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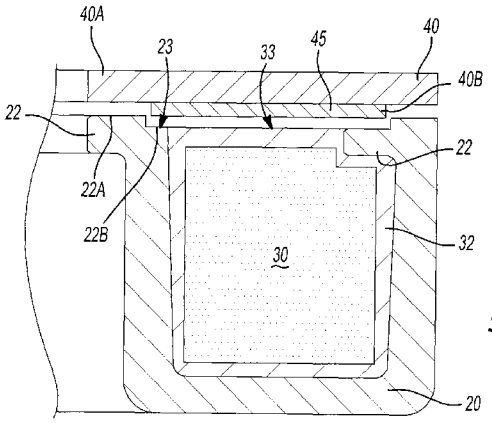


Fig-15

(57) Abstract: An electromagnet may comprise a pole piece (20) and coil assembly (30). The pole piece (20) may be magnetically susceptible and have a channel structure and a first flange member (22). The channel structure may have an annular inner side wall (24), an annular outer side wall (26) and an annular end wall (28) that fixedly couples the inner and outer side walls (24, 26) to one another on a first axial end (27) of the pole piece (20). The channel structure may be open on a second axial end (29) of the pole piece (20) that is opposite the first axial end (27). The first flange member (22) may be coupled to an end of one of the inner and outer side walls (24, 26) on the second axial end (29) and extend in a radial direction of the pole piece (20) towards an interior of the channel structure. The coil assembly (30) may be fixedly coupled to the channel structure between the inner and outer side walls (24, 26).

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ELECTROMAGNET AND ELECTROMAGNETIC COIL ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 61/384,379 filed September 20, 2010. The disclosure of the above-referenced application is incorporated by reference as if fully set forth in detail herein.

INTRODUCTION

[0002] The present disclosure generally relates to an electromagnet and electromagnetic coil assembly, and more specifically, to an electromagnetic coil assembly that may be used to selectively couple and decouple an element to a rotating shaft.

BACKGROUND

[0003] A conventional electromagnetic coil assembly typically includes a coil assembly in engagement with a multi-piece housing that, when the coil assembly is energized, magnetically attracts an armature plate to be in frictional engagement with the housing. The housing may have a box-like cross section that includes a pole piece that extends between first and second sidewalls. This conventional housing and pole piece construction creates a direct electrical path between the first and second sidewalls through the pole piece, thereby reducing the magnetic attraction for a given operating voltage of the coil assembly. An electromagnetic coil assembly that reduces the amount of energy required to attract and maintain the armature plate in frictional engagement with the housing would be desirable.

SUMMARY

[0004] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0005] In one form, the present teachings provide an electromagnet comprising a pole piece and a coil assembly. The pole piece may be

monolithically formed of a magnetically susceptible material and have a channel structure and a first flange member. The channel structure may have an annular inner side wall, an annular outer side wall and an annular end wall that fixedly couples the inner and outer side walls to one another on a first axial end of the pole piece. The channel structure may be open on a second axial end of the pole piece that is opposite the first axial end. The first flange member may be coupled to an end of one of the inner and outer side walls on the second axial end and extend radially from the channel structure. The coil assembly may be fixedly coupled to the channel structure between the inner and outer side walls.

[0006] The present teachings further provide an electromagnetic coil assembly comprising a pole piece, a coil assembly and an armature plate. The pole piece may be monolithically formed of a magnetically susceptible material and have a channel structure and a first flange member. The channel structure may have an annular inner side wall, an annular outer side wall and an annular end wall that fixedly couples the inner and outer side walls to one another on a first axial end of the pole piece. The channel structure may be open on a second axial end of the pole piece that is opposite the first axial end. The first flange member may be coupled to an end of one of the inner and outer side walls on the second axial end and extend radially from the channel structure. The first flange member may also define a first contact surface. The coil assembly may be fixedly coupled to the channel structure between the inner and outer side walls. The armature plate may define a second contact surface. The first contact surface may be in contact with the second contact surface in a first configuration when the coil assembly is energized so as to inhibit relative motion between the pole piece and armature plate. The first contact surface may be separated from the second contact surface by a gap in a second configuration when the coil assembly is de-energized so as to allow relative motion between the pole piece and armature plate. In the first configuration, the armature plate, pole plate and coil assembly may define an empty cavity.

