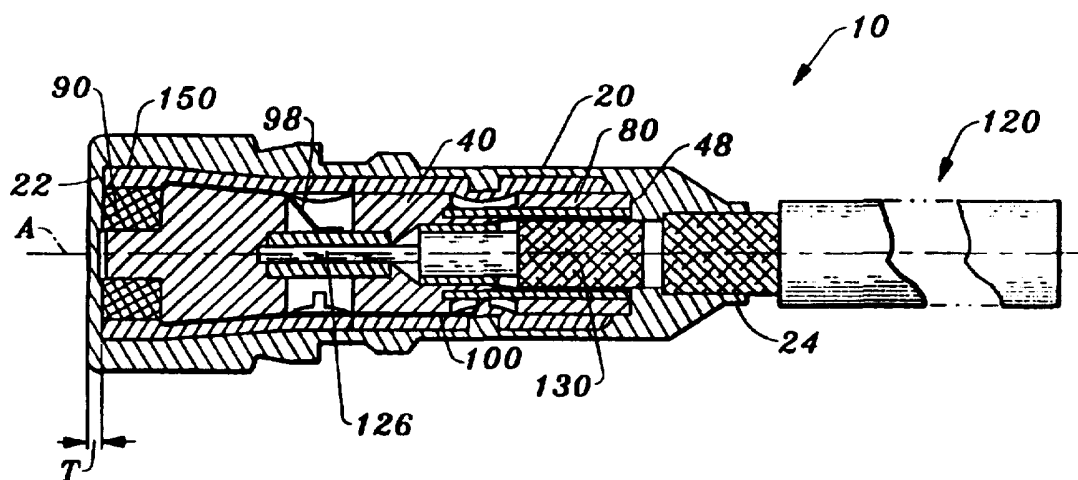




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(54) Title: ENCAPSULATED TRANSDUCER WITH SLEEVE AND COMPONENT ALIGNMENT**(57) Abstract**

An encapsulated transducer (10) includes an injection molded encapsulation (20) having front end (22) and back end (24). The encapsulation (20) is a monolith of cured moldable material ensconcing a sensing element or coil (90) proximate front end (22) and a portion of an information transmitting medium (120) emanating from back end (24). A component alignment preform (40) operatively couples sensing element (90) with information transmitting medium (120). A protective sleeve (150) is transfer molded over coil (90) and interlocked with preform (40) thereby forming a sleeved coil and cable assembly (170). This sleeved coil and cable assembly (170) is encapsulated by an injection molding process which provides the durable encapsulation (20) which bonds with itself and with sleeved coil and cable assembly (170). The sleeved coil and cable assembly (170) is symmetrically disposed within the encapsulation (20) and the encapsulation (20) includes an integrally formed protective wall having a uniform thickness "T" along a forwardmost portion of sensing element (90).

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--ENCAPSULATED TRANSDUCER WITH SLEEVE AND COMPONENT ALIGNMENT--

Method of Manufacture

Technical Field

The present invention relates generally to an encapsulated transducer with an integrally formed sleeve and a component alignment preform and, in particular, to an encapsulated transducer substantially impervious to adverse mechanical, physical or chemical aggressions from the surrounding environment and method of manufacturing such transducer which is used to monitor vibration of rotating machinery, temperature sensing and the monitoring and sensing of other physical phenomenon.

Background Art

Monitoring and diagnosing the status of rotating and reciprocating machinery start with accurate and dependable measurements from a transducer and its associated electronics and then proceed to other sophisticated analyzing apparatus for reduction and display. One such transducer is a proximity transducer which may be utilized for, *inter alia*, monitoring the vibration characteristics of a rotating shaft of a machine. In this environment, the transducer must operate under very adverse physical, chemical and mechanical conditions and it is often very difficult to replace such transducers. Thus, there is an ongoing effort to make the proximity transducer one of the most reliable parts of the monitoring system.

Typically, the proximity transducer, in conjunction with associated electronics, outputs a signal correlative to the spacing between an object or "target" (the rotating shaft of the machine) and a sensing coil of the proximity transducer. It is critical that the length or spacing between the target and the sensing coil of the proximity transducer remains within the linear range of the transducer for providing accurate and reliable measurements when in operation. Thus, the hallmark for providing accurate and reliable measurements relies on providing a transducer which is impervious to the predations of the environment and which does not consume an inordinate amount of the linear range of the transducer.

The following prior art reflects the state of the art of which applicant is aware and is included herewith to discharge applicant's acknowledged duty to disclose relevant prior art. It is stipulated, however, that none of these references teach singly nor render obvious when considered in any conceivable combination the nexus of the instant invention as disclosed in greater detail hereinafter and as particularly claimed.

U.S. PATENT DOCUMENTS

DOCUMENT NO.
2,361,348

DATE
October 24, 1944

NAME
Dickson et al.

2,890,505	June 16, 1959	Brand
3,932,828	January 13, 1976	Plunkett et al.
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4,470,786	September 11, 1984	Sano et al.
4,680,543	July 14, 1987	Kohen
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5,138,292	August 11, 1992	Forster
5,147,657	September 15, 1992	Giza
5,151,277	September 29, 1992	Bernardon, et al.
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5,226,221	July 13, 1993	Kilgore
5,240,397	August 31, 1993	Fay et al.
5,252,051	October 12, 1993	Miyamoto et al.
5,351,388	October 4, 1994	Van Den Berg, et al.
5,376,325	December 27, 1994	Ormson

FOREIGN PATENT DOCUMENTS

<u>DOCUMENT NO.</u>	<u>DATE</u>	<u>COUNTRY</u>
UK 1 313 748	April 18, 1973	Great Britain
UK 1 353 603	May 22, 1974	Great Britain
JA-139710	August 6, 1978	Japan
WO 84/03794	September 27, 1984	PCT
FR 2576-245-A	July 25, 1986	France
JA 6-37130-A	October 2, 1994	Japan

The two patents to Schutts and the patent to Van Den Berg, et al. reflect assignee's ongoing commitment to providing an accurate sensor which is impervious to predations of the environment.

The French patent to Jaeger teaches the use of a method and apparatus for injection molding of an elongated detector with a sensor at one end. One end of the detector is supported by the mold while the sensor end is engaged by a centering sleeve (130). The centering sleeve (130) terminates in a piston (132) which is mobile in a cylinder (126) and slides about a fixed rod (138). Thermoplastic is injected into the mold and the centering sleeve is removed from the sensor when the injection process is only partially complete.

The Japanese patent to Kawakami teaches the use of sealing a semiconductor chip by transfer molding. A semiconductor chip (4) is mounted on a carrier (1) and is held at a fixed position via mobile pins (17) and (18). The mobile pins (17) and (18) are movably fitted to a top force (11) and a bottom force (12) for freely advancing or retracting the pins into and out of the cavities (15) and (16). While the pins (17) and (18) are in contact with the carrier (1), a resin (20) is injected into the cavities (15) and (16) through gates (13) and (14) and the pins (17) and (18) are gradually retracted in accordance with the injecting state of resin (20).

The patent to Yokoyama teaches the use of an apparatus for manufacturing plastic encapsulated electronic semiconductor devices. A support pad (11) is firmly fixed by first and second sliders (24A) and (24B) and also by mold halves (19) and (20). The first and second sliders (24A) and (24B) are moved outwardly of a cavity (25) when the cavity is half filled with the plastic encapsulating material. Spaces, which are formed after movement of the sliders, are filled with the plastic encapsulating material directly poured through a gate (23). It should be noted that the sliders (24A), (24B) perform two functions in the cavity (25). The first function is to firmly grasp a thin end portion of the support pad (11) thereby fixing same in position and the second function is to narrow a passage through the gate (23).

The patent to Pierpont teaches the use of a method for encapsulating an electrical component having radial leads. A large multi-cavity mold is loaded with a plurality of horizontal radially leaded capacitors. The closed mold grips the leads (15). A top pin (25) pushes each component body downward a predetermined degree so that each body is left in about the same position within the corresponding mold cavity. A bottom pin (28) then pushes each component body upwardly only slightly above a center of the mold cavity so that upon bottom pin withdrawal, stresses within the lead wires of the electrical component cause the component bodies to spring back just to the mold cavity center portion. Molding resin is then introduced.

The other prior art listed above, but not specifically discussed, teach other sensor devices and molding processes and further catalog the prior art of which the applicant is aware. These references diverge even more starkly from the references specifically distinguished above.

Disclosure of Invention

The present invention is distinguished over the known prior art in a multiplicity of ways. For one thing, the present invention provides a transducer including a protective seamless encapsulation ensconcing a sensing element at one end and a cable extending out of the other end. In addition, the sensing element is symmetrically disposed about a long axis of the transducer and the seamless

encapsulation includes an integrally formed protective wall having an uniform thickness along a forwardmost portion of the sensing element.

Preferably, the sensing element is in the form of a sensing coil having a center void, a front face, a back face and at least a first lead and a second lead extending from the sensing coil and spaced from one another. The cable is preferably a triaxial cable comprised of an outer protective jacket circumscribing an interior of the cable which includes three concentrically disposed conductors separated from one another by at least two concentrically disposed insulators. Specifically, the outer protective jacket circumscribes the concentrically disposed triaxial, coaxial and center conductors which are in turn separated from one another by an insulator and a dielectric interposed between the triaxial and coaxial conductors and the coaxial and center conductors, respectively. At least one end of the cable is stripped in a step-like fashion to expose a length of the center conductor, the dielectric, the coaxial conductor, the insulator and the triaxial conductor.

In addition, the encapsulated transducer includes a front ferrule having a bore with an inner diameter substantially equal to the outer diameter of the center conductor and a rear ferrule having a bore with an inner diameter substantially equal to the outer diameter of the coaxial conductor.

A component alignment preform is molded in a single step. The component alignment preform includes an annular recess having a center post axially aligned with the front and rear ferrules which are bonded to the preform and linearly spaced apart along a long axis of the preform.

Once the preform has been molded, the sensing coil is placed over the center post and in the annular recess. The sensing coil is then electrically connected to the ferrules. This is accomplished by resistance welding the first lead of the sensing coil to the front ferrule and the second lead of the sensing coil to the rear ferrule.

Then, the stripped end of the cable is inserted into the bores of the molded together front and rear ferrules. The center conductor is mechanically and electrically connected to the front ferrule and the coaxial conductor is mechanically and electrically connected to the rear ferrule thereby forming a sensing coil and cable assembly. A protective sleeve is transfer molded over the sensing coil and interlocked with the preform, thus forming a sleeved coil and cable assembly. The transfer molded protective sleeve does not cover the front face of the coil.

