connections with terminals 171 and 172. In an alternative embodiment, instead of including terminals disposed within a cavity, sensor 99 includes lead wires extending from its end which lead to a plug connector remote from the body of bobbin 120. These wires can be positioned outside a mold during the overmolding process used to form shell 100 which is described in greater detail below. Overmolded shell 100 can extend to and encapsulate the junction between the lead wires and bobbin 120, or can extend along bobbin 120 to an area before the junction. Fig. 5 shows an enlarged detailed view of the portion of sensor 99 indicated by arrow 5 in Fig. 3. Fig. 6 shows an enlarged detailed view of the portion of sensor 99 indicated by arrow 6 in Fig. 3. Fig. 7 shows a bottom view of sensor 99.

Fig. 8 shows a side sectional view of sensor 99. Fig. 8 shows wire 110 wound around bobbin 120. One end portion of wire 110 extends from the windings and is electrically interconnected to pin terminal 141, for example by soldering, and another end of wire 110 similarly extends from the windings and is electrically interconnected with pin terminal 142. Pin terminals 141 and 142 are electrically interconnected with terminals 171 and 172 through a conductive pathway routed through bobbin 120. As shown in Fig. 8, overmolded resin shell 100 contacts portions of bobbin 120, wire 110 and portions of cap 140. Shell 100 preferably contacts and supports wire 110 at its windings and further preferably contacts and supports portions of wire 110 extending between the windings around bobbin 120 and the pin terminals 141 and 142. Fig. 9 shows a detailed view of the portion of sensor 99 indicated by arrows 9 in Fig. 8. As shown in Fig. 9, sealing rings 160 are formed in cap 140 and overmolded resin shell 100 fills sealing rings 160. Contact between shell 100 and cap 140 preferably forms a hermetic seal between the interior of sensor 99 and the exterior environment. Fig. 10 shows a perspective view of sensor 99.

A preferred embodiment of output sensor 99 according to the present invention can be manufactured according to dimensions and tolerances specified for use in connection with a variety of automatic transmissions from a variety of manufacturers including, for example, the dimensions of part number 0400879 which was mentioned above. Similarly, a preferred embodiment of input sensor 199 discussed below with respect to Fig. 13 according to the present invention can be manufactured according to dimensions and tolerances specified for use in connection with a variety of automatic transmissions from a variety of manufacturers including, for example, the dimensions of part number 0400878 which was mentioned above. These dimensions and tolerances are merely exemplary of one preferred embodiment, however, and sensors of a variety of different configurations, sizes, dimensions, and tolerances are contemplated as within the scope of the invention including, for example, dimensions and tolerances for sensors adapted for use in other automatic transmissions and those adapted for use in other applications and environments where it is desirable or useful to obtain information relating to the rotational speed of a toothed ring or other rotating structure.

According to a preferred embodiment of the present invention, overmolded resin shell 100 is preferably formed from a resin material adapted for use in an injection molding system, most preferably of Zytel #70G43L NC010 resin which is a 43% glass filled, natural colored polyamide 6/6 grade nylon material available from DuPont corporation of Wilmington, Delaware. It is also contemplated that shell 100 could be formed from a variety of other materials, for example, other grades of Zytel with different glass contents, copolymers or colors, 4/6 grades of polyamide such as DSM Stanyl TW241F10 or others, other members of the polyamide family of resins including other 4/6 and 6/6 grades, other materials having similar properties, other plastics, thermoplastics, epoxy resins, and/or other materials suitable to maintain their integrity in an injection molding environment.

According to a preferred embodiment of the present invention, wire 110 is preferably NEMA MW79-C which is a copper wire with polyurethane coating and is rated to 155 degrees Celsius. Wire 110 could also be a variety of other conductive materials including, for example, NEMA MW82C or 83C, or any other type of wire suitable for hermetic overmolding applications. A preferred embodiment according to the present invention includes 6200 turns or windings of wire 110 which gives a coil resistance of about 650 Ohms +/- about 10%. This number of windings and resistance are merely exemplary, however, and a variety of numbers of windings and resistances are contemplated as within the scope of the present invention.

With reference to Fig. 13 there is illustrated a view of an input transmission sensor according to one embodiment of the present invention. Fig. 13 shows input sensor 199 which is a threaded variable reluctance sensor for sensing the rotational speed of the input shaft of an automatic transmission. Input sensor 199 includes bobbin 220 and a centering cap which are hermetically encapsulated by overmolded resin shell 200. Shell 200 includes threads, stopping flange 202, hexagonal section 203, and top section 204. Input sensor 199 also preferably includes O-ring. Sensor 199 is preferably adapted to be installed in a threaded bore formed in the housing of an automatic transmission near a toothed ferrous rotating ring associated with the input shaft of an automatic transmission.

Fig. 13 shows cavity 270 formed in the terminal connection end of sensor 199. Terminals 271 and 272 are disposed within cavity 270 and are electrically interconnected to a wire wound around a portion of the bobbin 220 within sensor 199 in a manner similar to that shown and described above in connection with Figs. 8 and 9. During operation a plug of an electrical cable can be inserted into terminal cavity 270 to establish electrical connections with terminals 271 and 272. In an alternative embodiment, instead of including terminals disposed within a cavity, sensor 199 includes lead wires extending from its end which lead to a plug connector remote from the body of bobbin 220.

Details concerning resin selection for the shell and selection of a wire described above with respect to the output sensor are equally applicable to the input sensor. However, a preferred embodiment according to the present invention includes 6350 turns or windings of wire 210 which gives a coil resistance of about 760 Ohms +/- about 10%. This number of windings and resistance is merely exemplary, however, and other numbers of windings and resistances are contemplated as within the scope of the present invention.

With reference to Figs. 14-18 there are shown multiple views of centering cap 140 which is also illustrated and described above in connection with Figs. 1-10. As shown in Figs. 14-18 cap 140 includes cap body 163, cap flange 162, sealing rings 160, and cap cavity 161. Cap cavity 161 receives magnet 150 and an end portion of pole piece 130, as illustrated and described above. Cap body 163, cap flange 162 and cap cavity 161 have generally circular cross sectional shapes for sections taken perpendicular to axis BB shown in Fig. 15.

A preferred embodiment of cap 140 according to the present invention can be manufactured to dimensions and tolerances which allow magnet 150 and an end portion of pole piece 130 to fit snugly within cavity 161. These dimensions and tolerances are merely exemplary of one preferred embodiment, however, and centering caps of a variety of different configurations, sizes, dimensions, and tolerances are contemplated as within the scope of the invention.

Cap 140 is preferably formed from a resin material adapted for use in an injection molding system, most preferably of Zytel #70G43L NC010 resin which is a 43% glass filled, natural colored polyamide 6/6 grade nylon material available from DuPont corporation of Wilmington, Delaware. It is also contemplated that cap 140 could be formed from a variety of other materials, for example, other grades of Zytel with different glass contents, copolymers or colors, 4/6 grades of polyamide such as DSM Stanyl TW241F10 or others, other members of the polyamide family of resins including other 4/6 and 6/6 grades, other materials having similar properties, other plastics, thermoplastics, epoxy resins, and/or other materials suitable to maintain their integrity in an injection molding environment. In one embodiment according to the present invention, cap 140 is formed from a conductive thermoplastic material.

With reference to Figs. 19-21 there are shown multiple views of locating plug 300 according to an embodiment of the present invention. Locating plug 300 includes tip portion 310, middle portion 320 and body 330. Tip portion and middle portion of locator plug 300 are preferably adapted to be inserted into and substantially or completely fill cavity 170 of sensor 99 or cavity 270 of sensor 199 which were described above, or to be inserted into and substantially or completely fill sensors cavities of a variety of other configurations, sizes, dimensions and tolerances. Plug 300 is preferably used in connection with the manufacturing of a sensor according to the present invention such as, for example, sensors 99 and 199 which are described above.

With reference to Fig. 22 there is shown flow diagram 500 according to a preferred embodiment of the present invention. Sensors according to the present invention, for example, sensors 99 and 199 described above and other sensors can be manufactured according to the manufacturing process of flow diagram 500. For clarity flow diagram 500 is described using the reference numerals associated with sensor 99, but similar or identical manufacturing operations could also be performed for sensor 199 and other sensors according to the present invention. At operation 510 centering cap 140 is formed as a single piece preferably using an injection molding technique and preferably using one or more materials described above in connection with Figs. 14-18. It is contemplated however that cap 140 could be formed using a variety of other techniques, processes, and materials. From operation 510 flow diagram proceeds to operation 520.

At operation 520 wire 110 is wound around bobbin 120 and end portions of wire 110 are soldered to pin terminals 141 and 142. Bobbin 140 could be formed by injection molding, other molding techniques, or using any other technique known to those of skill in the art. It is also contemplated that wire 110 and bobbin 120 could be provided as a preassembled unit. From operation 520 flow diagram proceeds to operation 530.

At operation 530, pole piece 130 is inserted into bobbin 120 and magnet 150 is placed at the end of pole piece 130. It is also contemplated that pole piece 130 and/or magnet 150 could be provided as part of a preassembled unit. From operation 530 flow diagram proceeds to operation 540.

At operation 540 centering cap 140 is placed over magnet 150 and an end portion of pole piece 130 so that its end surface contacts the end surface of bobbin 120. It is also contemplated that centering cap 140 could be provided as part of a preassembled unit. Furthermore, it is contemplated that one or more of operations 510, 520, 530 and 540 could be performed as a single operation, could be performed in parallel, in series or a combinations of parallel and serial operations, or could be broken into sub-operations including additional separate steps. From operation 540, flow diagram proceeds to operation 550.

At operation 550, locating plug 300 is inserted into cavity 170 at the terminal end of bobbin 120 and substantially or completely fills cavity 170, or fills a portion of cavity 170 and is effective to prevent resin from filling cavity 170 during injection molding and to support and maintain the position of the other components within a mold. From operation 550, flow diagram 500 proceeds to operation 560.