[0007] The present teachings further provide an electromagnetic coil assembly comprising a pole piece, a coil assembly and an armature plate. The pole piece may be monolithically formed of a magnetically susceptible material and have a channel structure and a first flange member. The channel structure may have an annular inner side wall, an annular outer side wall and an annular end wall that fixedly couples the inner and outer side walls to one another on a first axial end of the pole piece. The channel structure may be open on a second axial end of the pole piece that is opposite the first axial end. The first flange member may be coupled to the inner side wall on the second axial end and the second flange member may be coupled to the outer side wall on the second axial end. The first flange member may extend radially from the channel structure. The coil assembly may be fixedly coupled to the channel structure between the inner and outer side walls and define a first contact surface. The armature plate may define a second contact surface. The second contact surface may be in contact with the first contact surface in a first configuration when the coil assembly is energized so as to inhibit relative motion between the pole piece and armature plate. The second contact surface may be separated from the first contact surface by a gap in a second configuration when the coil assembly is de-energized so as to allow relative motion between the pole piece and armature plate.

[0008] In yet another form, the present teachings provide an electromagnet comprising a pole piece and a coil assembly. The pole piece may be formed of a magnetically susceptible material and have a channel structure and a first flange member. The channel structure may have an annular inner side wall, an annular outer side wall and an annular end wall that fixedly couples the inner and outer side walls to one another on a first axial end of the pole piece. The channel structure may be open on a second axial end of the pole piece that is opposite the first axial end. The first flange member may be coupled to an end of one of the inner and outer side walls on the second axial end and extend in a radial direction of the pole piece towards an interior of the channel structure. The coil assembly may be fixedly coupled to the channel structure between the inner and outer side walls.

[0009] In yet another form, the present teachings further provide an electromagnetic coil assembly comprising a pole piece, a coil assembly and an armature plate. The pole piece may be formed of a magnetically susceptible material and have a channel structure and a first flange member. The channel structure may have an annular inner side wall, an annular outer side wall and an annular end wall that fixedly couples the inner and outer side walls to one another on a first axial end of the pole piece. The channel structure may be open on a second axial end of the pole piece that is opposite the first axial end. The first flange member may be coupled to an end of one of the inner and outer side walls on the second axial end and extend in a radial direction of the pole piece towards an interior of the channel structure. The first flange member may define a first contact surface. The coil assembly may be fixedly coupled to the channel structure between the inner and outer side walls. The armature plate may define a second contact surface. The first contact surface may be in contact with the second contact surface in a first configuration when the coil assembly is energized so as to inhibit relative motion between the pole piece and armature plate. The first contact surface may be separated from the second contact surface by a gap in a second configuration when the coil assembly is de-energized so as to allow relative motion between the pole piece and armature plate. In the first configuration, the armature plate, pole plate and coil assembly may define an empty cavity.

[0010] In another form, the present teachings also provide a method of assembling an electromagnet of an electromagnetic coil assembly. The method includes providing a magnetically susceptible pole piece that has a channel structure and a flange projection. The channel structure may have an annular inner side wall, an annular outer side wall and an annular end wall that fixedly couples the inner and outer side walls to one another on a first axial end of the pole piece. The channel structure may be open on a second axial end of the pole piece that is opposite the first axial end. The flange projection may be coupled to an end of one of the inner and outer side walls on the second axial end and arranged to provide unobstructed access to an interior of the channel structure. The method also includes arranging a coil

assembly within the channel structure of the pole piece. The method further includes rotating the flange projection to form a flange member such that the flange member extends in a radial direction of the pole piece towards the interior of the channel structure.

[0011] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way. Similar or identical elements are given consistent identifying numerals throughout the various figures.

[0013] Figure 1 is a sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0014] Figure 2 is a partially exploded view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0015] Figure 3 is a perspective view of a pole piece of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0016] Figure 4 is a sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0017] Figure 5 is a perspective view of a pole piece of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0018] Figure 6 is a sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0019] Figure 7 is a sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0020] Figure 8 is a partial sectional view of the exemplary electromagnetic coil assembly of Figure 7 illustrating exemplary flux lines.