Once the process of forming the sleeved coil and cable assembly is completed, the sleeved coil and cable assembly is ready to be encapsulated using an injection molding process. The injection mold is defined by an upper mold plate having an upper cavity and a lower mold plate having a lower cavity. The upper and lower cavities form a mold cavity when in the closed position which is complementary to the desired form of the encapsulation of the coil and cable assembly. The mold

cavity is defined by an upper wall, a lower wall, a front wall and a back wall having an opening extending therethrough. Preferably, the upper mold plate and the lower mold plate are each provided with at least one slideable support pin which extends into the respective upper or lower cavity of the mold and when retracted remain flush with the respective upper or lower wall of the mold cavity. In addition, a slideable locator pin is provided adjacent the front wall of the mold cavity and is capable of extending into and out of the lower cavity when the mold is in an opened position.

The sleeved coil and cable assembly is placed into the lower cavity of the lower mold plate such that the cable of the sleeved coil and cable assembly extends out the opening of the back wall of the mold cavity. At least one slideable support pin is extended into the lower cavity of the lower mold plate and is placed in engagement with a portion of the sleeved coil and cable assembly therein. This supports and centers the sleeved coil and cable assembly within the mold cavity. In addition, the slideable locator pin is extended into the mold cavity such that it properly locates the sensing coil within the mold cavity and helps space it a predetermined distance from the front wall of the mold cavity. Once the slideable locator pin and at least one slideable support pin has centered the coil and spaced it a predetermined distance from the front wall of the mold cavity, the locator pin is withdrawn and the injection mold is closed. At least one slideable support pin in the upper mold plate is extended into the upper cavity and comes into engagement with a portion of the sleeved coil and cable assembly when the injection mold is closed. This provides additional means for supporting and centering the assembly within the mold cavity such that there is a void completely surrounding the assembly (except of course where the pins are touching the assembly). Note that the location and the number of slideable support pins may be configured to best support the assembly being encapsulated within the cavity.

Once the mold is in the closed position a self-bonding moldable material is injected into the mold cavity via runners and gates. This process is continued until the mold cavity is completely filled and the coil and cable assembly is completely ensconced within the moldable material. The slideable support pins are then retracted flush with the respective upper and lower walls of the mold cavity prior to the moldable material solidifying. Note that an additional charge of moldable material may be injected into the mold as the support pins are being withdrawn so as to accommodate for any additional material needed to completely fill the voids left by the previously extended support pins. Once the process of injecting the moldable material into the cavity is completed and the support pins have been retracted, the mold may be opened and the encapsulated transducer allowed to cool in the lower mold plate. Once the encapsulated transducer is cooled one or more

bottom support pins may be actuated to eject the encapsulated transducer therefrom. Preferably the moldable material is polyphenylene sulfide (PPS) which has the characteristic of bonding to itself.

Industrial Applicability

The industrial applicability of this invention shall be demonstrated through discussion of the following objects of the invention.

It is a general object of the present invention to provide an improved transducer and a method of manufacturing such transducer.

A primary object of the present invention is to provide improved encapsulated transducers with an integrally formed sleeve and a component alignment preform and method of manufacturing same.

A further object of the present invention is to provide an encapsulated transducer as characterized above which has an injection molded seamless encapsulation ensconcing a sensing coil at one end and a cable extending out of the other end, one end of the cable being electrically connected to the sensing coil within the encapsulation and the other end connected to an electrical processing unit distal from said encapsulation.

Another further object of the present invention is to provide an encapsulated transducer as characterized above wherein the encapsulation provides a seamless sealing envelope around the sensing coil and an end portion of the cable, thus providing an impervious seal against any mechanical, physical or chemical aggressions from the surrounding medium.

Another further object of the present invention is to provide an encapsulated transducer as characterized above wherein the sleeved coil and cable assembly is centered within the encapsulation and wherein a distance between the front face of the sensing coil and a front face of the encapsulation is held to a very close tolerance which is reproducible from one transducer to another in mass production.

Another further object of the present invention is to provide an encapsulated transducer as characterized above which is comparatively less expensive to manufacture than existing transducers for use in monitoring and diagnosing the status of rotating and reciprocating machinery and which also lends itself to rapid mass production techniques.

Another further object of the present invention is to provide a preform which substantially axially aligns the sensing coil with the front and rear ferrules and the respective conductors of the cable.

Another further object of the present invention is to provide an integrally formed protective sleeve which interlocks with the preform and circumscribes the coil and its associated leads, thus forming a sleeved coil and cable assembly.

Another further object of the present invention is to provide an encapsulated transducer as characterized above wherein the encapsulation strongly bonds to the sleeved coil and cable assembly for providing a leak tight seal and resisting axial forces applied to the encapsulation or cable which may cause the electrical connections to completely or partially break resulting in an inoperative or unreliable transducer.

Another further object of the present invention is to provide an encapsulated transducer as characterized above which is capable of being mass produced with reproducible operational characteristics without appreciable alterations of the signals they admit when in operation.

Another further object of the present invention is to maintain a predetermined linear range capability for each manufactured transducer.

Another further object of the present invention is to provide a slideable locator pin which centers the coil within the mold cavity and spaces the front face of the coil from the front wall of the mold cavity prior to the injection molding process.

Another further object of the present invention is to provide a plurality of slideable support pins for supporting and centering the sleeved coil and cable assembly during the injection molding process and for rigidly maintaining the spacing of the front face of the coil from the front wall of the mold cavity.

Viewed from a first vantage point it is an object of the present invention to provide an information transmitting sensor and housing comprising: a sensing element; a cable coupled to the sensing element; a monolith of cured moldable material ensconcing both the sensing element and a portion of the cable to define a seamless mass circumscribing the sensing element up to the cable.

Viewed from a second vantage point it is an object of the present invention to provide an encapsulated transducer for use in monitoring the status of rotating equipment in a harsh environment with a component alignment preform having a leading end with an active element and a trailing end with an information transmitting medium emanating therefrom, formed by: molding a protective sleeve over said active element and a portion of said component alignment preform; integrally forming a locating means proximate the active element; locating the active element in a mold cavity with the locating means coupled thereto, assuring proper registry in the mold cavity; integrally forming a supporting means proximate the component alignment preform; further supporting and locating the active element and the component alignment preform in the mold cavity with the support means and removing the locator means; molding over the active element, the protective sleeve, the preform and a portion of the information transmitting medium with a moldable material except for an area of support; removing the

support means; injecting moldable material adjacent the support means for filling in the areas heretofore occupied by the support means, whereby said active element is precisely located in a moldable material to accurately address the rotating equipment.

Viewed from a third vantage point it is an object of the present invention to provide a transducer for monitoring the status of rotating equipment wherein a shaft of the rotating equipment is exposed to the transducer, comprising, in combination: means for mounting the transducer a distance from the shaft such that a tangent of the shaft is perpendicular to a long axis of the transducer, the transducer having a sensing coil located proximate the shaft, a front portion of the transducer including a protective wall having uniform thickness along a forwardmost portion of the sensing coil, the sensing coil symmetrically disposed about the long axis, and a protective seamless encapsulation including a full length sleeve integrally formed with the protective front wall ensconcing the sensing coil and a leading portion of a cable operatively coupled to the sensing coil, the cable extending away from the transducer to an electrical processing unit.

Viewed from a fourth vantage point it is an object of the present invention to provide a process for making a transducer, comprising the steps of: providing a sensing coil having a center void, a front face, a rear face and at least a first lead and a second lead extending from the sensing coil; providing a cable having at least one outer conductor surrounding at least one insulator carrying at least one center conductor; stripping an end of the cable in a step-like fashion to expose a portion of the center conductor, the insulator and the outer conductor; forming a front and rear pair of ferrules with the front ferrule having a bore with a diameter substantially matching the diameter of the center conductor and the rear ferrule having a bore with a diameter substantially matching the diameter of the outer conductor; molding together in linearly spaced proximity with a self-bonding moldable material the front and rear ferrules and providing in such molding step an annular recess near the front ferrule and linearly aligned therewith and a chamber interposed between and in open communication with the front and rear ferrules, thereby forming a component alignment preform; inserting the coil in the annular recess and electrically connecting the first lead to the front ferrule and the second lead to the rear ferrule; inserting the stripped cable end into the bores of the molded together front and rear ferrules and mechanically and electrically connecting the outer conductor to the rear ferrule and the center conductor to the front ferrule, thereby forming a sensing coil and cable assembly; molding a sleeve over the sensing coil and a portion of said component alignment preform thereby forming a sleeved coil and cable assembly; supporting and centering the sleeved coil and cable assembly within a mold cavity with at least one slideable support;

orienting the cable to extend out from the mold cavity; locating the sensing coil within the mold cavity and spacing the front face of the sensing coil a distance from a front wall of the mold cavity with at least one slideable locator and at least one slideable support; retracting the slideable locator from the mold cavity; injecting the self-bonding moldable material into the cavity of the mold to precisely ensconce the sleeved coil and cable assembly and providing a precise face thickness covering the face of the coil; retracting the slideable supports from the sleeved coil and cable assembly so that the self-bonding moldable material will flow into the areas heretofore occupied by the slideable supports; allowing the moldable material to set; and removing the thus formed transducer from the mold cavity as an integrated unit having a seamless mass of moldable material ensconcing the sleeved coil and cable assembly.

These and other objects will be made manifest when considering the following detailed specification when taken in conjunction with the appended drawing figures.

Brief Description of Drawings

Figure 1 is an elevational view of an encapsulated transducer with an integrally formed sleeve and a component alignment preform according to the present invention which is juxtaposed to a rotating shaft of a machine for monitoring the vibration thereof.

Figure 2 is a partial sectional view of the encapsulated transducer with the integrally formed sleeve and component alignment preform according to the present invention.

Figure 3 is a cross-sectional exploded parts view of the component alignment preform.

Figure 4 is a cross-sectional view of a sensing coil and the component alignment preform formed by the combination of the elements of figure 3.

Figure 5 is a cross-sectional view of the combination of the elements of figure 4.

Figure 6 is a diagrammatic view of an assembly step of the present invention and a cross-sectional view of the combination of the elements of figure 4.

Figure 7 is a partial sectional view of the combination of the elements of figure 6 forming a coil and cable assembly.

Figure 8 is a partial sectional view of a sleeve integrally formed with the coil and cable assembly shown in figure 7.

Figure 9 is a simplified cross-sectional view of a mold in an open position and having all included slideable support and locator pins in an extended position.

Figure 10 is a view of the mold of figure 9 with the slideable support pins centering and supporting that which is shown in figure 8.

Figure 11 is a simplified cross-sectional view of the mold in a closed position with the slideable locator pin retracted from engagement of the sensing coil.

Figure 12 is a simplified cross-sectional view of the mold in a closed position with the slideable support pins retracted after an injection molding according to the present invention is completed.

Figure 13 is an elevational view of an injection mold used to mass produce a plurality of encapsulated transducers sequentially.