At operation 560 the assembly including cap 140, magnet 150, pole piece 130, bobbin 120 wire 110 and plug 300 is placed into a mold. The mold is preferably a book mold, and the assembly is placed into one half of the book mold and the other half of the book mold is closed over the assembly. The mold defines a cavity having the shape of overmolded resign shell 100. Centering cap 140 and plug 300 support the assembly within the mold and maintain it in a position such that the assembly is spaced away from the interior surfaces of the mold. Thus, there is a void in the area between the inside surface of the mold and the outer region of the assembly. This void extends along the length of the assembly from before the sealing rings 160 of the locating cap 140 up to about the portion of bobbin 120 which is visible in Fig. 1. From operation 560, flow diagram 500 proceeds to operation 570.

At operation 570, molten resin is introduced into the mold under pressure and is forced to fill the void defined by any space not occupied by the assembly and/or plug. Introduction of molten resin is preferably accomplished using a rotary table rotating beneath an injection molding machine that injects the resin into the cavity of the book mold through various gates or ports formed in the book mold. From operation 570, flow diagram 500 proceeds to operation 580.

At operation 580, the molten resin cools within the sensor assembly with the overmolded resin shell is removed from the mold after an appropriate cooling period. From operation 580, flow diagram proceeds to operation 590.

At operation 590 quality control procedures may be performed on the sensor. Additional post-mold procedures, such as addition of O-ring 180, polishing, trimming or otherwise removing molding artifacts can also be performed.

After operation 590, the sensor is in a finished or substantially finished state. In the finished state resin shell 100 preferably hermetically encapsulates and supports all portions of the assembly not visible outside shell 100 as shown in Fig. 1. Seals are preferably formed between shell 100 and sealing rings 160 and between shell 100 and the bobbin sealing flanges located under top portion 104 as shown in Fig. 8. Thus, pole piece 130, magnet 150, wire 110, pin terminals 141 and 142, and portions of bobbin 120 are preferably hermetically encapsulated, contacted and supported by the overmolded resin shell 100. Furthermore, overmolded resin shell 100 holds locating cap 140 in a position relative to the assembly as shown and described above in connection with Figs. 1-10.

A number of variations of the foregoing manufacturing process and devices are contemplated. For example, it is contemplated that two or more of the foregoing operations could be performed as a single operation, could be performed in parallel, in series or a combinations of parallel and serial operations, or that one or more of the foregoing operations could be broken into sub-operations including additional separate steps. It is also contemplated that one or more of the foregoing operations could be omitted, for example, operation 590 or other operations. It is further contemplated that additional operations could be interposed between the operations described above. Furthermore, it is contemplated that a centering cap could be omitted from the assembly that is introduced into the mold and the injected resin could form the structure of the assembly cap. According to this process overmolded resin shells 100 (and 200) described above constitute the structure of cap 140. This process reduces the number of parts of the assembly that are inserted into the mold. The absence of centering cap may result in undesired displacement of the magnet or other parts. Thus, it is contemplated that a thin sleeve could be used to hold the magnet in place relative to the pole piece during molding. It is also contemplated that a variety of molds and injection molding techniques could be utilized in addition to those discussed above. It is also contemplated that a thin sleeve or ring with 2 or more tabs could be located on the tip of the sensor at 130 or 150. These tabs would center the sensor within the mold, allowing the overmolded resin shells 100 and 200 to constitute the structure of the caps 140 and 240, respectively, except in the areas where the tabs contact the mold.

With reference to Fig. 23 there is shown sensor 600 according to another embodiment of the present invention. Sensor 600 includes housing 610 which is formed, for example, using injection molding and/or other processes and techniques. Housing 610 includes a threaded portion 612 and tip portion 614 and could be a single piece or multiple coupled pieces. Housing 610, and all other aspects of sensor 600, could also include some or all of the features described above and those embodiments could likewise include some or all of the features described below.

Sensor 600 also includes bobbin 620 including sections 628 and 629 which could be a unitary piece or compound or composite structures and could be formed, for example, using injection molding and/or other processes and techniques. Wire 630 is wound about section 628 and extends to and is coupled to terminals 634A and 634B, for example, with solder and/or other connector(s) or connection(s). Terminals 634A and 634B are electrically coupled to terminals 638 through conductive pathways in section 629.

Sensor 600 further includes pole piece 622, which is inserted into a cavity or bore in bobbin 620, and magnet 624 which, as illustrated, can be positioned adjacent pole piece 622 and at least partially within end portion 614. Magnet and pole piece can also be in a variety of other shapes and configurations. During operation a current can be induced in wire 630 by virtue of a sensed element moving relative to magnet 624 as is the case in various variable reluctance sensors. It is also contemplated that other types of sensors could be used.

Sensor 600 also includes a seal formed between housing 610 and bobbin 620. As shown in Fig. 23 the seal is formed by flange 635 extending into groove 631 of housing 610 and a sealing flange at the end of housing 635 being heat crimped into the illustrated position. A variety of other seals are also contemplated, including for example those formed by adding a sealant around the junction of housing 610 and bobbin 620.

With reference to Fig. 24 there is shown an exploded view of sensor 600. According to one preferred embodiment of the present invention sensor core 690 can be formed and assembled independent from housing 610. Core 690 can be assembled in various steps, including, for example, those described herein, and can be preassembled or can be partially assembled. Once assembled, core 690 can be inserted into housing 610 and a seal can formed, for example, as described above.

With reference to Fig. 25 there is shown one example of the addition of resin to serve as a support structure for a portion of wire 632A. Injector 695 can be positioned relative to the portion of wire 630 extending from the windings to terminal 634A and can then introduce resin to form a support structure for a portion of wire 630. Injector 695 can be held stationary during introduction, or can be moved during introduction of resin. Injector 695 can also be a variety of differently sized and shaped injectors. As illustrated in Fig. 25, introduction of resin and/or other support structures can occur prior to insertion of bobbin 620 into housing 610.

With reference to Fig. 26 there is shown another example of the addition of resin to serve as a support structure for a portion of wire 632A. Injector 696 can be positioned relative to the portion of wire 630 extending from the windings to terminal 634A and can then introduce resin to form a support structure for a portion of wire 630. Injector 695 can be held stationary during introduction, or can be moved during introduction of resin. Injector 696 can also be a variety of differently sized and shaped injectors. As illustrated in Fig. 25, introduction of support structure can occur after insertion of bobbin 620 into housing 610. The hole in housing 610 created by injector 696 can be sealed with the resin itself or can be sealed with a separate material or sealant or heat sealed, for example.

With reference to Figs. 27, 28 and 29 there are shown several examples of configurations of resin serving as support structure for a portion of wire 632A. In Fig. 27 resin 640A extends to contact part of wire 632A. In Fig. 28 resin 640A extends to encapsulate wire 632A. In Fig. 29 resin 640A substantially fills a region extending between housing 610 and bobbin 620. A variety configurations in addition to those illustrated in Figs. 41, 42 and 43 are also contemplated.

In various embodiments according to the present invention support structure could include a variety or resins and thermosetting materials and other materials such as an adhesive thermoset, elastomer, epoxy, fluoropolymer, phenolic, polyester, silicone, vinyl ester or any combination of the aforementioned materials such as silicone adhesives, phenolic adhesives and other similar materials. These can be applied in a liquid, solid or semi-solid form such as a paste or foam. Examples of suitable materials include Aptek 2712-A/B adhesive, GE Silicones TSE392 Translucent Adhesive Sealant, GE Silicones RTV6136 Potting/Encapsulating Gel, Loctite® 5071 Silicone Encapsulant, Bayer MaterialScience Bayfit®, Cal Polymers ND3200 and Polyurethane Flexible Molded Foam. The above mentioned thermoplastic materials could include materials such as acrylonitrilebutadiene-styrene (ABS), acrylic, elastomers, fluoropolymers, nylons including 6/6 and 4/6, polyamides, polyimides, polyesters, polyetheretherketone (PEEK), polyethylene including low density (LDPE) and high density (HDPE), polypropylene, polystyrene, polysulfone, polyurethane and others. These can be applied in a molten form. Examples of suitable materials include Dupont Zytel #70G43L NC010 and DSM Stanyl TW241F10. The foregoing and additional materials, for example, numerous polymerized synthetics, chemically modified, or natural materials including cements, glues, plastics, putties, struts, tabs, other support structures and/or combinations of the foregoing are contemplated as examples of support structures according to the present invention.

With reference to Fig. 30 there is shown flow diagram 700 according to a preferred embodiment of the present invention. Flow diagram 700 begins at operation 710 where a sensor shell or housing is formed, for example by injection molding, or a preformed housing or shell is provided. From operation 710, flow diagram 700 proceeds to operation 720. At operation 720 a bobbin assembly is formed, for example, using injection molding, or a preformed bobbin assembly is provided. From operation 720, flow diagram 700 proceeds to operation 730. At operation 730 a wire is wound around a portion of the bobbin. From operation 730, flow diagram 700 proceeds to operation 740. At operation 740 the ends of the wire are electrically coupled to terminals of the bobbin, for example, by soldering. From operation 740, flow diagram 700 proceeds to operation 750. At operation 750, a pole piece is introduced at least partially into the bobbin and a magnet is placed at one end of the pole piece. From operation 750, flow diagram 700 proceeds to operation 760. It will be appreciated that the foregoing operations could be performed in a variety of orders, or could have been previously performed to provide a pre-assembled bobbin assembly.

At operation 760 a support structure, for example, one or more materials or structures described herein, such as a resin, is added to support a portion of wire. From operation 760, flow diagram 700 proceeds to operation 770. At operation 770 the resin can be cured, or subjected to thermal variation to cure or harden it. From operation 770, flow diagram 700 proceeds to operation 780. At operation 780 the bobbin assembly is introduced into a housing. From operation 780, flow diagram 700 proceeds to operation 790. At operation 790 a seal is formed between the housing and the inserted assembly.