[0021] Figure 9 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0022] Figure 10 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0023] Figure 11 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0024] Figure 12 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0025] Figure 13 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0026] Figure 14 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0027] Figure 15 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0028] Figure 16 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0029] Figure 17 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0030] Figure 18 is a partial sectional view of an exemplary electromagnetic coil assembly constructed in accordance with the teachings of the present disclosure;

[0031] Figure 19 is a graph illustrating the attractive force at a number of operating voltages between a pole piece and armature plate on the y-axis versus separating distance between the pole piece and armature plate on the x-axis for an electromagnetic coil assembly that does not include a flange member; and

[0032] Figure 20 is a graph illustrating the attractive force at a number of operating voltages between a pole piece and armature plate on the y-axis versus separating distance between the pole piece and armature plate on the x-axis for the electromagnetic coil assembly of Figure 10.

[0033] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE VARIOUS EMBODIMENTS

[0034] An exemplary electromagnetic coil assembly according to various embodiments of the present disclosure is generally indicated by reference numeral 10. The electromagnetic coil assembly 10 may include a pole piece 20, a coil assembly 30 and an armature plate 40. The electromagnetic coil assemblies 10 described herein may be utilized in a clutch assembly to selectively couple and decouple an accessory with a rotating shaft, such as those described in U.S. Patent Application No. 12/620,023, the disclosure of which is herein incorporated in its entirety. Such accessories include, but are not limited to, an engine water pump, an engine vacuum pump, a vehicle air conditioning pump and a power steering pump. In a non-limiting example, the armature plate 40 may be a component of an accessory that is powered by coupling the armature plate 40 with a rotating shaft in a powered configuration. In an unpowered configuration, the armature plate 40 may be coupled with a non-rotating pole piece 20 such that the armature plate 40 does not rotate with the rotating shaft and, thus, the associated accessory is not powered.

[0035] The pole piece 20 may be made of a magnetically susceptible material such that the pole piece 20 can control the distribution of magnetic flux generated by the coil assembly 30. With additional reference to Figure 3, the pole piece 20 can have a channel structure including an annular inner side wall 24, an annular outer side wall 26 and an annular end wall 28 that couples the inner and outer side walls 24, 26 to each other. The annular end wall 28 can be located on one axial end 27 of the pole piece 20. On a second axial end 29 opposite the first axial end 27, the channel structure may be open. Additionally, the pole piece 20 may be monolithically formed or, alternatively, formed from a plurality of individual pieces that are coupled together. The pole piece 20 can have various shapes, e.g., a U-shape (Figures 1-16) or a V-shape (Figure 17). For example only, referring to Figure 17, in a V-shaped pole piece 20 the outer side wall 26 can have a recessed portion 26A that is curved or angled from the outer side wall 26 and/or annular end wall 28. The recessed portion 26A can be arranged such that the pole piece 20/coil assembly 30 combination has a specific configuration that corresponds to the area in which the electromagnetic coil assembly 10 is placed. In this manner, the electromagnetic coil assembly 10 can be arranged within a relatively small area without interfering with or obstructing access to the remainder of the clutch assembly, rotating shaft, etc.

[0036] A flange member 22 can be coupled to the inner side wall 24 (Figures 1-5 and 15-16) or outer side wall 26 (Figure 6) on the second axial end 29. According to various additional embodiments, a flange member 22 can be coupled to each of the inner side wall 24 and outer side wall 26 on the second axial end 29 (Figures 7-14). While each of the Figures illustrates one of three configurations, i.e., inner flange, outer flange and both inner and outer flange, it is understood that each of the exemplary embodiments may be modified to include a different flange configuration without departing from the scope of the present disclosure. The flange member 22 can extend radially from the channel structure, i.e., in the direction of the radius of the pole piece 20. Each of the flange members 22 may extend away from (Figures 1-14) or toward (Figures 15-16) the interior of the channel structure of the pole piece

20. As shown in Figures 15-16, the pole piece 20 may include one flange member 22 that extends away from and one flange member 22 that extends toward the interior of the channel structure of the pole piece 20. For those flange members 22 that extend towards the interior of the pole piece 20, the coil assembly 30 can provide additional support to the flange 22/contact plate 70 during actuation.