Best Mode(s) For Carrying Out The Invention

Considering the drawings, wherein like reference numerals denote like parts throughout the various drawing figures, reference numeral 10 is directed to the encapsulated transducer with a component alignment preform according to the present invention.

In essence, and referring to figures 2 and 6, the encapsulated transducer 10 includes an injection molded encapsulation 20 having a front end 22 and a back end 24. The encapsulation 20 is a monolith of cured moldable material ensconcing a sensing element 90 proximate the front end 22 and a portion of an information transmitting medium 120 emanating from the back end 24. A component alignment preform 40 operatively couples the sensing element 90 with the information transmitting medium or cable 120. The component alignment preform 40 includes a front ferrule 70 and a rear ferrule 80 bonded thereto and linearly spaced apart along a long axis "A". The component alignment preform 40 further includes an annular recess 44 (figure 3) in which the sensing element or coil 90 is placed so that it is linearly spaced and aligned along the common long axis "A" in which the front and rear ferrules 70, 80 are aligned. A first lead 98 (figures 4 and 5) of the coil is electrically connected to the front ferrule 70 and a second lead 100 of the coil 90 is electrically connected to the rear ferrule 80. A back end 48 of the component alignment preform 40 receives a stripped end 122 (figure 6) of the cable 120 such that a center conductor 126 mates with the front ferrule 70 and a coaxial conductor 130 mates with the rear ferrule 80. The respective conductors 126, 130 are electrically and mechanically connected to the pair of front and rear ferrules 70, 80. A protective "full length" sleeve 150 (figure 2) is transfer molded over the coil 90 and interlocked with the preform 40 thereby forming a sleeved coil and cable assembly 170 (figure 8). This sleeved coil and cable assembly 170 is encapsulated by an injection molding process which provides the durable encapsulation 20 (figure 2) which bonds with itself and with the sleeved coil and cable assembly 170. The sleeved coil and cable assembly 170 is symmetrically disposed within the encapsulation 20 and the encapsulation 20 includes an integrally formed protective wall having a uniform thickness "T" along a forwardmost portion of the sensing element 90.

More specifically, and referring to figures 3 and 4, the component alignment preform 40 is formed in a first injection molding process where the moldable material is preferably polyphenylene sulfide (PPS). The PPS material is a dielectric and thus an electrical insulating material which has the characteristic of bonding to itself. The front and rear ferrules 70, 80 are preferably placed on a pin support within a mold and the PPS material is molded around the front and rear ferrules 70, 80 thereby forming the component alignment preform 40 as shown in figure 4. The

front and rear ferrules 70, 80 are inner-locked and linearly spaced apart along the long axis "A" by the PPS material. A front end 42 of the preform 40 includes an annular recess 44 having a center post 46 axially aligned with the front and rear ferrules 70, 80. The preform 40 further comprises a chamber 50 including a bridging section 54 of constant cross-sectional area traversing between a front and a rear truncated cone 52, 56 which isolate the front and rear ferrules 70, 80. The front ferrule 70 includes a bore 76 with an inner diameter substantially equal to the outer diameter of the center conductor 126. The rear ferrule 80 includes a bore 86 with an inner diameter substantially equal to the outer diameter of the coaxial conductor 130. The ferrules 70, 80 are preferably formed from brass.

Referring to figures 4 and 5, the sensing element 90 is preferably a sensing coil 90 comprised of a center void 92, a front face 94, a back face 96, a body 102 and first and second leads 98, 100 extending from the coil 90 and spaced from one another. Once the component alignment preform 40 has been formed, the sensing coil 90 may be electrically connected to the respective ferrules 70, 80 of the preform 40. This is accomplished by placing the sensing coil 90 within the annular recess 44 of the preform such that the post 46 extends a distance within the center void 92 of the coil 90. The first lead 98 is then preferably induction welded to the front ferrule 70 and the second lead 100 is preferably induction welded to the rear ferrule 80, thus forming a coil and preform assembly 110. Next, the cable 120 is electrically and mechanically connected within the preform 40.

Referring to figures 6 through 8, the cable 120 is preferably a triaxial cable comprised of an outer jacket 136 circumscribing an interior of the cable which includes three concentrically disposed conductors 126, 130 and 134 separated from one another by at least two concentrically disposed dielectrics or insulators 128, 132. More specifically, the outer protective jacket 136 circumscribes the concentrically disposed triaxial, coaxial and center conductors 134, 130 and 126 which are separated from one another by an insulator 132 and a dielectric 128 interposed between the triaxial and coaxial conductors 134, 130 and the coaxial and center conductors 130, 126, respectively. At least one end 122 of the cable 120 is stripped in a step-like fashion to expose a length of the center conductor 126, the dielectric 128, the coaxial or outer conductor 130, the insulator 132 and the triaxial conductor 134.

Referring to figure 6, solder paste 140 is inserted into the bore 76 of the front ferrule 70 preferably, via a syringe which is pneumatically driven so as to dispense an uniform predetermined amount of paste 140 which is reproducible every time. A solder ring 142 is placed onto the stripped end 122 of the cable 120. The solder ring 142 encircles the coaxial conductor 130 and abuts the insulator 132 which is interposed between the coaxial and triaxial conductors 130, 134. An elastomeric sleeve 144 is placed over the dielectric 128 of the cable 120 and includes an inner

diameter which substantially matches the outer diameter of the dielectric 128. The elastomeric sleeve 144 may be of an insulating material such as fluorosilicone rubber. The elastomeric sleeve 144 has an outer diameter which is slightly larger than the bridging section 54. The cable 120 is then inserted into the back end 48 of the component alignment preform 40 such that the center conductor 126 fits within the bore 76 of the front ferrule 70 and the coaxial conductor fits within the bore 86 of the rear ferrule 80. An axial force exerted as shown by the arrows F_1 and F_2 , deform the elastomeric sleeve 144 against the conical transition between the bridging section 54 and the rear truncated cone 56. This provides a tight seal between this transition area and the dielectric 128 of the cable 120 as shown in figure 7. A permanent mechanical and electrical connection is made between the coaxial conductor 130 and the bore 86 of the rear ferrule 80 and also between the center conductor 126 and the bore 76 of the front ferrule 70. Use of inductive heating with the above forces F_1 , F_2 being applied, the solder paste 140 and solder ring 142 melt and flow over the exposed conductors 126, 130 affixing them permanently throughout their length to the bores 76, 86 of the front ferrule 70 and the rear ferrule 80 respectively. Of course, rather than solder, an adhesive or welding may be used. Note that the preformed amount of solder paste 140 and the preformed solder ring 142 provide effective repeatability of the electromagnetic characteristics of the entire encapsulated transducer 10, especially with respect to the inductance parameter of the sensing coil 90 which as illustrated is relatively close to the center conductor 126.

Referring to figures 7 and 8, the protective sleeve 150 is transfer molded over the coil 90 and its associated leads 98, 100 and interlocked with the preform 40. This is accomplished by preferably placing the coil and cable assembly 112 into a transfer mold such that the front face 94 of the coil 90 abuts a wall of the mold so as not to allow transfer moldable material to cover the front face 94 of the coil 90. The transfer moldable material is gently emitted into the transfer mold at a force which allows the material to flow over the coil 90 and its associated leads 98, 100 without deforming or destroying the coil 90, the leads 98, 100 or the connection between the respective leads 98, 100 and the front and rear ferrules 70, 80. Thus, by transfer molding the protective sleeve 150 without deforming or destroying the coil 90 mechanically, the original electrical characteristics which the coil and cable assembly 112 had prior to integrally forming the protective sleeve 150 therewith are retained.

The transfer molded protective sleeve 150 includes a first end 152 which is molded flush with the front face 94 of the coil 90 and a second end 154 preferably terminating proximate the back end 48 of the preform 40. A body 156 of the sleeve 150 traverses from the first end 152 to the second end 154. The body 156 takes on the contour of both the preform 40 and the body 102 of the coil 90 thereby eliminating

any gaps between the protective sleeve 150 and both the preform 40 and the body 102 of the coil 90. Furthermore, the transfer molded sleeve 150 fills in the front and the rear passages 58, 60 of the preform 40. By filling in the front and rear passages 58, 60 the sleeve ensconces the leads 90, 100 of the coil 90 which drops down the respective passages 58, 60 and connects with the respective front and rear ferrules 70, 80. As a result of the protective sleeve filling in the gaps and passages 58, 59, 60, 61 of the preform 40, the protective sleeve mechanically locks into the coil and cable assembly 112 thus becoming an integral part thereof. Preferably, the protective sleeve 150 preferably includes a peripheral groove having an upper groove portion 158 opposed from a lower groove portion 160. The two grooves 158, 160 are integrally formed in the body 156 of the sleeve 150 at a precise distance "L" from the front face 94 of the coil 90. When manufacturing a plurality of transducers 10 this distance "L" is accurately reproducible from one transducer to the next as a result of the transfer molded protective sleeve 150 being able to accommodate for any fluctuation in the size of each coil 90 and preform 40. The grooves 158, 160 are used in the injection molding process to accurately control the face thickness "T" of the encapsulation 20. Once the sleeved coil and cable assembly 170 (figure 8) is formed, it is ready to be encapsulated.

Referring to figures 9 and 11, an injection mold 180 is defined by an upper mold plate 182 having an upper cavity 184 and a lower mold plate 186 having a lower cavity 188 forming a single mold cavity 190 when in the closed position. The mold cavity 190 is shaped complementary to the desired form of the encapsulation 20 ensconcing the sleeved coil and cable assembly 170. The mold cavity 190 is defined by an upper wall 192, a lower wall 194, a front wall 196 and a back wall 198 having an opening 200 extending therethrough.

The upper mold plate 182 is preferably provided with a pair of sleeves 212a, 212b through which a pair of slideable support pins 210a, 210b may be moved into or out of the upper cavity 184 by corresponding drive means 230a, 230b. The lower mold plate 186 is preferably provided with a pair of sleeves 212c, 212d through which a pair of slideable support pins 210c, 210d may be moved into or out of the lower cavity 188 by corresponding drive means 230c and 230d. In addition, the injection mold 180 is provided with a slideable locator pin 220 which is preferably disposed on the lower mold plate 186 at a location adjacent the front wall 196 of the mold cavity 190. The slideable locator pin 220 preferably includes a pair of concentrically disposed slideable pins 222, 224 in which an inner pin 222 slides within an outer pin 224 which in turn slides within a sleeve 226. Both the inner pin 222 and the outer pin 224 may be moved by an associated drive means 230e such that they are capable of extending into or out of the lower cavity 188 when the mold

180 is in the opened position. Preferably, the inner pin 222 is capable of extending further into the lower cavity 188 than the outer pin 224.

Alternatively, the slideable locator pin 220 may be an integrally formed T-shaped pin having a top branch resembling the outer pin 224 and a base branch resembling the inner pin 222 in an extended and rigidly fixed position with respect to the top branch.