This can be accomplished, for example, by heat crimping a portion of the housing or shell around the inserted bobbin assembly. It will be appreciated that the foregoing operations could be performed in a variety of orders, for example the resin could be added before or after the assembly is inserted into the housing, and before or after the sealing of the housing and the bobbin assembly.

According to one embodiment a portion of a wire extending between a windings and terminal area is supported by a thermosetting or thermoplastic material. In this embodiment, the body (incorporating the threaded, main body, holding flange and cap as one piece) is injection molded. Copper wire is wound on the bobbin (incorporating the black terminal connection end, pins and winding section) and soldered to the pins. A pole piece and magnet are positioned into a bobbin assembly. A thermosetting or thermoplastic material is either injected or applied in the area between the windings and the terminal connection. The wound bobbin with magnet and pole piece assembly is inserted into the body. This assembly is completed by bending the holding flange or end portion of the housing over the bobbin assembly, for example, by using heat and pressure to bend the thin holding flange without breaking the plastic. The heat can be applied using convection, conduction or ultrasonic.

This sequence of the foregoing embodiment can be modified in multiple manners, for example, by applying the thermosetting or thermoplastic material before inserting the pole piece and magnet. The thermosetting or thermoplastic material can either be fully cured or cooled, or may be curing or cooled at the time of the insertion. In this case, the sequence above could be re-arranged in a variety of orders, for example by switching the third and fourth operations described above. It is envisioned that the magnet and pole piece could be assembled at a different times in the sequence. There are also a variety of other modifications to the manufacturing sequence that would result in the same or similar results.

According to another embodiment a thermosetting or thermoplastic is applied into the cavity in the main body molding. In this case, the wound bobbin with pole piece and magnet would be inserted into the body while the thermosetting or thermoplastic material is still uncured or molten. As the wound bobbin assembly is inserted into the body, the thermosetting or thermoplastic material would flow up around the coil and into the void between the windings and terminals. In this embodiment, the thermosetting or thermoplastic material would cure or cool and form an encapsulation of both the windings and the void between the windings and terminals.

A number of variations of the foregoing manufacturing processes and devices are contemplated. For example, it is contemplated that two or more of the foregoing operations could be performed as a single operation, could be performed in parallel, in series or a combinations of parallel and serial operations, or that one or more of the foregoing operations could be broken into sub-operations including additional separate steps. It is also contemplated that one or more of the foregoing operations could be omitted. It is further contemplated that additional operations could be interposed between the operations described above.

As used herein terms relating to properties such as geometries, shapes, sizes, and physical configurations, include properties that are substantially or about the same or equal to the properties described unless explicitly indicated to the contrary.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only preferred embodiments have been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

CLAIMS

What is claimed is:

1. A sensor comprising:

a bobbin including a first region adapted to receive windings and a second region defining a cavity formed in the bobbin;

a first electrical terminal coupled to the bobbin and disposed in the cavity;

a second electrical terminal coupled to the bobbin and disposed in the cavity;

a wire including a wound portion wound about the first region the wire conductively coupled to the first terminal and the second terminal to provide an electrically conductive pathway from the first terminal to the second terminal;

a magnetizable core disposed at least partially within the wound portion;

a magnet positioned adjacent the magnetizable core; and

an overmolded shell defining an exterior surface of the sensor and encapsulating at least the first region and the wound portion and contacting at least the wound portion.

2. The sensor of claim 1 wherein the overmolded shell includes threads formed on the outermost surface of the shell.

3. The sensor of claim 1 wherein the overmolded shell is formed of a polyamide resin.

4. The sensor of claim 1 wherein the wire further comprises a first and second lead portions extending from the wound portion and the overmolded shell encapsulates and contacts the first and second lead portions.

5. The sensor of claim 1 wherein overmolded shell encapsulates a region of the second portion but does not encapsulate or obstruct the cavity.

6. The sensor of claim 5 wherein the first region and the second region are spaced apart along a longitudinal axis of the bobbin.

7. A method of overmolding a resin shell about a variable reluctance sensor assembly including a bobbin a conductor wound about the bobbin and an aperture defined at an end of the bobbin a comprising:

connecting a positioning tool to the assembly at the aperture;

placing the assembly and the positioning tool in a mold;

maintaining the position of the assembly using the tool;

introducing resin into the mold; and

allowing the resin to set;

wherein the introducing is effective to substantially hermetically encapsulate a portion of the assembly excluding the aperture and to form an outermost surface of the sensor.

8. The method of claim 7 wherein the resin is a polyamide resin.

9. The method of claim 7 wherein the introducing is effective to define threads on the outermost surface.

10. The method of claim 7 wherein the introducing is effective to define a stopping flange on the outermost surface.

11. The method of claim 7 wherein the conductor is a polyurethane coated wire.

12. The method of claim 7 wherein resin introduced into the mold is heated resin and the allowing the resin to set includes cooling the resin.

13. The method of claim 7 wherein the introducing resin into the mold utilizes injection molding.

14. The method of claim 7 wherein the mold is a book mold and further comprising closing the book mold about the assembly and the tool.

15. An apparatus comprising:

a variable reluctance sensor element including a wound wire, a magnet, and a pole piece the sensor element including a first end;

a cap positioned about the first end of the sensor element the cap including at least one groove defined in the cap; and

an overmolded shell encapsulating at least a portion of the sensor element and contacting the groove effective to provide a seal between the shell and the cap.

16. The apparatus of claim 15 wherein the cap is formed of polyamide resin.

17. The apparatus of claim 15 wherein the cap is at least partially formed of at least partially electrically conductive resin.

18. The apparatus of claim 15 where the magnet and a portion of the pole piece are positioned within the cap.

19. The apparatus of claim 15 further comprising a cavity defined at a second end of the sensor element and two electrical terminals positioned within the cavity.

20. The apparatus of claim 15 wherein the cap further includes a second groove, the overmolded shell contacts the second groove, and the first groove and the second groove are ring shaped.

21. The apparatus of claim 15 wherein the cap is formed of polyamide resin, the magnet and a portion of the pole piece are positioned within the cap, and the groove is defined in a flange of the cap.

22. A method of overmolding a resin shell about a variable reluctance sensor element including a pole piece, a magnet, and a wound wire, the method comprising:

positioning a cap at one end of the element;

placing the element and the cap in a mold;

maintaining the position of the element within the mold using at least the cap; and

introducing resin into the mold effective to encapsulate the element.

23. The method of claim 22 wherein the positioning is effective to introduce the magnet into the cap.

24. The method of claim 22 wherein the mold is a book mold and further comprising closing the book mold about the element and the cap.

25. The method of claim 22 wherein the cap includes a groove and the introducing is effective to substantially fill the groove.

26. The method of claim 22 wherein the positioning is effective to introduce the magnet into the cap, the cap includes a groove and the introducing is effective to substantially fill the groove, and the introducing is effective to encapsulate a portion of the cap.

27. The method of claim 22 wherein the maintaining also uses a positioning plug and the maintaining is effective to substantially center the element within the mold.

28. A sensor comprising:

a sensor core including a magnet, a pole piece, a bobbin, at least two terminals coupled to the bobbin, and a conductor including windings wound about the bobbin, the conductor coupled to the terminals, at least a portion of the windings disposed about at least a portion of the pole piece, the magnet disposed substantially adjacent the pole piece;

a support contacting at least a portion of the conductor said portion of the conductor being located between the windings and the terminals; and a sensor housing surrounding at least a portion of the sensor core.

29. The sensor of claim 28 wherein the support is an epoxy or a thermosetting resin.

30. The sensor of claim 28 further comprising a seal between the housing and the core formed after introduction of the core, including the support, into the housing.

31. The sensor of claim 28 wherein the support is resin occupying a region located between the windings and at least one of the terminals.

32. The sensor of claim 31 wherein the resin further extends to contact a portion of the housing adjacent said region and to substantially encapsulate both of the terminals.

33. The sensor of claim 28 further comprising threads integrally formed with the housing and located on the exterior of the housing.

34. The sensor of claim 28 wherein the conductor is a wire and the resin is a thermosetting resin which encapsulates substantially the entire portion of the wire intermediate the terminals and the bobbin, and further comprising threads integrally formed with the housing and located on the exterior of the housing.

35. A method of manufacturing a sensor comprising:

providing a sensor core including a magnet, a pole piece, a bobbin, at least two terminals, and a conductor, the conductor including windings wound about the bobbin and coupled to the terminals, at least a portion of the windings surrounding at least a portion of the pole piece, the magnet disposed substantially adjacent the pole piece;

adding support for a portion of conductor located in a region between the windings and at least one of the terminals;

introducing the sensor core into a housing; and

forming a seal between the sensor core and the housing.

36. The method of claim 35 wherein the region is a volume adjacent the conductor and the adding support includes adding resin to said area.

37. The method of claim 35 wherein the conductor is a wire and said providing a sensor core includes injection molding a bobbin, winding the wire about the bobbin, soldering one end of the wire to one of the terminals, and soldering the other end of the wire to the other of the terminals.

38. The method of claim 35 wherein the adding support includes encapsulating a portion of the wire extending from the windings to the terminal with resin.

39. The method of claim 38 wherein the resin is thermosetting resin and further comprising setting the thermosetting resin.

40. The method of claim 35 wherein the providing a sensor core includes placing the pole piece within the bobbin and placing the magnet at the end of the pole piece, the adding support occurs before the introducing, and the support is resin contacting at least a portion of the conductor intermediate the windings and the terminal.

41. The method of claim 35 wherein said providing a sensor core includes placing the pole piece within the bobbin and placing the magnet at the end of the pole piece, the adding support occurs after the introducing, and the support is resin which substantially encapsulates at least a portion of the conductor located between the windings and the terminal.

42. The method of claim 41 wherein the resin is epoxy, the conductor is wire, the shell is threaded on a part of its exterior surface and the resin is deposited such that it extends to contact the shell.