[0037] In various embodiments in which the flange member 22 extends toward the interior of the pole piece 20, the pole piece 20/coil assembly 30 combination can be assembled by arranging the coil assembly 30 within a pole piece 20' that includes a flange projection 22' that extends from the annular inner side wall 24 and/or an annular outer side wall 26 (Figure 18). The coil assembly 30 can be placed within the channel structure of the pole piece 20 with the flange projection 22' in a position that does not obstruct access to the interior of the channel structure of the pole piece 20. After the coil assembly 30 is arranged within the channel structure of the pole piece 20, the flange projection 22' can be bent or otherwise rotated to form the flange member 22, such as shown in Figure 15. In other embodiments, one or both of the annular inner side wall 24 and annular outer side wall 26 can be initially formed such that there is unobstructed access to the interior of the pole piece 20. After the coil assembly 30 is arranged in the appropriate position, the inner side wall 24/outer side wall 26 can be bent to form the final channel structure of the pole piece 20, e.g., the pole piece 20 illustrated in Figure 15.

[0038] The flange member 22 may define a flange surface or contact surface 23. As described more fully below, the flange or contact surface 23 can be a relatively flat surface that may be used to contact and frictionally engage the armature plate 40. Further, the flange or contact surface 23 may be perpendicular to the centerline L of the channel structure of the pole piece 20. For example only, flange or contact surface 23 may be flat within 0.25 millimeters and have a runout relative to centerline L within 0.25 millimeters. In some embodiments, the flange member 22 can have a stepped design (Figures 9 and 15-16) in which the flange surface 23 includes a first surface

portion 22A and a second surface portion 22B offset from the first surface portion 22A.

[0039] In some embodiments, the flange 22 may be constructed of the pole piece 20 coupled with a separate contact plate 70 (Figure 16) to define the contact surface 23. The contact plate 70 may be a ring-shaped member that is coupled to the inner or outer side wall 24, 26 of the pole piece 20. In some embodiments, the contact plate 70 may be fixedly coupled with either one of the inner or outer side walls 24, 26 only, in other words, the contact plate 70 is fixedly coupled one of the inner and outer side walls and is separated from the other of the inner and outer side walls. The contact plate 70 may be coupled to the pole piece 20 by an adhesive, a welding process, by being in frictional engagement (such as press-fitting) or other process. The contact plate 70 may be made of a magnetically susceptible material such that the contact plate 70 can control the distribution of magnetic flux generated by the coil assembly 30. In some embodiments, the contact plate 70 can have a stepped design that includes a first surface portion 70A and a second surface portion 70B offset from the first surface portion 70A, similar to the flange member 22 having a stepped design described above.

[0040] One or more finishing processes may be utilized to ensure that the contact surface 23 is relatively flat, smooth, free of irregularities and perpendicular to the centerline L of the pole piece 20. Such finishing operations include, but are not limited to, rapid stamping, impact or hydraulic coining, punching, flattening, smoothing, milling, grinding, lathing and burnishing. In addition to these processes, or alternatively, the contact surface 23 may be coated with a coating 21. For example only, the coating 21 may be a friction-enhancing coating (such as the products sold under the brand-name EKagrip® by ESK Ceramics GmbH & Co. KG (www.esk.com/en)) such that the coating 21 may have a coefficient of friction greater than the coefficient of friction of the contact surface 23 without a coating 21. Further, the contact surface 23 may define one or more depressions 25 that extend radially away from the annular inner side wall 24. These depressions 25 may be formed by stamping, coining, pressing or other machining process. During

operation of the electromagnetic coil assembly 10, the depressions 25 may collect wear by-products and other contaminants (water, engine fluids, etc.) and channel them away from the contact surface 23.