The slideable support pins 210a - 210d and the slideable locator pin 220 are each preferably provided with separate drive means, 230a - 230e respectively and may be independently controlled by a programmable logic controller (PLC) 250 or the like.

Each drive means 230a - 230e includes a valve and solenoid unit 232a - 232e, a pneumatic cylinder 234a - 234e and an ejector plate 236a - 236e. Each ejector plate 236a - 236d is connected to each respective support pin 210a - 210d and ejector plate 236e is connected to locator pin 220. Each ejector plate 236a - 236e is received within the corresponding pneumatic cylinder 234a - 234e which in turn is connected to the corresponding valve and solenoid unit 232a - 232e. Each valve and solenoid unit 232a - 232e is electrically connected to the PLC 250 and mechanically connected to a gas source 260. The PLC 250 independently sends out an electrical signal to each solenoid of each valve and solenoid unit 232a - 232e. Each solenoid receives the signal and physically opens and closes the corresponding valve. This allows gas to be sent to each respective pneumatic cylinder 234a - 234e and depending on the location of each ejector plate 236a - 236e will cause each support pin 210a - 210d and locator pin 220 to extend into or retract out of the mold cavity 190. The ejector plate 236e may be coupled to the inner pin 222 such that the inner pin 222 extends or retracts a short distance and then catches the outer pin 224 and causes it to correspondingly extend or retract.

When the injection mold 180 is in the closed position only the support pins 210a - 210d are used to support and symmetrically locate the sleeved coil and cable assembly 170 within the mold cavity 190 (figure 11). However, the retracted locator pin may form the front wall 196 of the mold cavity 190. The support pins 210b and 210c are received in the respective upper and lower grooves 158, 160 of the protective sleeve 150. This rigidly maintains the precise spacing of the front face of the sensing coil 90 from the front wall 196 of the mold cavity 190. Depending upon the specific assembly 170 configuration and the way molten moldable material is filling around the assembly 170, one of the support pins may be retracted sooner than another. Retracting the support pins is sequenced with the timing in the PLC 250 and may be calibrated until all of the support pins 210a - 210d retract in a manner which allows the assembly 170 to remain centered both radially and axially within the mold cavity 190 and allows a constant spacing between the front wall 196

of the mold cavity 190 and the front face 94 of the coil 90. Note that if the retraction of the support pins 210a - 210d is not sequenced correctly the assembly 170 may shift to one side or the other in the mold cavity 190. This may cause an alteration of the electrical characteristics of the encapsulated transducer 10.

Referring to figure 10, the sleeved coil and cable assembly 170 is radially and axially centered by way of the extended support pins 210c, 210d and an extended locator pin 220. The locator pin 220 centers the coil 90 and helps space it a predetermined distance from the front wall 196 of the mold cavity 190 by way of the inner pin 222 being partially received within the void 92 of the coil 90 and the outer pin 224 abutting against a front face 94 of the coil 90. In addition, support pin 210c is extended into the lower cavity 188 and is received in the lower groove 160 of the preform 40 for spacing the front face 94 of the sensing coil 90 a precise distance from the front wall 196 of the mold cavity and for providing support thereto. Support pin 210d also extends into the lower cavity 188 and is placed in engagement with the protective sleeve 150 thus providing support thereto. Once the sleeved coil and cable assembly 170 has been symmetrically centered within the lower cavity 188, the locator pin 220 is withdrawn and the mold cavity 190 is placed in a closed position (figure 11).

At this time, the slideable support pin 210b is received in the upper groove 158 of the preform 40 and works in combination with support pin 210c for rigidly maintaining the precise spacing of the front face 94 of the sensing coil 90 from the front wall 196 of the mold cavity 190. This allows the encapsulated traducers 10 to include an integrally formed protective wall having an uniform thickness "T" (figure 2) and thus, a predetermined linear range. This is particularly important when manufacturing a plurality of encapsulated transducers 10 which are suppose to have the same electrical characteristics. Furthermore, once the mold 180 is closed the cable 120 extends out of the opening 200 in the back wall 198 of the mold cavity 190. The engagement of the upper mold plate 182 and the lower mold plate 186 provides additional support by having the cable 120 cantilevered therebetween. Support pin 210a extends into the upper cavity 184 from the upper mold plate 182 and comes into engagement with the preform 40 of the cable 170 thereby providing further top support to the sleeved coil and cable assembly 170. A void completely surrounds the sleeved coil and cable assembly 170 except of course where the pins 210a - 210d are abutting the assembly 170. An alternative embodiment to figure 11 may use fewer or more support pins 210a - 210d for centering and supporting the sleeved coil and cable assembly 170 in the mold cavity 190.

The moldable material is injected into the mold cavity via runners 240 and gates 242 provided in the lower mold plate 182 and/or the upper mold plate 186. Preferably, one gate is located adjacent each slideable support pin 210a - 210d. The

moldable material is preferably polyphenylene sulfide (PPS) which has the characteristic of bonding to itself. The injection of the moldable material is continued until the mold cavity 190 is completely filled. Once the mold cavity 190 is filled, the support pins 210a - 210d are retracted such that the sleeved coil and cable assembly 170 remains centered within the mold cavity 190. Note that an additional charge of moldable material may be introduced into the mold cavity 190 simultaneously with the retractions of the support pins 210a - 210d such that the sleeved coil and cable assembly 170 is completely ensconced within the moldable material and all voids have been filled.

Referring to figure 12, once the process of injecting the moldable material into the mold cavity 190 is completed and the support pins 210a - 210d have been retracted, the mold 180 may be opened and the encapsulated transducer 10 allowed to cool in the lower mold plate 186. Once the encapsulated transducer is cooled one or more of the bottom support pins, 210c, 210d may be actuated to eject the encapsulated transducer 10 therefrom.

In mass production it is preferred that an injection molding device be provided which includes a single upper mold plate 182 and a plurality of lower mold plates 186 disposed on a rotatable table 270 (figure 3). The lower mold plates 186 may each be preloaded with a single sleeved coil and cable assembly 170. Then, the upper mold plate 182 comes down onto the first inline lower mold plate 186 and the respective sleeved coil and cable assembly 170 is encapsulated. Once the encapsulation process is completed the upper mold plate 182 is lifted and the table 270 is rotated about arrow "R" to align a subsequent lower mold plate 186 with the stationary upper mold plate 182 so that the encapsulation process may be repeated.

Meanwhile, the previously encapsulated transducer 10 may remain within the lower mold plate 186 and be allowed to cool as the table is rotated and then ejected as delineated above. Now, after the encapsulated transducer 10 is ejected the lower mold plate 186 is reloaded with a sleeved coil and cable assembly 170 and extends back to the upper mold plate 182 as the table 270 is rotated. This process may continue for encapsulating a batch of sleeved coil and cable assemblies 170.

In use and operation, and referring to figures 1 and 2, the encapsulated transducer 10 may, for example, be utilized as a proximity transducer for monitoring the vibrational characteristics of a rotating shaft 282 of a machine 280. In this environment the encapsulated transducer 10 operates on the eddy current principle and outputs a signal correlative to the spacing between the rotating shaft 282 and the sensing coil 90 of the encapsulated transducer 10.

Typically, the encapsulated transducer 10 is circumscribed by a threaded metal case 284 which is mounted adjacent the rotating shaft of the machine 280. A mounting means 286 is used to strategically mount the encapsulated transducer 10

such that the sensing coil 90, proximate the front end 22 of the encapsulation 20, and the rotating shaft 282 are in a juxtaposed relation. The sensing coil 90 is electrically and mechanically connected to the cable 120. The cable 120 extends out the back end 24 of the encapsulation 20 and runs through a casing 288 of the machine 280 where it preferably terminates to a connection 290 capable of directly coupling to an electrical processing unit 310 or to an extension cable which in turn couples to the electrically processing unit 310.

Preferably, the cable 120 is routed through the machine case 288 by passing through a rubber grommet 294 internal to an adaptor 292 operatively coupled to the machine case 288. The adaptor 292 includes a first end 296 having external and internal threads. The external threads of the adaptor are coupled with a threaded bore 300 in the machine case 288 for firmly connecting the adaptor 292 thereto. In some instances, the internal threads of the first end 296 of the adaptor 292 allow the mounting of the encapsulated transducer 10 via the threaded metal case 284. A second end 298 of the adaptor 292 having external threads may be coupled to a threaded aperture 304 in a junction box 302 such that the junction box 302 is mounted to the machine case 288. The junction box 302 allows any electrical connections operatively coupling the cable 120 to the electrical processing unit 310 to be enclosed in a weather-proof or explosion-proof environment.

In addition to use as a proximity transducer, the present invention may be employed very broadly in the monitoring and diagnostic field. One example is as a temperature transducer which would use a coil formed from a single wire thermocouple of the RTD type. The coil would be molded within the encapsulation 20 and the only change in the above delineated process may be in the use of perhaps a thinner overall encapsulation. This would provide for a suitable heat transfer to the RTD temperature sensing coil.

Moreover, having thus described the invention, it should be apparent that numerous structural modifications and adaptations may be resorted to without departing from the scope and fair meaning of the instant invention as set forth hereinabove and as described hereinbelow by the claims.

Claims

I Claim:

Claim 1 - An information transmitting sensor and housing comprising:
a sensing element;
a cable coupled to said sensing element;
sleeve means protecting said sensing element and overlying and extending between a portion of said cable and said sensing element;
a monolith of cured moldable material ensconcing said sensing element and a portion of said cable defining a seamless mass circumscribing said sensing element and a portion of said cable.

Claim 2 - The sensor of claim 1 further comprising a component alignment preform disposed within both said monolith of cured moldable material and said sleeve means, said preform including a front end having an annular recess and a center post, a back end having an opening and a medial portion interposed between said front end and said rear end of said preform, said medial portion having a chamber in open communication with the opening in said back end.

Claim 3 - The sensor of claim 2 wherein said component alignment preform includes a front ferrule and a rear ferrule bonded thereto and linearly spaced apart by said chamber along a long axis of said sensor and in open communication with said chamber.

Claim 4 - The sensor of claim 3 wherein a front passage and a rear passage within said component alignment preform are in open communication with said front and rear ferrules respectively.

Claim 5 - The sensor of claim 4 wherein said sensing element is a coil having a center void, a front face, a rear face, a body and at least a first lead and a second lead extending from said coil.

Claim 6 - The sensor of claim 5 wherein said coil is disposed within said annular recess of said preform and receives said center post within the center void of said coil thereby axially aligning said coil with said front and rear ferrules along the long axis of said sensor.

Claim 7 - The sensor of claim 6 wherein said first lead extends into the front passage of said preform and is electrically connected to said front ferrule.

Claim 8 - The sensor of claim 7 wherein said second lead extends into the rear passage of said preform and is electrically connected to said rear ferrule.