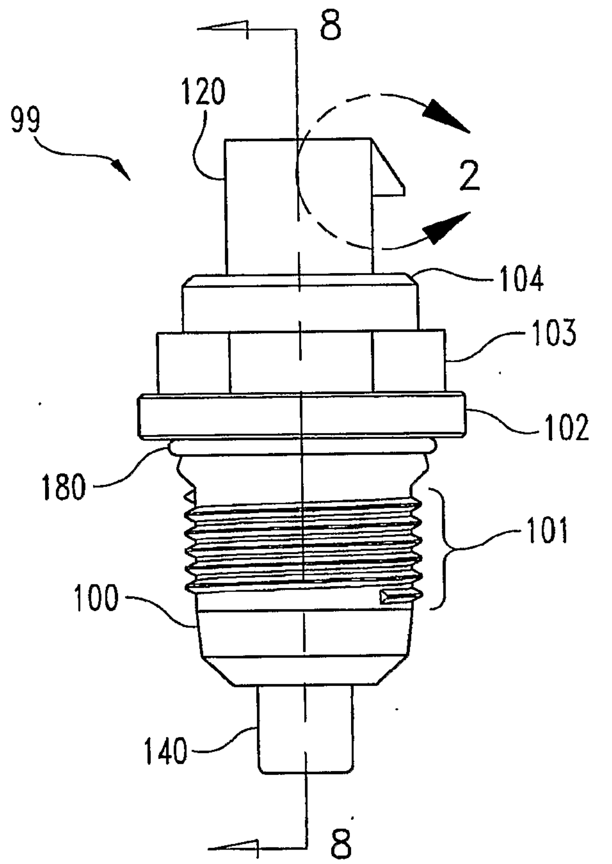


Fig. 1

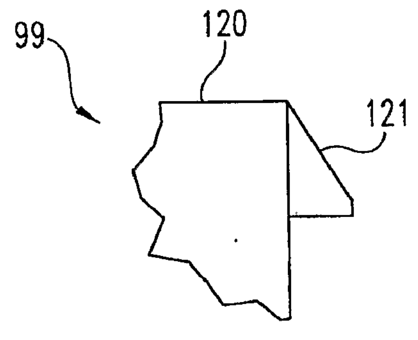
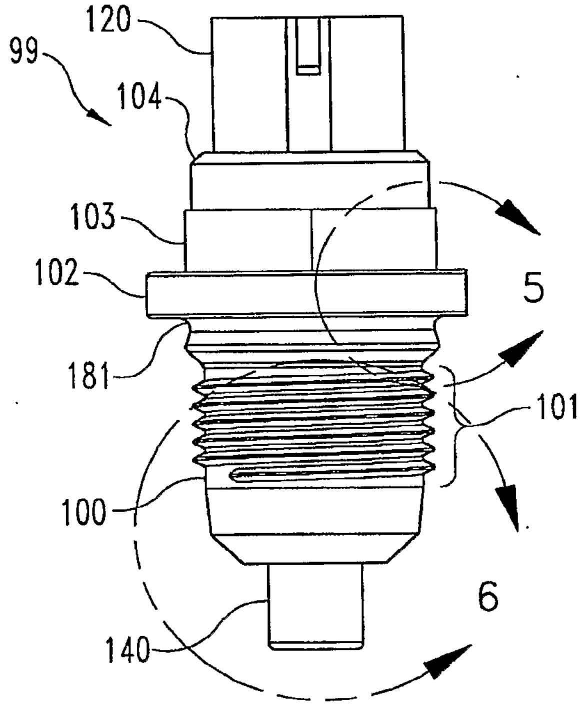


Fig. 2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140

Fig. 3

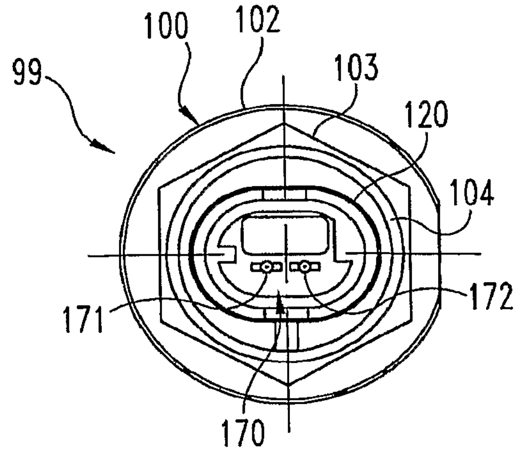
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Fig. 4