[0041] The coil assembly 30 can be fixedly coupled to the channel structure of the pole piece 20. The coil assembly 30 may include a plurality of windings surrounding a core such that magnetic flux is generated when current is provided to the windings. The coil assembly 30 may also include a bonding material 32, e.g., to surround the plurality of windings and the core, and/or act as a contact surface 33 for armature plate 40 as described below. The combination of the pole piece 20 and coil assembly 30 may be referred to as an electromagnet. The coil assembly 30 may be fixedly coupled to the pole piece 20 between the annular inner and outer side walls 24, 26, for example, by the bonding material 32 or an adhesive, such as glue or epoxy. In some embodiments, the coil assembly 30 may be in contact the annular end wall 28 on the first axial end 27. On the second axial end 29 opposite the first axial end 27, there may be nothing between the coil assembly 30 and the open end of the pole piece 20 such that the coil assembly 30 is accessible and open. One or more wires or connectors (not shown) may be utilized to provide power to the coil assembly 30. The pole piece 20 may define one or more openings, e.g., in the annular inner side wall 24, annular outer side wall 26 or annular end wall 28, through which the wires and/or connectors pass such that power may be provided to the coil assembly 30.

[0042] The armature plate 40 may define a contact surface 43 configured to selectively contact the pole piece 20, e.g., contact surface 23 of flange member 22 or coil assembly 30, e.g., contact surface 33. In addition, or alternatively, to the depressions 25 on the contact surface 23, one or more depressions (similar to depressions 25) may be formed on a contact surface 43 of the armature plate 40 to collect wear by-products and other contaminants (water, engine fluids, etc.) and channel them away from the contact surface 43. The armature plate 40 may also include a friction material 45 that defines contact surface 43. The friction material 45 may be a coating formed on the main portion of the armature plate 40, or may be a separate

member that is bonded or otherwise adhered to the main portion of the armature plate 40. In one non-limiting example, the friction material 45 may be a separately formed material (such as the products sold under the brand-name EKagrip® by ESK Ceramics GmbH & Co. KG (www.esk.com/en)) that is bonded to the main portion of the armature plate 40. Friction material 45 may be utilized to obtain the appropriate friction, durability and/or other properties for contact surface 43, while also allowing armature plate 40 to have the appropriate magnetic, strength, durability and/or other properties for efficient operation of the electromagnetic coil assembly 10.

[0043] As the electromagnetic coil assembly 10 is actuated, the armature plate 40 may be selectively coupled and decoupled with the pole piece 20. As illustrated in Figure 8, which shows a portion of the exemplary pole piece 20 with two flange members 22 shown in Figure 7, the coil assembly 30 may generate a plurality of flux lines 60 when energized. The flux lines 60 may travel through the pole piece 20, across gap 50 and through armature plate 40. The flux lines 60 can attract and move the armature plate 40 into contact with the pole piece 20. An empty cavity 55 may be defined by the pole piece 20, coil assembly 30 and armature plate 40 when the armature plate 40 is coupled with the pole piece 20. In this manner, the flux lines 60 may travel through the flange member(s) 22, and not across the empty cavity, to increase the attractive force between pole piece 20 and armature plate 40.

[0044] When the coil assembly 30 is energized, electromagnetic coil assembly 10 may enter a first configuration (Figure 8) in which the contact surface 43 of the armature plate 40 contacts the pole piece 20, e.g., contact surface 23, the second portion 22B of the contact surface 23 (Figure 9), and/or contact surface 33. The contact surface 43 may frictionally engage the contact surface 23 such that relative motion between the pole piece 20 and armature plate 40 is inhibited. When the coil assembly 30 is de-energized, electromagnetic coil assembly 10 may enter a second configuration (Figure 1) in which the contact surface 43 of the armature plate 40 is separated from the pole piece 20, e.g., contact surface 23 and/or contact surface 33, by a gap 50. The gap 50 may permit relative motion between the pole piece 20 and

armature plate 40. The electromagnetic coil assembly 10 may be biased to be in the second configuration by a biasing member, e.g., a spring (not shown). In a non-limiting example, the contact surface 43 may solely contact the contact surface 23 in the first configuration (see Figures 8-9) such that the pole piece 20, coil assembly 30 and armature plate 40 define empty cavity 55.