Claim 9 - The sensor of claim 8 wherein said cable includes at least a center conductor and a coaxial conductor separated from one another by at least one dielectric.

Claim 10 - The sensor of claim 9 wherein at least one end of said cable is stripped in a step-like fashion to expose a length of at least said center conductor, dielectric and coaxial conductor.

Claim 11 - The sensor of claim 10 wherein said stripped end of said cable passes through the opening in said back end of said preform and said center conductor is electrically and mechanically connected within a bore of said front ferrule and said coaxial conductor is electrically and mechanically connected within a bore of said rear ferrule.

Claim 12 - The sensor of claim 11 including a seal circumscribing said dielectric at the stripped end of said cable and wedged between said dielectric and said chamber of said preform thereby providing a barrier therebetween.

Claim 13 - The sensor of claim 12 wherein said sleeve means includes a transfer molded protective sleeve having a first end molded flush with said front face of said coil, a second end terminating proximate said back end of said preform and a body extending from said first end to said second end of said protective sleeve.

Claim 14 - The sensor of claim 13 wherein said body of said protective sleeve contours to said preform and the outer surface of said body of said coil and uniformly extends therefrom to a substantially smooth outer surface thereby eliminating any gaps between the protective sleeve and both the preform and said body of said coil.

Claim 15 - The sensor of claim 14 wherein said body of said protective sleeve fills in the passages of said preform thereby interlocking with said preform and ensconcing said leads of said coil.

Claim 16 - The sensor of claim 15 wherein said component alignment preform is formed from said moldable material.

Claim 17 - The sensor of claim 16 wherein said monolith of cured moldable material bonds with said preform and said sleeve.

Claim 18 - The sensor of claim 17 wherein said monolith of cured moldable material contacts and contours to the front face of said coil and uniformly extends therefrom to form a substantially uniform thick wall substantially parallel with said front face of said coil.

Claim 19 - The sensor of claim 18 wherein said monolith of cured moldable material ensconces a length of said cable proximate the back end of said preform where the cable emanates therefrom.

Claim 20 - An encapsulated transducer for use in monitoring the status of rotating equipment in a harsh environment with a component alignment preform having a leading end with an active element and a trailing end with an information transmitting medium emanating therefrom, formed by:

molding a full length protective sleeve over said active element and a portion of said component alignment preform;

integrally forming a locating means proximate said active element;

locating said active element in a mold cavity with said locating means coupled thereto, assuring proper registry in said mold cavity;

integrally forming a supporting means proximate said component alignment preform;

further supporting and locating said active element and said component alignment preform in said mold cavity with said support means and removing said locator means;

molding over said active element, said protective sleeve, said preform and a portion of said information transmitting medium with a moldable material except for an area of support;

removing said support means;

injecting moldable material adjacent the support means for filling in the areas heretofore occupied by said support means;

whereby said active element is precisely located in a moldable material to accurately address the rotating equipment.

Claim 21 - The encapsulated transducer as formed in claim 20 wherein the forming steps further include locating said active element in said mold cavity with an axially slideable support being received within a center void of said active element.

Claim 22 - The encapsulated transducer as formed in claim 21 wherein the forming steps further include providing grooves in said protective sleeve at a precise length from a front face of said active element.

Claim 23 - The encapsulated transducer as formed in claim 22 wherein the forming steps further include supporting said active element and said component alignment preform with a plurality of radially slideable supports and spacing said front face of said active element a precise distance from a front wall of said mold cavity by said grooves receiving said radially slideable supports.

Claim 24 - The encapsulated transducer as formed in claim 23 wherein the forming steps further include providing a drive means to the axially slideable support and to the plurality of radially slideable supports for sliding each support into or out of the mold cavity.

Claim 25 - The encapsulated transducer as formed in claim 24 wherein the forming steps further include providing a control means for signaling the drive means for independently sliding each support into or out of the mold cavity.

Claim 26 - The encapsulated transducer as formed in claim 25 wherein the forming steps further include providing an alterable timing sequence for orchestrating the control means signaling of the drive means.

Claim 27 - A transducer for monitoring the status of rotating equipment wherein a shaft of the rotating equipment is exposed to said transducer, comprising, in combination:

- means for mounting said transducer a distance from the shaft such that a tangent of the shaft is perpendicular to a long axis of said transducer,
- said transducer having a sensing coil located proximate the shaft,
- a front portion of said transducer including a protective wall having uniform thickness along a forwardmost portion of said sensing coil,
- said sensing coil symmetrically disposed about the long axis, and
- a protective seamless encapsulation including a full length sleeve integrally formed with said protective front wall ensconcing said sensing coil and a leading portion of a cable operatively coupled to said sensing coil,
- said cable extending away from said transducer to an electrical processing unit.

Claim 28 - A process for making a transducer, comprising the steps of:

- providing a sensing coil having a center void, a front face, a rear face and at least a first lead and a second lead extending from said sensing coil;
- providing a cable having at least one outer conductor surrounding at least one insulator carrying at least one center conductor;
- stripping an end of the cable in a step-like fashion to expose a portion of said center conductor, said insulator and said outer conductor;
- forming a front and rear pair of ferrules with said front ferrule having a bore with a diameter substantially matching the diameter of said center conductor and said rear ferrule having a bore with a diameter substantially matching the diameter of said outer conductor;
- molding together in linearly spaced proximity with a self-bonding moldable material said front and rear ferrules and providing in such molding step an annular recess near said front ferrule and linearly aligned therewith and a chamber interposed between and in open communication with said front and rear ferrules, thereby forming a component alignment preform;
- inserting said coil in said annular recess and electrically connecting said first lead to said front ferrule and said second lead to said rear ferrule;
- inserting said stripped cable end into said bores of said molded together front and rear ferrules and mechanically and electrically connecting said outer conductor to said rear ferrule and said center conductor to said front ferrule, thereby forming a sensing coil and cable assembly;

molding a full length sleeve over said sensing coil and a portion of said component alignment preform thereby forming a sleeved coil and cable assembly;

supporting and centering said sleeved coil and cable assembly within a mold cavity with at least one slideable support;

orienting the cable to extend out from the mold cavity;

locating said sensing coil within the mold cavity and spacing said front face of said sensing coil a distance from a front wall of the mold cavity with at least one slideable locator and at least one slideable support;

retracting the slideable locator from the mold cavity;

injecting said self-bonding moldable material into the cavity of the mold to precisely ensconce the sleeved coil and cable assembly and providing a precise face thickness covering said face of said coil;

retracting the slideable supports from the sleeved coil and cable assembly so that said self-bonding moldable material will flow into the areas heretofore occupied by the slideable supports;

allowing the moldable material to set; and

removing the thus formed transducer from the mold cavity as an integrated unit having a seamless mass of moldable material ensconcing the sleeved coil and cable assembly.

Claim 29 - The process for making a transducer as in claim 28 wherein said annular recess is formed by a post on which said sensing coil is placed thereby axially aligning said sensing coil with said front and rear ferrules.

Claim 30 - The process for making a transducer as in claim 29 wherein the step of inserting said stripped cable end into said bores of said molded together front and rear ferrules includes the step of placing a seal around said insulator at said stripped cable end, said seal providing a barrier between said insulator and said chamber.

Claim 31 - The process for making a transducer as in claim 30 including the step of placing a measured amount of solder paste into said front ferrule and placing a preformed solder ring around said outer conductor which are heated to make said respective connections of said center conductor with said front ferrule and said outer conductor with said rear ferrule.

Claim 32 - The process of claim 31 wherein the step of retracting the slideable supports from the sleeved coil and cable assembly includes the step of injecting an additional charge of self-bonding moldable material adjacent the slideable supports for filling in the areas heretofore occupied by the slideable supports.

Claim 33 - The process for making a transducer as in claim 32 including the step of inserting said formed transducer into an open ended metal case and affixing the metal case thereto.

Claim 34 - A method of making a transducer having a component alignment preform having a leading end with an active element and a trailing end with an information transmitting medium emanating therefrom, the steps including:

- molding a full length protective sleeve over said active element and a portion of said component alignment preform;

- providing at least one indentation in the full length sleeve;

- integrally forming a support means proximate said full length sleeve;

- supporting and locating said active element in a mold cavity with said support means coupled thereto and being received within at least the one indentation for assuring proper registry of said component alignment preform in said mold cavity;

- injecting moldable material over said active element, said protective sleeve, said preform and a portion of said information transmitting medium with a moldable material except for an area of support;

- removing said support means;

- injecting moldable material adjacent the support means for filling in the areas heretofore occupied by said support means;

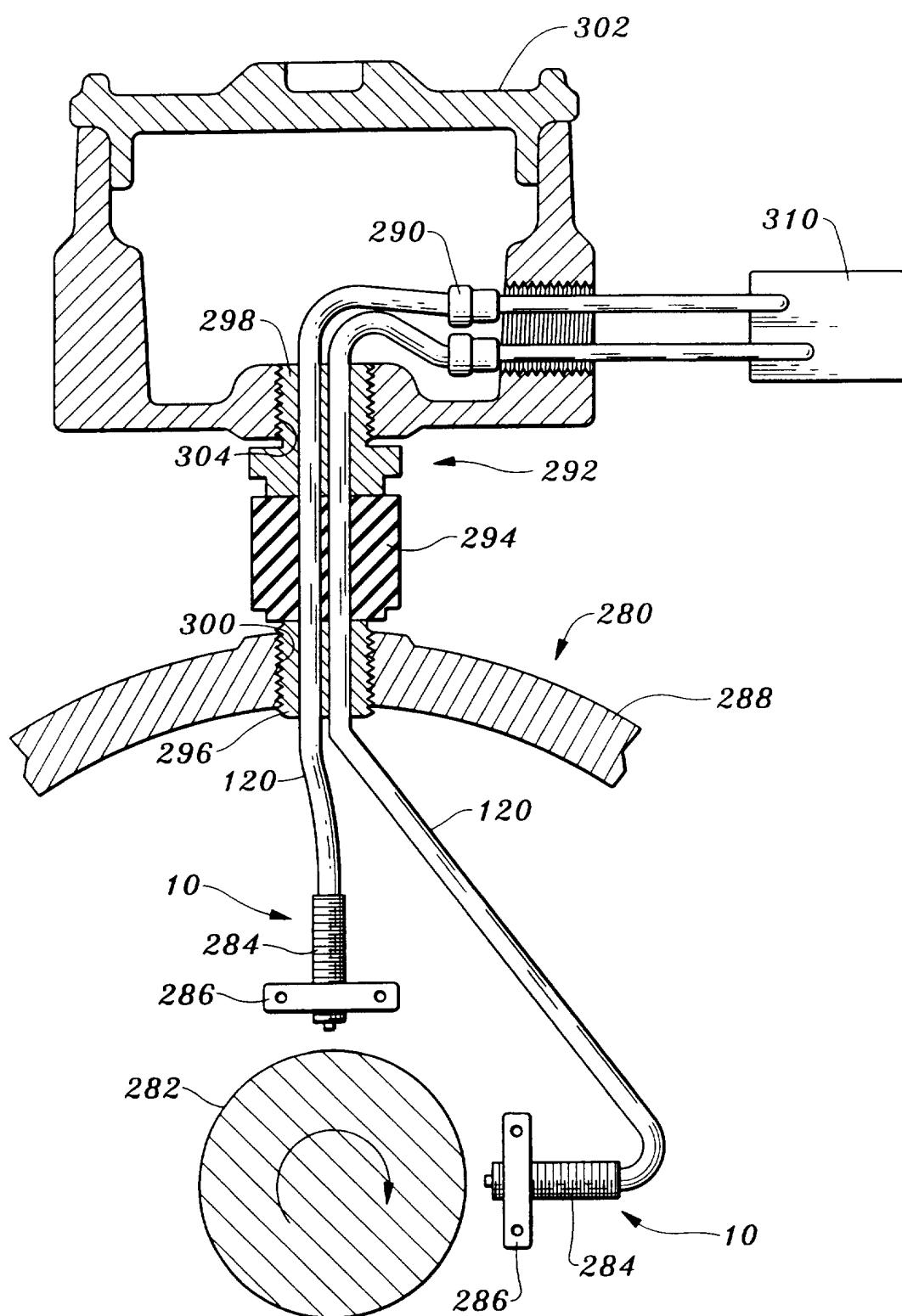
- whereby said active element is precisely located in the moldable material when cured.