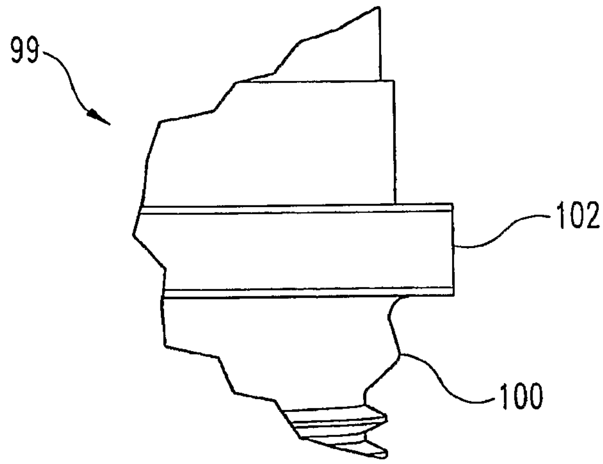


Fig. 5

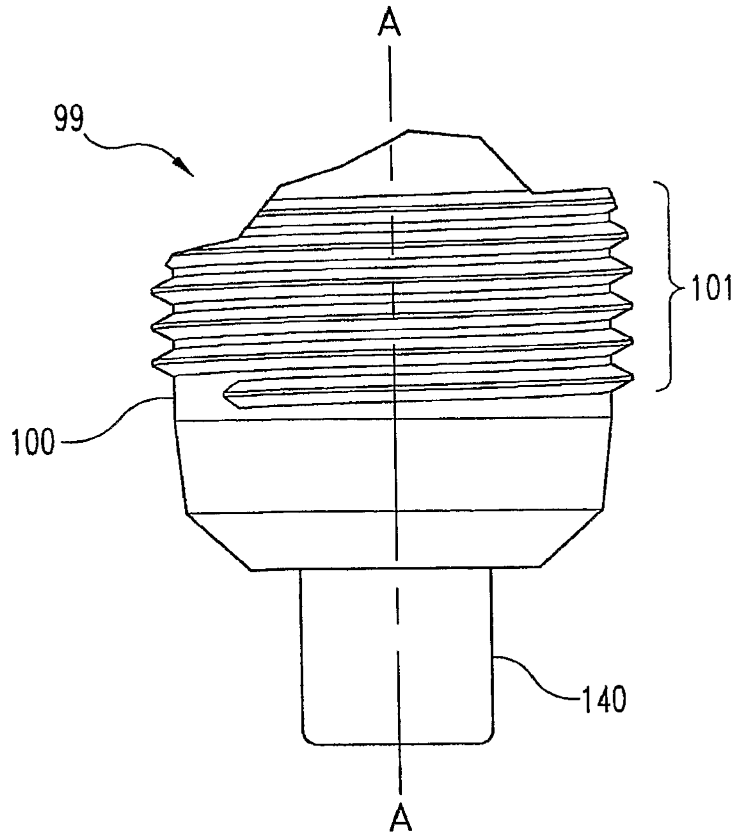


Fig. 6

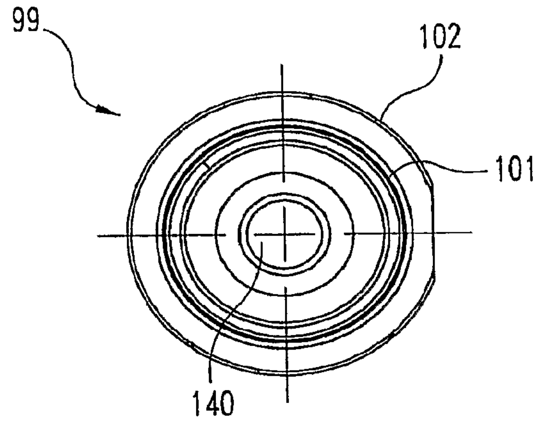


Fig. 7

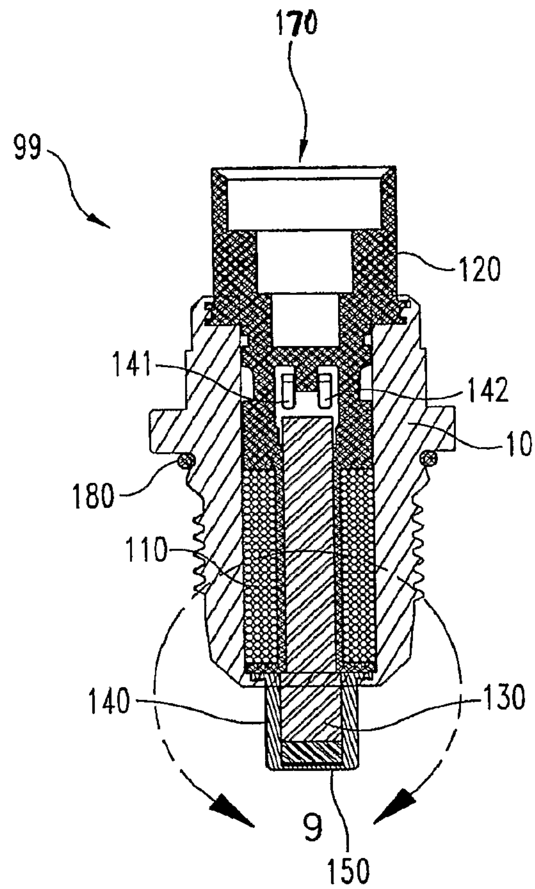


Fig. 8

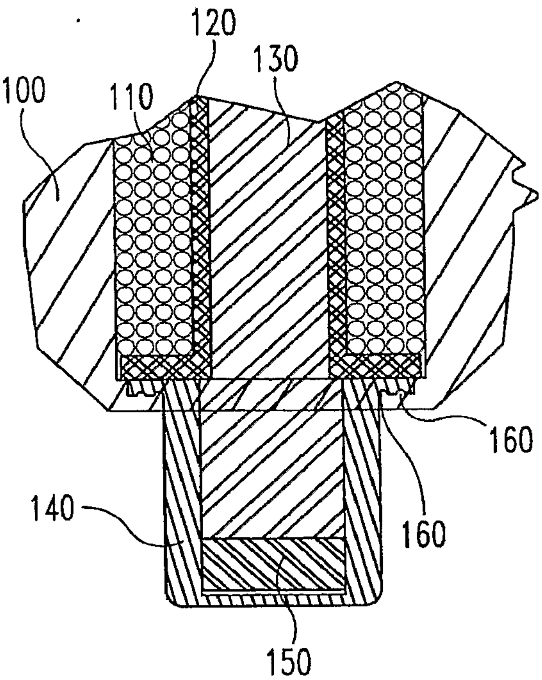


Fig. 9

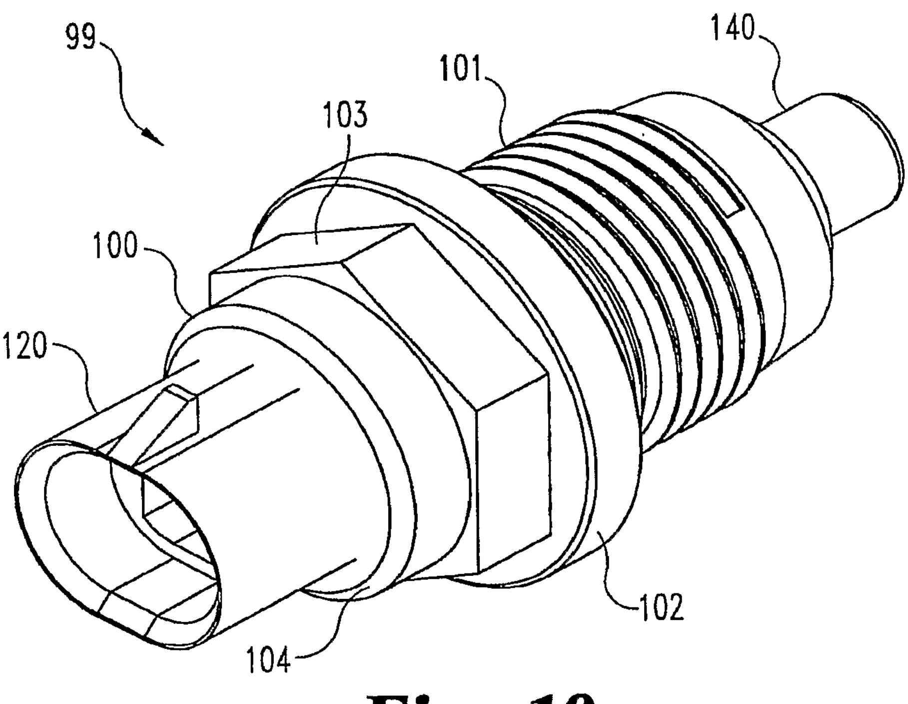


Fig. 10

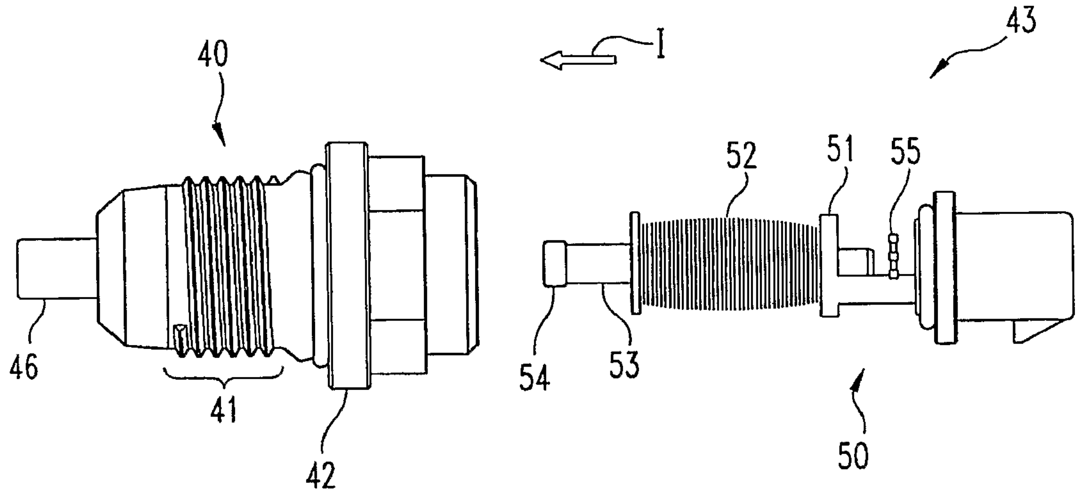


Fig. 11 (prior art)

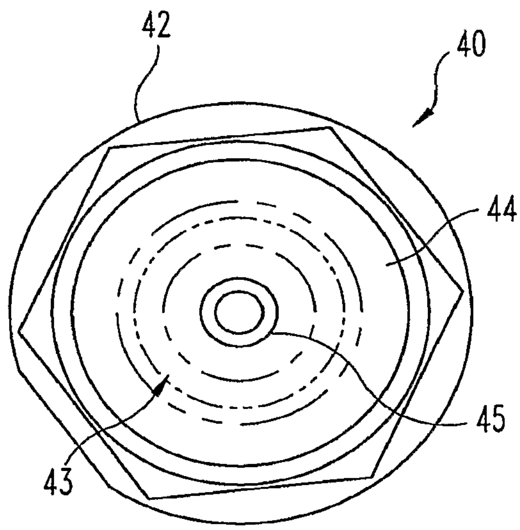


Fig. 12 (prior art)