[0045] In various embodiments of the present invention, the coil assembly 30 may include a contact or coil assembly surface 33 that frictionally engages the contact surface 43 of the armature plate 40 in the first configuration. In some embodiments, the coil assembly surface 33 may cooperate with the flange surface 23 to define a contact surface 35 that contacts the armature plate 40 in the first configuration (Figures 10-11). Alternatively, the coil assembly surface 33 may provide the sole contact surface between the pole piece 20 and coil assembly 30 in the first configuration (Figures 12-14). In various embodiments, the bonding material 32 may define the coil assembly/contact surface 33. As shown in Figures 10-12, the armature plate 40 may include friction material 45 to interact with and frictionally engage the contact surface(s) 23, 33, 35. Alternatively, as shown in Figures 13-14, the armature plate 40 may be monolithically formed and directly interact with and frictionally engage the contact surface(s) 23, 33, 35.

[0046] The bonding material 32 may be formed of a non-magnetic material, such as a polymer or ceramic material. For example only, the bonding material 32 may be a bulk molding compound, such as DIELECTRITE 48-50 BMC sold by IDI Composites International (www.idicomposites.com), that is injection molded into the pole piece 20. In various embodiments, the bonding material 32 may be a composite material engineered to obtain the performance characteristics desired for coil assembly surface 33. For example, the bonding material 32 may include a base material (such as a plastic resin) with one or more additives (such as carbon or other fibers or a ceramic material) to change the frictional and/or durability characteristics of the base material. In some embodiments, a metallic or magnetic material (such as steel or iron rods) may be added to the

base material and arranged to tune the distribution of flux lines 60 of the combination of the pole piece 20 and coil assembly 30.

[0047] In various embodiments, as shown in Figures 9-13 and 15-16, the armature plate 40 may include a base portion 40A and an offset portion 40B. The base portion 40A may define a base plane 140A that extends in the radial direction of the pole piece 20. The offset portion 40B may define an offset plane 140B that extends in the radial direction of the pole piece 20. The offset plane 140B may be parallel and offset from base plane 140A. In this manner, the offset portion 40B may project from the face of the base portion 140B (as shown in Figures 9-13 and 15-16), or may be recessed within the base portion 140B (not shown). The offset portion 140B may also define the contact surface 43 such that a gap 52 exists between the flange member 22 and the armature plate 40 (or base portion of the armature plate 40) in the first configuration.

[0048] Figure 19 is a graph illustrating the attractive force - at a number of operating voltages - between pole piece 20 and armature plate 40 (on the y-axis) versus distance between the contact surface 23 and the contact surface 33, 43 (on the x-axis) for an electromagnetic coil assembly that does not include a flange member. Figure 20 is a similar graph for the electromagnetic coil assembly 10 of Figure 10. Referring to Figure 19 and the electromagnetic coil assembly without a flange member, curve 100 corresponds to an operating voltage of nine volts direct current, curve 102 corresponds to an operating voltage of eleven volts direct current, curve 104 corresponds to an operating voltage of fourteen volts direct current, curve 106 corresponds to an operating voltage of sixteen volts direct current, and curve 108 corresponds to an operating voltage of eighteen volts direct current. Similarly, referring to Figure 20 and the electromagnetic coil assembly 10 of Figure 10, curve 110 corresponds to an operating voltage of nine volts direct current, curve 112 corresponds to an operating voltage of eleven volts direct current, curve 114 corresponds to an operating voltage of fourteen volts direct current, curve 116 corresponds to an operating voltage of sixteen volts direct current, and curve 118 corresponds to an operating voltage of eighteen volts

direct current. As can be seen by comparing these graphs, the attractive force between the pole piece 20 and armature plate 40 is higher for a given operating voltage for the electromagnetic coil assembly 10 of Figure 10.

[0049] It will be appreciated that the above description is merely exemplary in nature and is not intended to limit the present disclosure, its application or uses. While specific examples have been described in the specification and illustrated in the drawings, it will be understood by those of ordinary skill in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure as defined in the claims. Furthermore, the mixing and matching of features, elements and/or functions between various examples is expressly contemplated herein so that one of ordinary skill in the art would appreciate from this disclosure that features, elements and/or functions of one example may be incorporated into another example as appropriate, unless described otherwise, above. Moreover, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular examples illustrated by the drawings and described in the specification as the best mode presently contemplated for carrying out the teachings of the present disclosure, but that the scope of the present disclosure will include any embodiments falling within the foregoing description and the appended claims.