Claim 35 - The method of claim 34 further including the step of integrally forming an axial locator means proximate said active element.

Claim 36 - The method of claim 35 further including the step of further locating said active element and said component alignment preform in said mold cavity with said axial locator means.

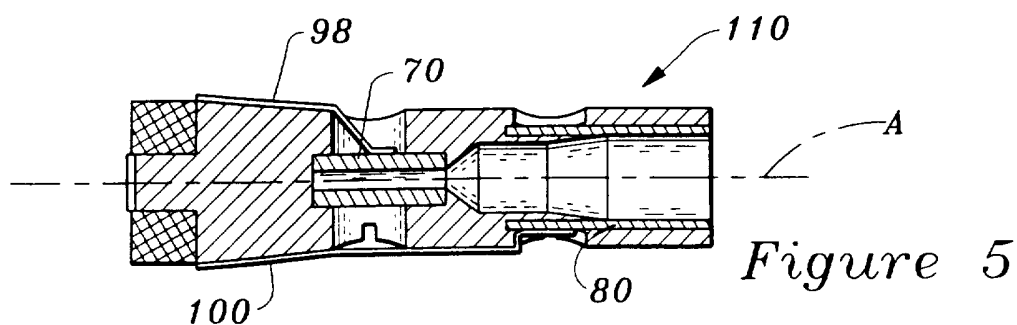
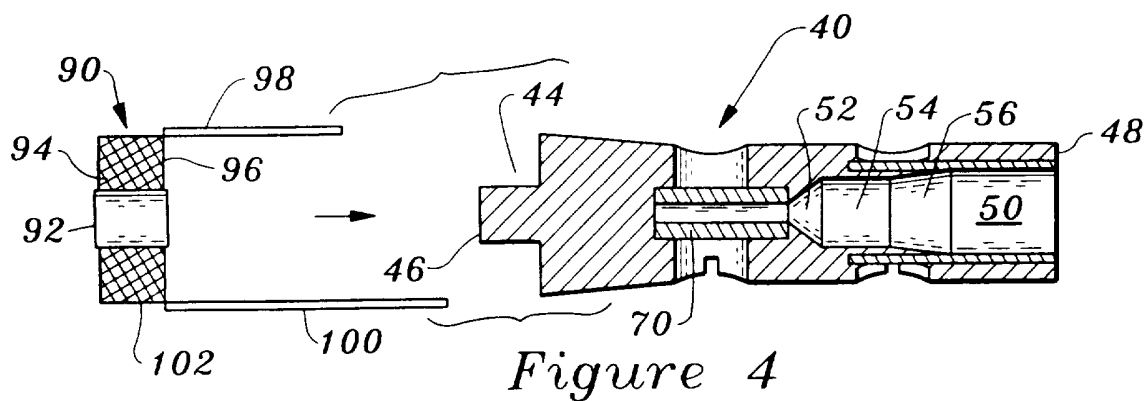
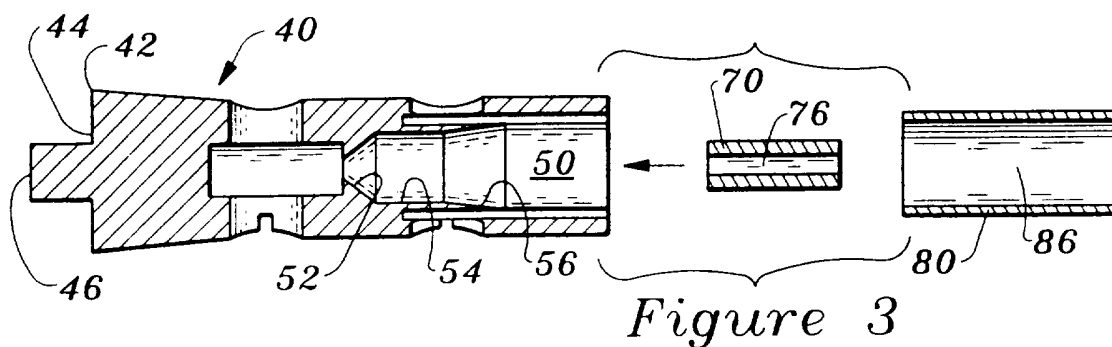
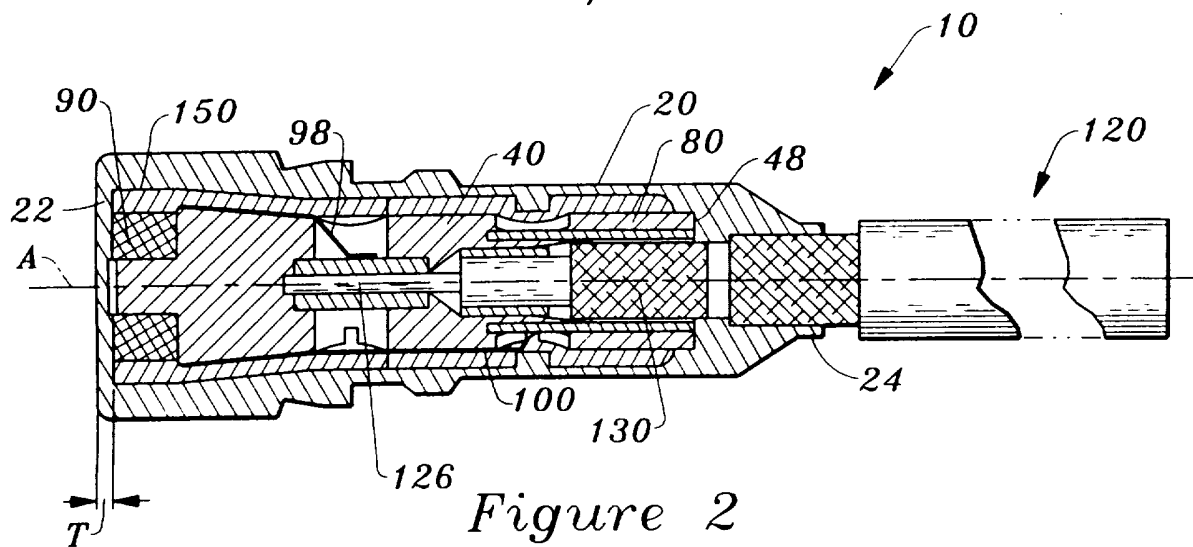
Claim 37 - The method of claim 36 further including the step of removing said axial locator means prior to injecting moldable material within said mold cavity.

1/8

*Figure 1*

SUBSTITUTE SHEET (RULE 26)