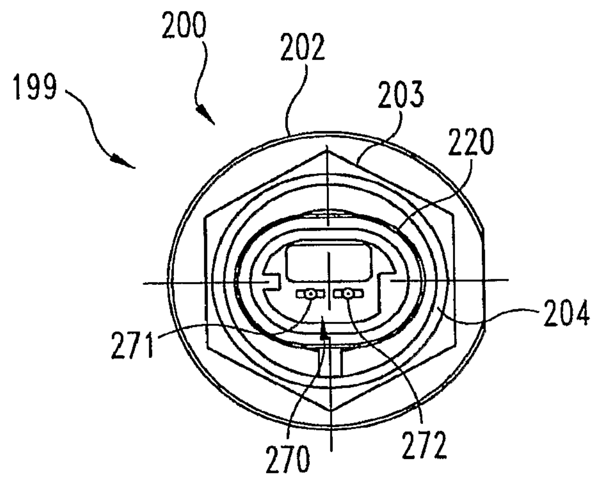


Fig. 13

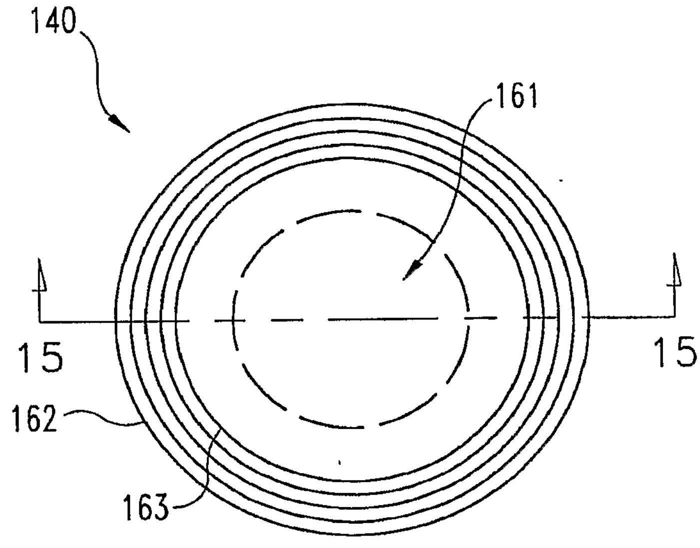


Fig. 14

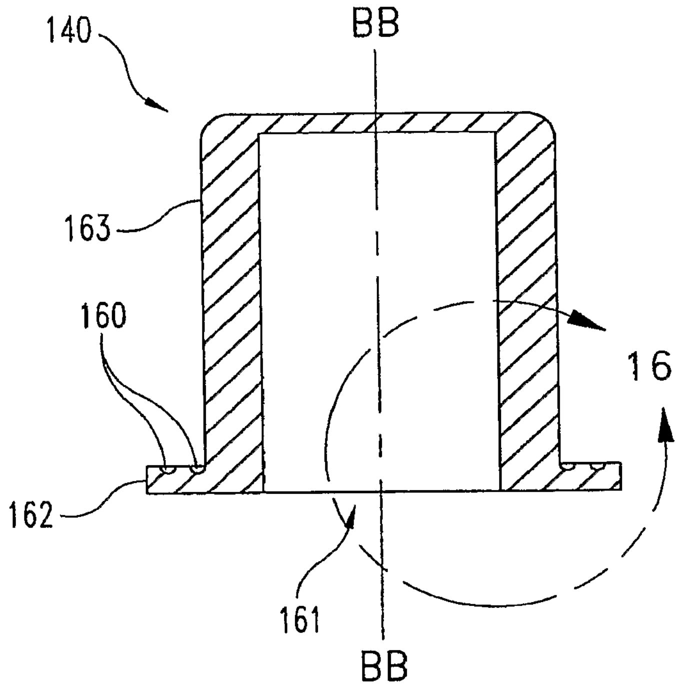


Fig. 15

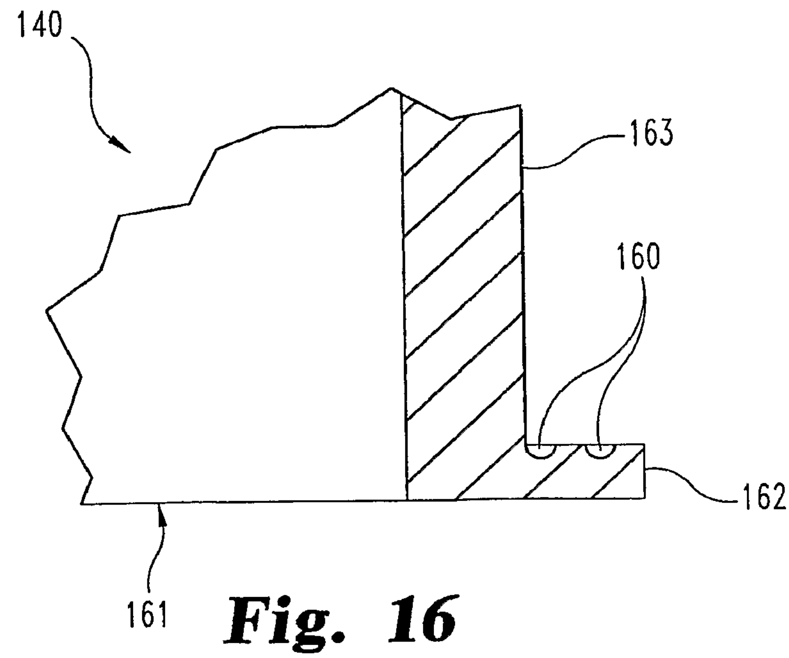


Fig. 16

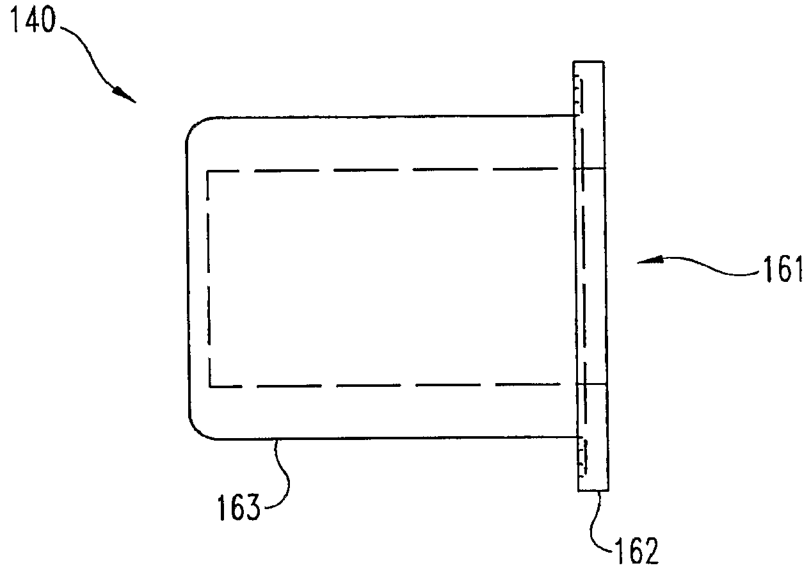


Fig. 17

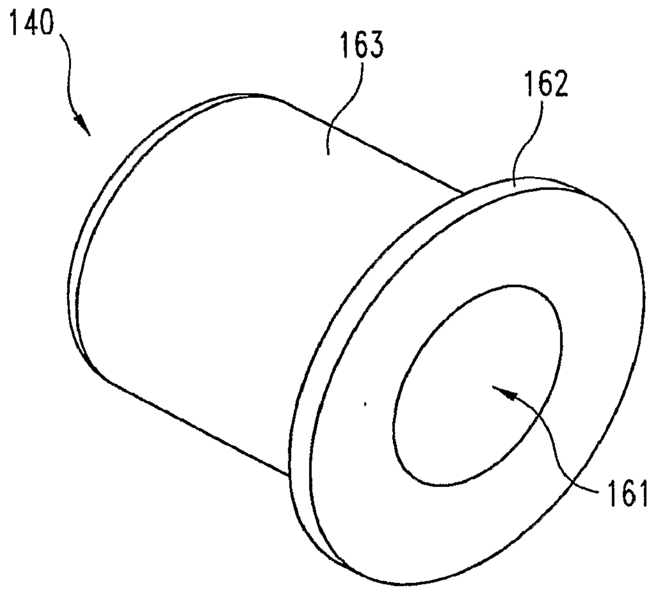


Fig. 18

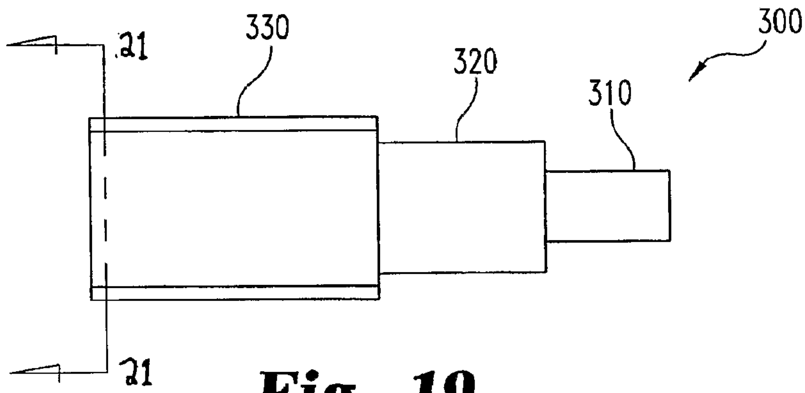


Fig. 19

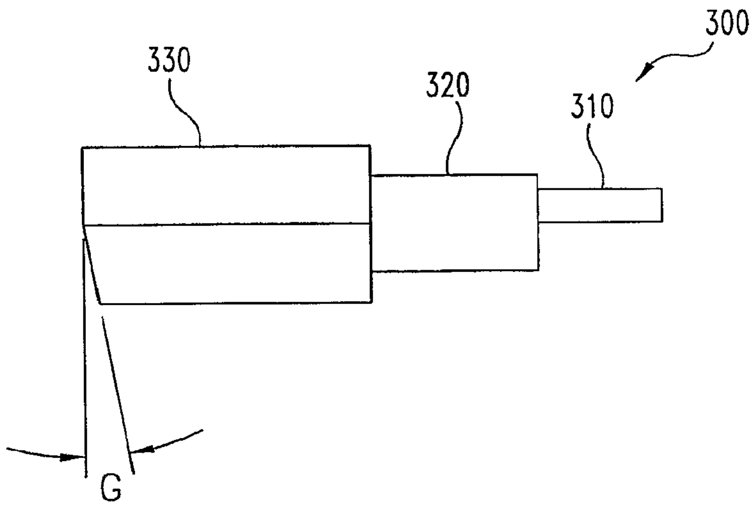


Fig. 20

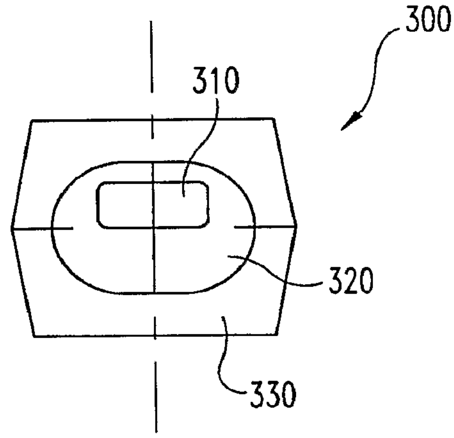


Fig. 21

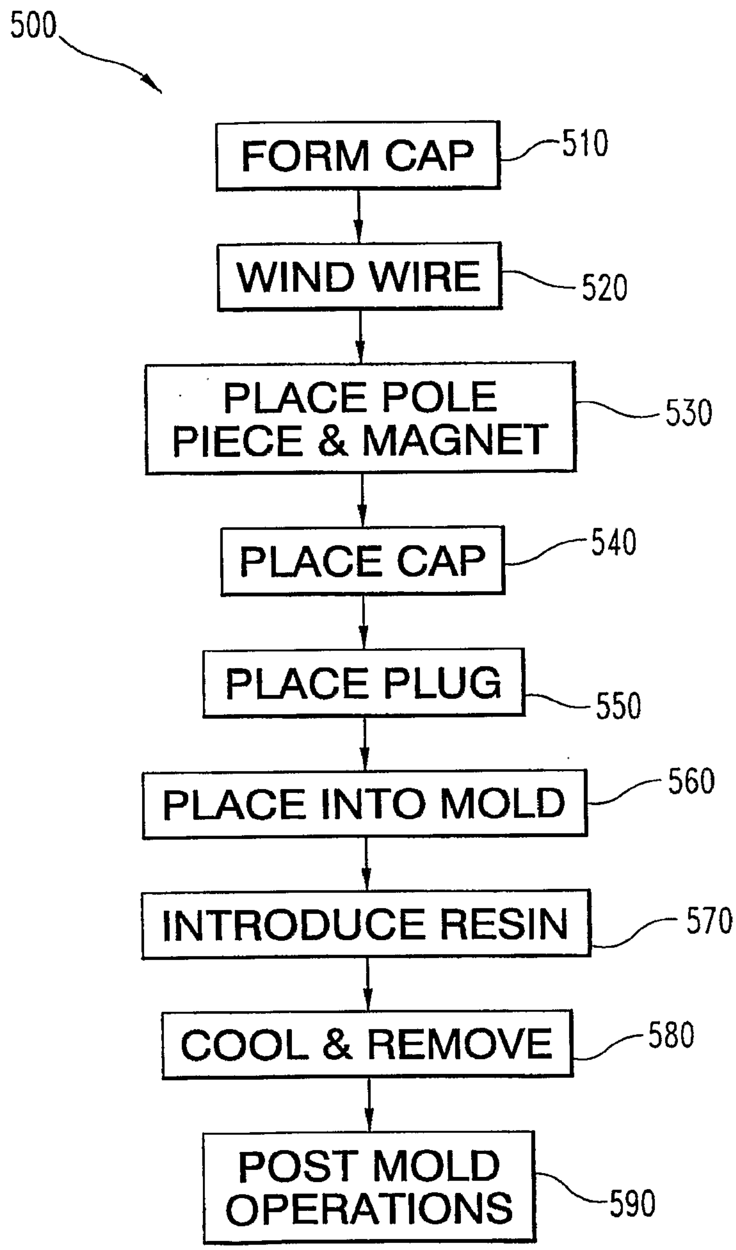
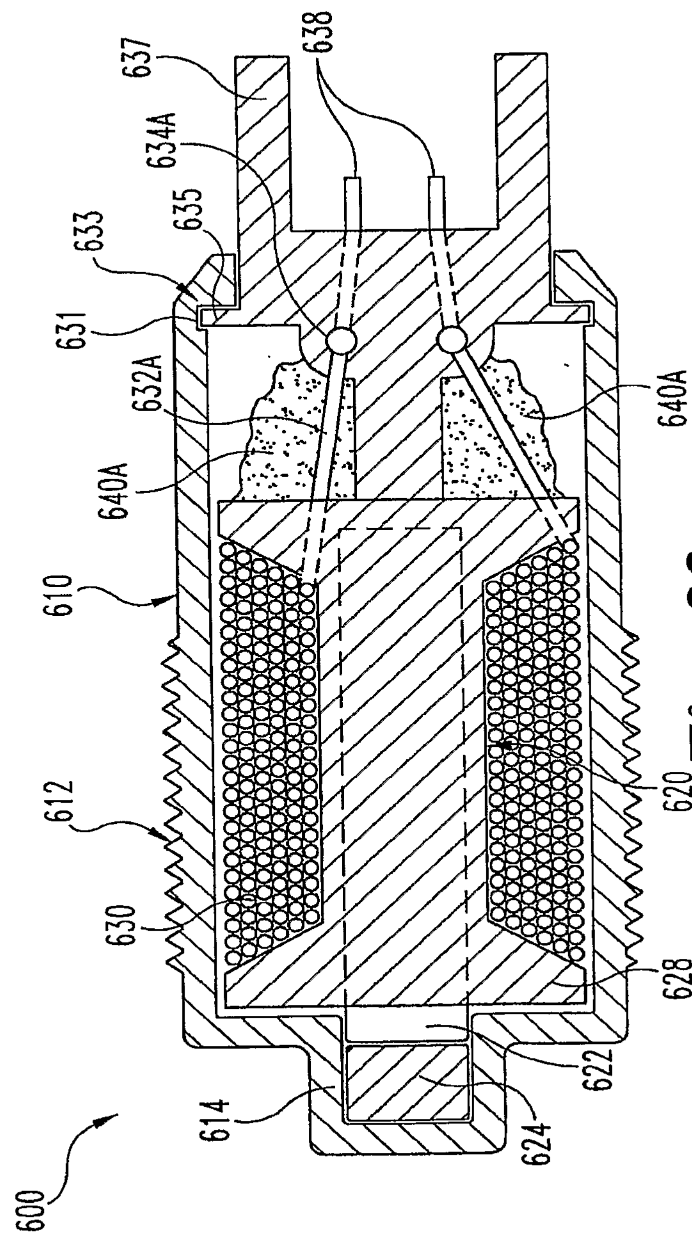

500
FORM CAP
510
WIND WIRE
520