2/8



3/8

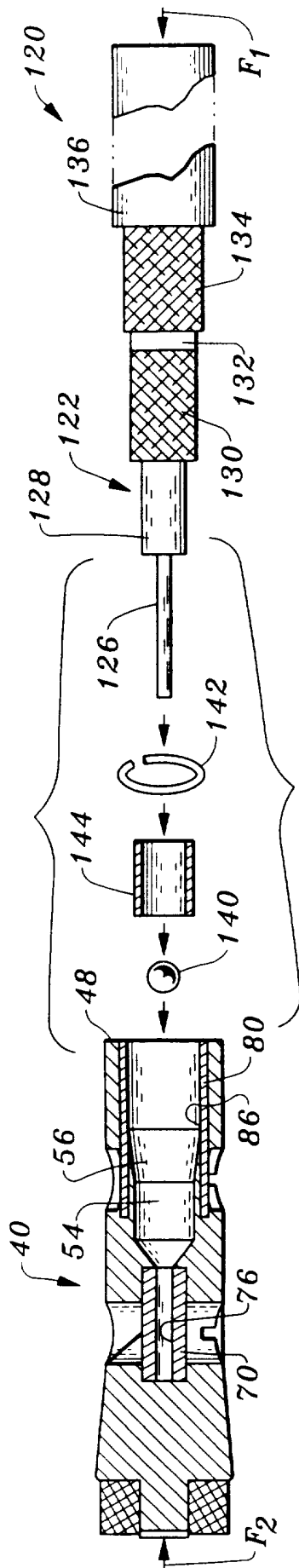


Figure 6

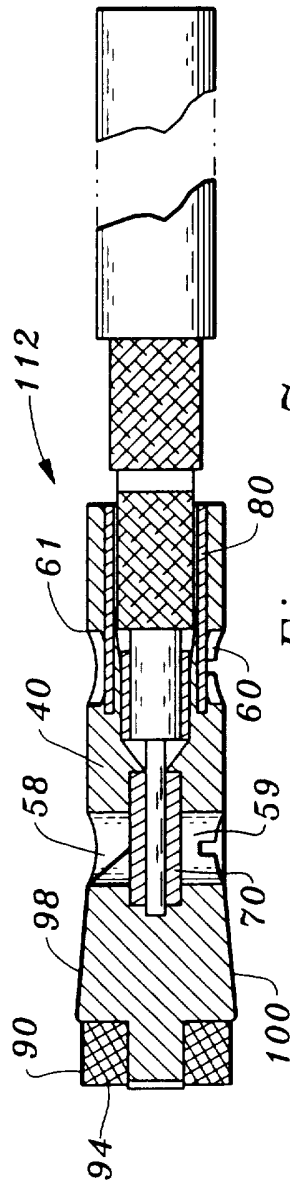


Figure 7

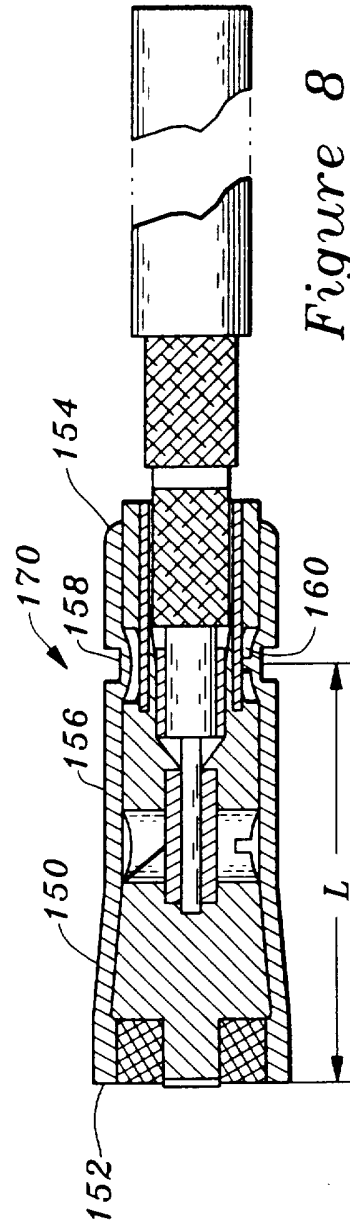


Figure 8

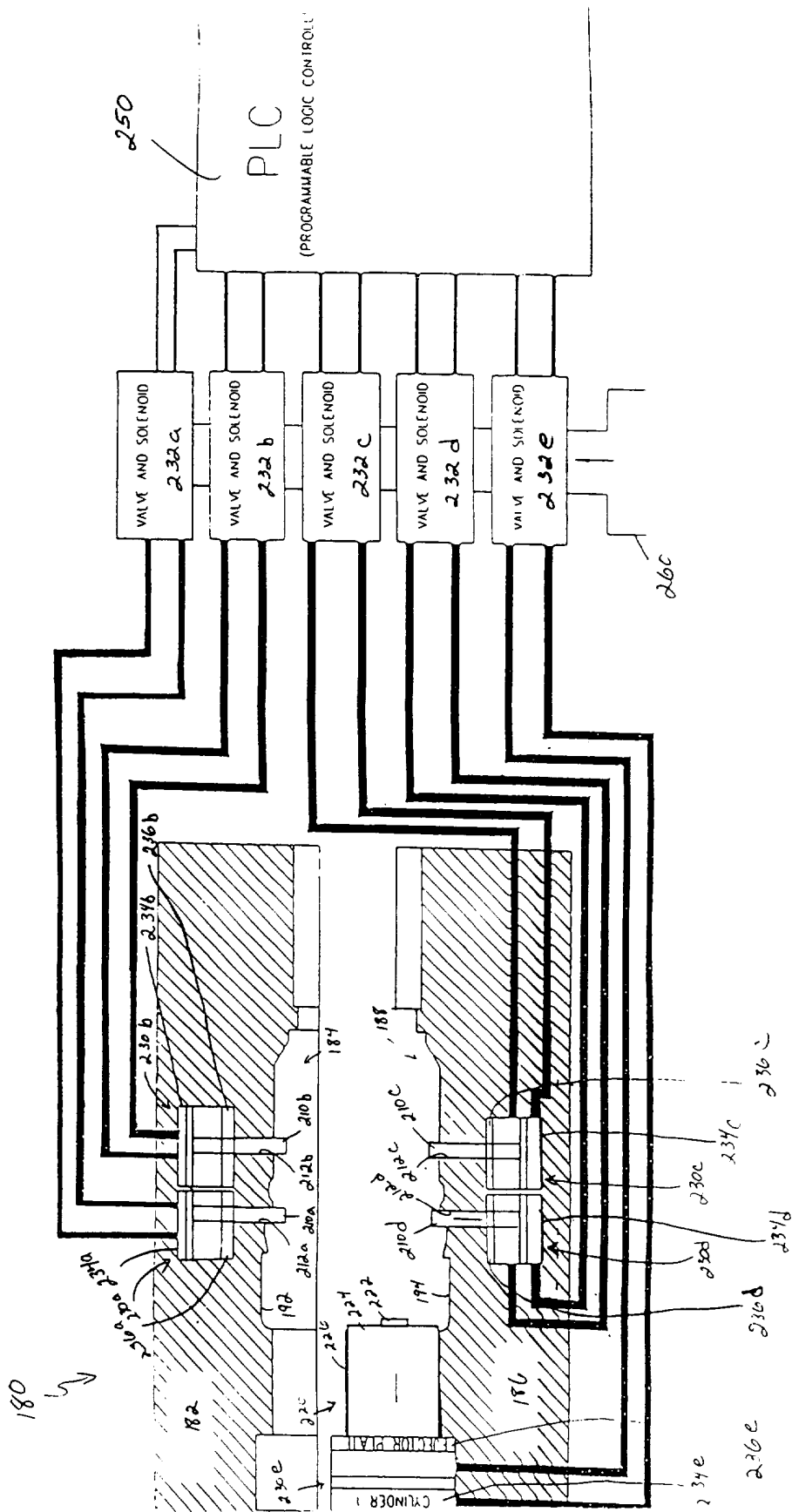


Figure 9

5/8

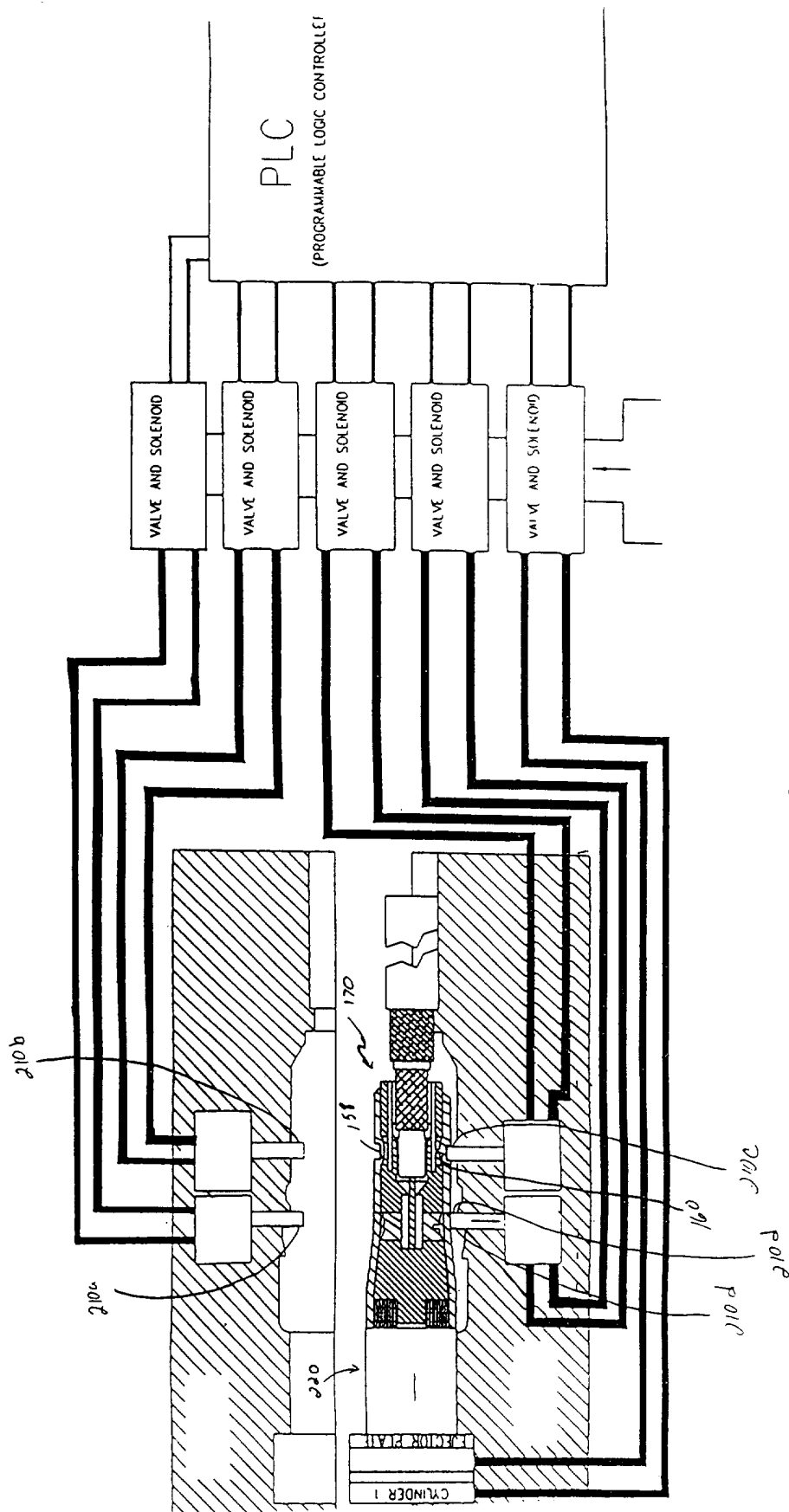


Figure 10

6/8

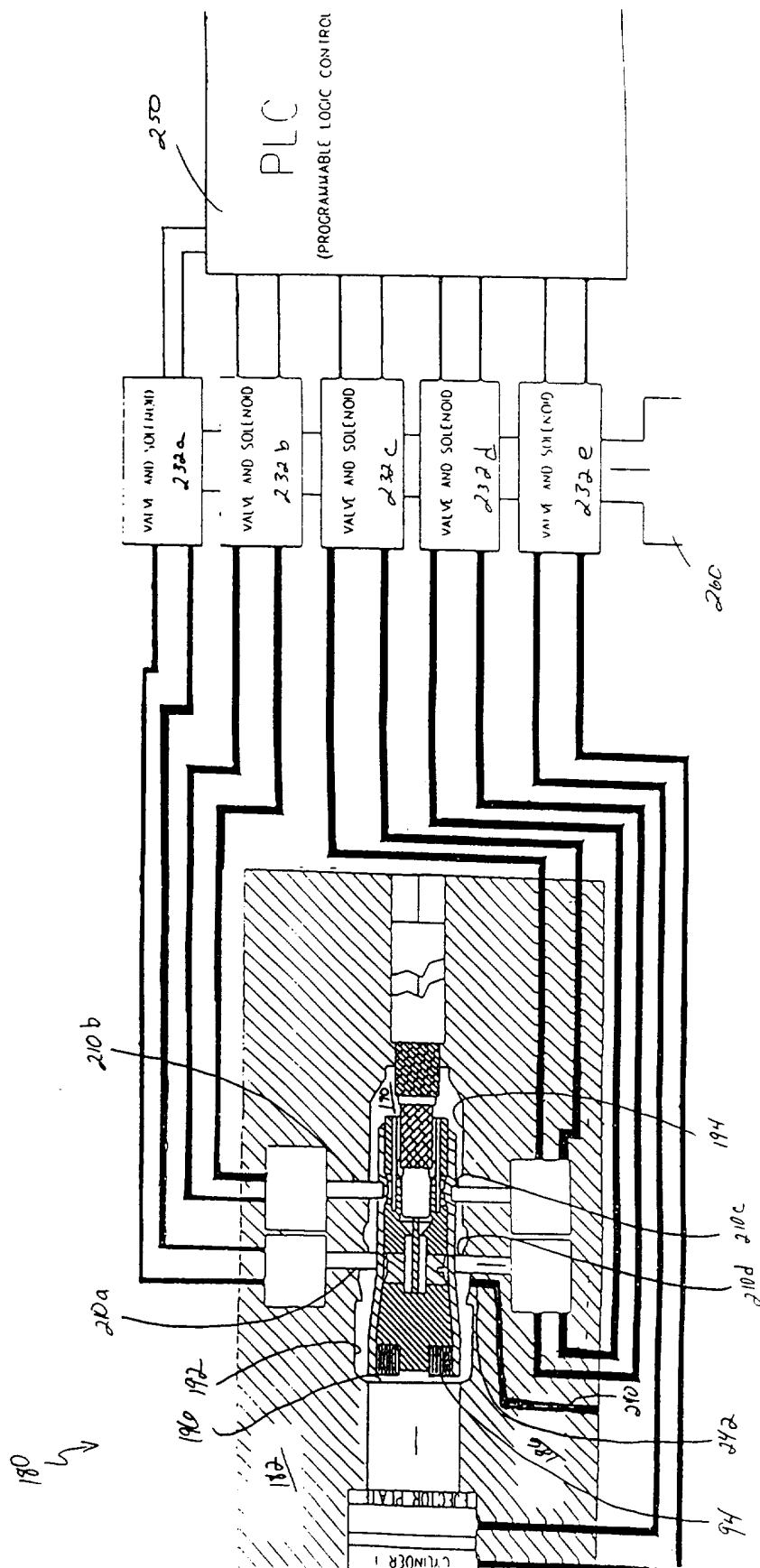


Figure 11

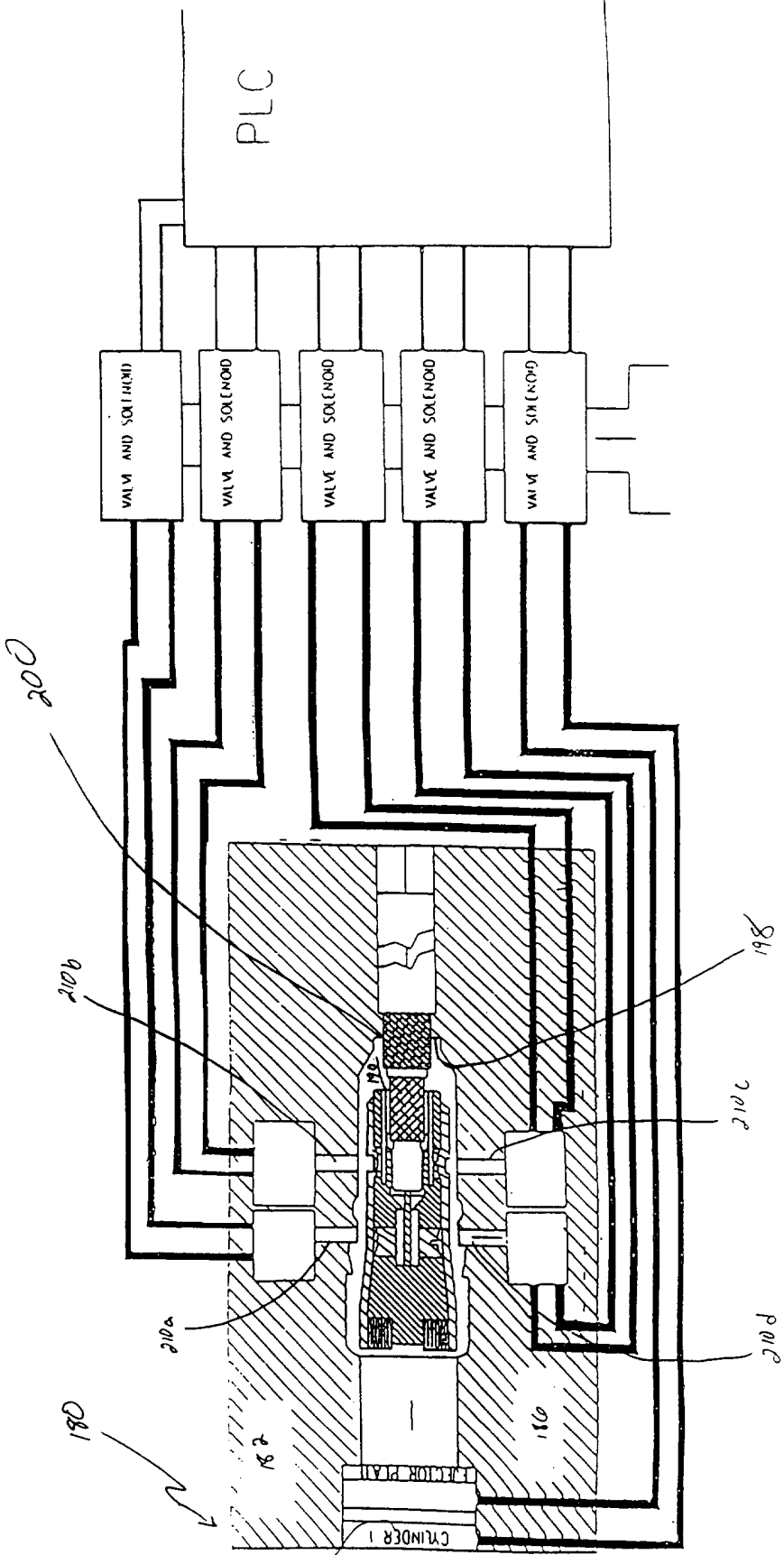


Figure 12

8/8

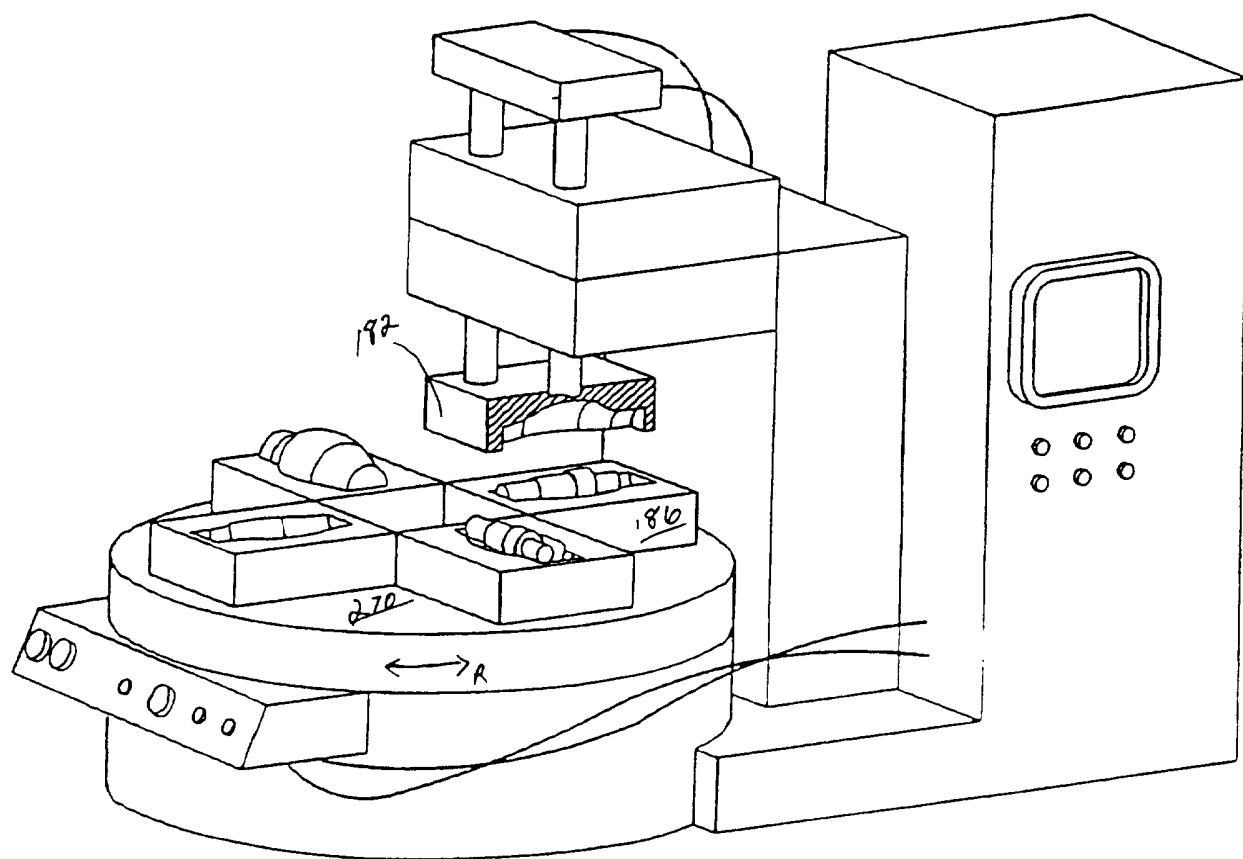


Figure 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/16336

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G01H 11/02; G01B 7/30; H01F 5/04, 17/02, 41/00

US CL :Please See Extra Sheet.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,351,388 (VAN DEN BERG ET AL) 04 October 1994 FIGS. 9-20; col. 7, line 8 - col. 8, line 37.	1-37
Y	US, A, 4,829,245 (ECHASSERIAU, ET AL) 09 May 1989 col. 2, lines 60-66	1-37
Y	US, A, 5,418,454 (TOGO) 23 May 1995 FIGS. 1-4, col. 3, line 63 - col. 4, line 26	1-37
A	US, A, 5,381,089 (DICKMEYER ET AL) 01 January 1995	1-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

02 JANUARY 1997

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

73/660,661; 29/602.01; 174/52.2; 264/272.15, 272.19; 324/207.16; 336/92

B. FIELDS SEARCHED

Minimum documentation searched

Classification System: U.S.

73/660,661; 29/595,602.1,605,606; 174/52/2, 52.3; 264/272.11, 272.13, 272.15, 272.19; 324/207.15, 207.16, 207.25, 236,237,173,174; 336/90,92,96