PLACE POLE PIECE & MAGNET
530
PLACE CAP
540
PLACE PLUG
550
PLACE INTO MOLD
560
INTRODUCE RESIN
570
COOL & REMOVE
580
POST MOLD OPERATIONS
590

Fig. 22


638
637
634A
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633
631
632A
640A
640A
610
612
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628
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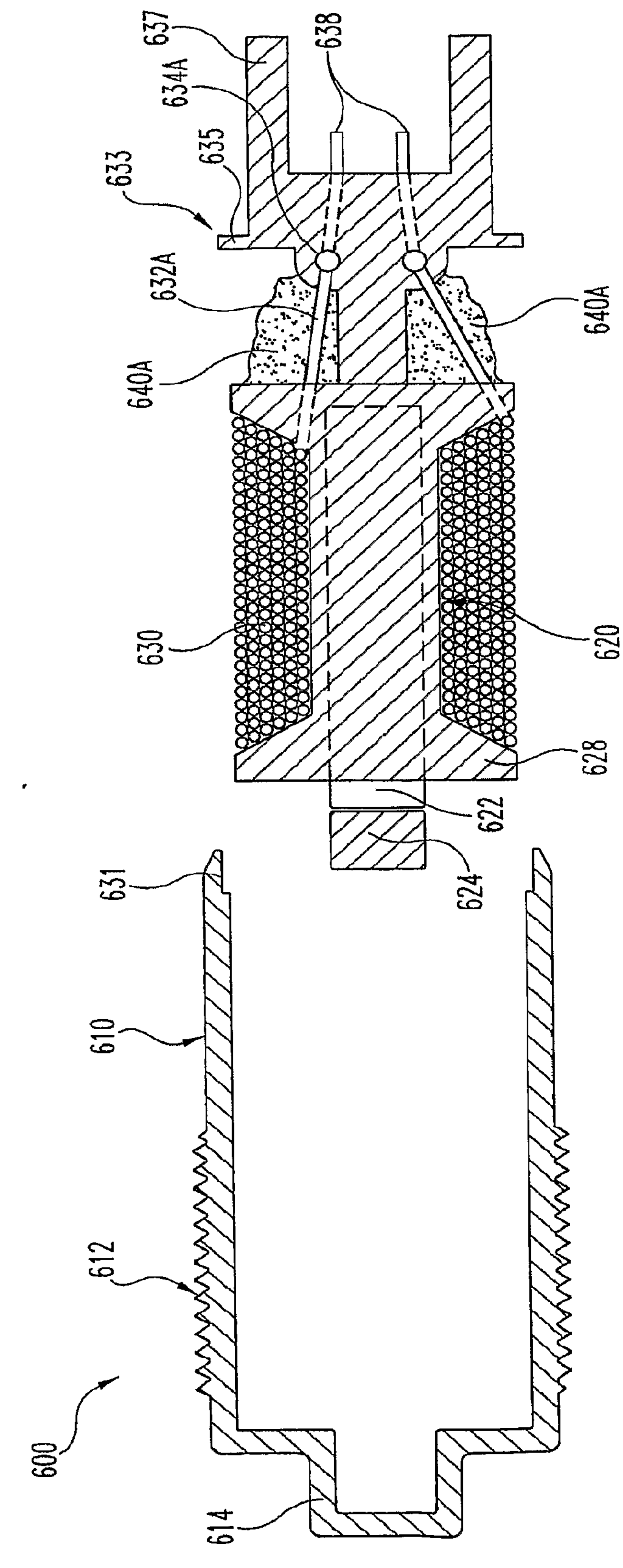
614
624
600

Fig. 23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600
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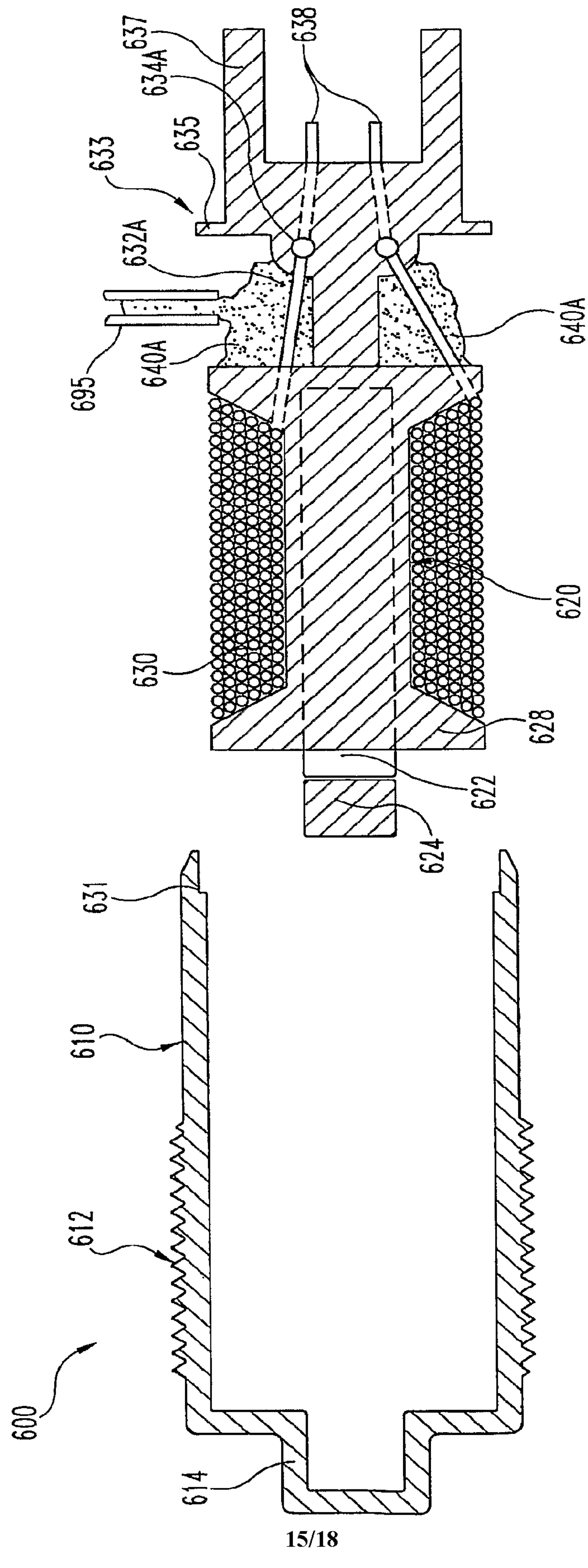
Fig. 24


637
638
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640A
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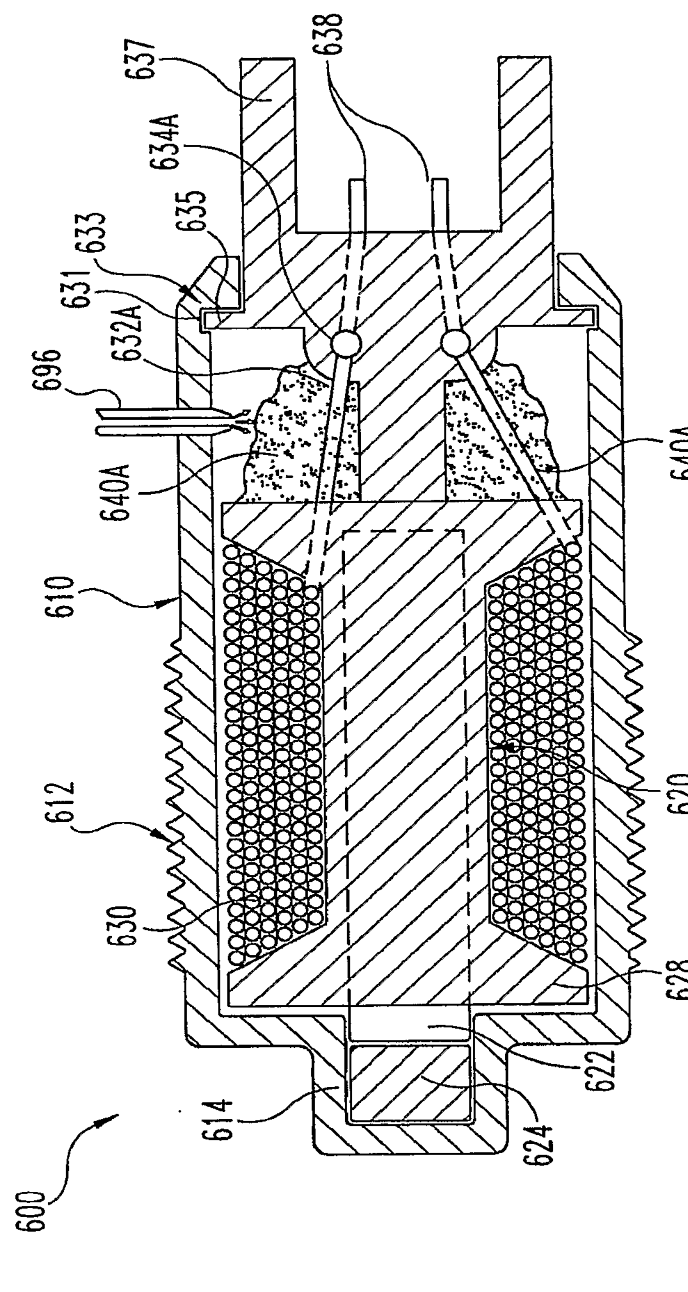
614

Fig. 25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634A
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632A
696
640A
640A
610
612
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622
624
614
600

Fig. 26

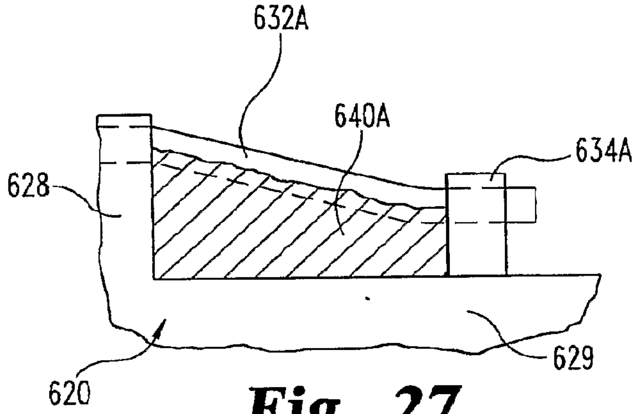

Fig. 27

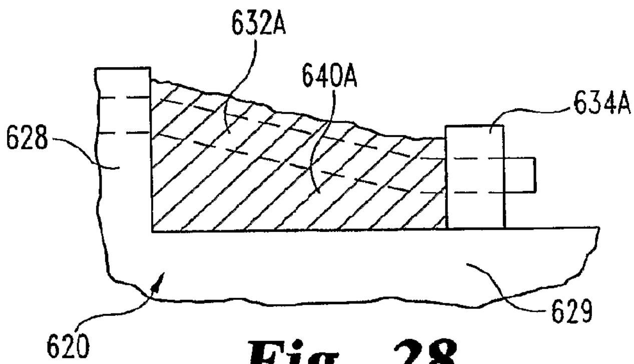

Fig. 28

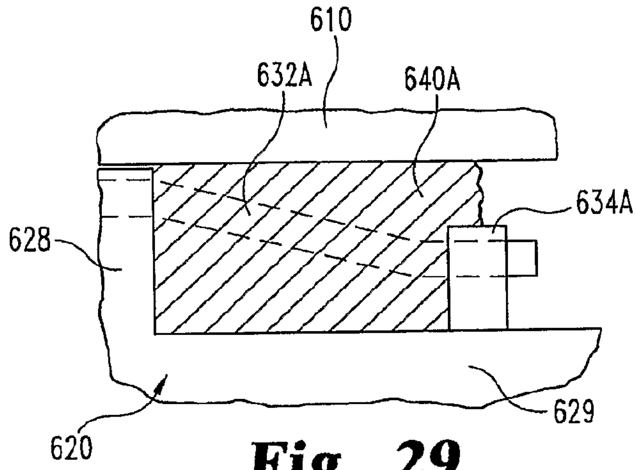

Fig. 29

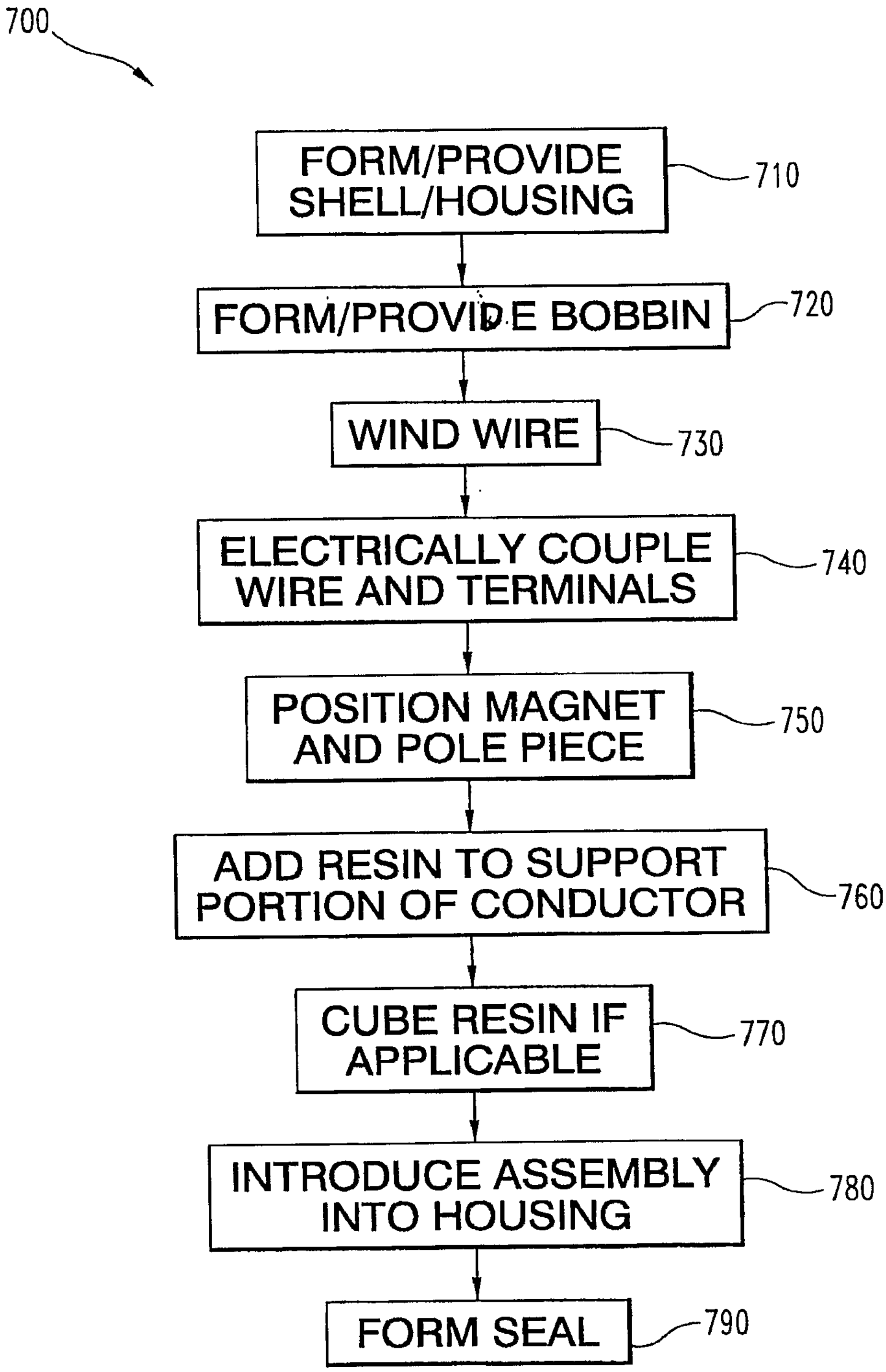
700
FORM/PROVIDE SHELL/HOUSING
710
FORM/PROVIDE BOBBIN
720
WIND WIRE
730
ELECTRICALLY COUPLE WIRE AND TERMINALS
740
POSITION MAGNET AND POLE PIECE
750
ADD RESIN TO SUPPORT PORTION OF CONDUCTOR
760
CUBE RESIN IF APPLICABLE
770
INTRODUCE ASSEMBLY INTO HOUSING
780
FORM SEAL
790

Fig. 30