CLAIMS

What is claimed is:

1. An electromagnet comprising:

a magnetically susceptible pole piece (20) having a channel structure and a first flange member (22), the channel structure having an annular inner side wall (24), an annular outer side wall (26) and an annular end wall (28) that fixedly couples the inner and outer side walls to one another on a first axial end (27) of the pole piece (20), the channel structure being open on a second axial end (29) of the pole piece (20) that is opposite the first axial end (27), the first flange member (22) being coupled to an end of one of the inner and outer side walls on the second axial end, the first flange member (22) extending in a radial direction of the pole piece (20) towards an interior of the channel structure; and

a coil assembly (30) fixedly coupled to the channel structure between the inner and outer side walls.

2. The electromagnet of claim 1, wherein the first flange member (22) includes an annular contact plate (70) fixedly coupled with the one of the inner and outer side walls and separated from the other of the inner and outer side walls.

3. The electromagnet of claim 2, wherein the pole piece (20) includes a second flange member (22) that is coupled to an end of the other one of the inner and outer side walls on the second axial end (29), the second flange member (22) extending radially away from the interior of the channel structure.

4. The electromagnet of claim 3, wherein the annular contact plate (70) defines a contact surface (23) that includes a first surface portion (70A) and a second surface portion (70B) offset from the first surface portion (70A).

5. The electromagnet of claim 3, wherein the annular inner side wall (24), the annular outer side wall (26), the annular end wall (28) and the second flange member (22) are monolithically formed.

6. The electromagnet of claim 1, wherein the first flange member (22) defines a contact surface (23) that includes a first surface portion (22A) and a second surface portion (22B) offset from the first surface portion (22A).

7. The electromagnet of claim 1, wherein the first flange member (22) defines a contact surface (23) that defines a plurality of depressions (25) extending radially away from the annular inner side wall (24).

8. The electromagnet of claim 1, wherein the annular outer side wall (26) includes a recessed portion (26A) that is angled from the annular outer side wall (26) such that the pole piece (20) is V-shaped.

9. An electromagnetic coil assembly (10) comprising:

a magnetically susceptible pole piece (20) having a channel structure and a first flange member (22), the channel structure having an annular inner side wall (24), an annular outer side wall (26) and an annular end wall (28) that fixedly couples the inner and outer side walls to one another on a first axial end (27) of the pole piece (20), the channel structure being open on a second axial end (29) of the pole piece (20) that is opposite the first axial end (27), the first flange member (22) being coupled to an end of one of the inner and outer side walls on the second axial end (29), the first flange member (22) (i) extending in a radial direction of the pole piece (20) towards an interior of the channel structure, and (ii) defining a first contact surface (23);

a coil assembly (30) fixedly coupled to the channel structure between the inner and outer side walls; and

an armature plate (40) defining a second contact surface (43), the first contact surface being in contact with the second contact surface (23) in a first configuration when the coil assembly (30) is energized so as to inhibit relative motion between the pole piece (20) and armature plate (40), the first contact surface (23) being separated from the second contact surface (43) by a gap (50) in a second configuration when the coil assembly (30) is de-energized so as to allow relative motion between the pole piece (20) and armature plate (40).

10. The electromagnet coil assembly (10) of claim 9, wherein the first flange member (22) includes an annular contact plate (70) fixedly coupled with the one of the inner and outer side walls and being separated from the other of the inner and outer side walls.

11. The electromagnet coil assembly (10) of claim 10, wherein the pole piece (20) includes a second flange member (22) that is coupled to an end of the other one of the inner and outer side walls on the second axial end (29), the second flange member (22) extending radially away from the interior of the channel structure.

12. The electromagnet coil assembly (10) of claim 11, wherein the annular inner side wall (24), the annular outer side wall (26), the annular end wall (28) and the second flange member (22) are monolithically formed.

13. The electromagnet coil assembly (10) of claim 9, wherein the first flange member (22) defines a contact surface (23) that defines a plurality of depressions (25) extending radially away from the annular inner side wall (24).

14. The electromagnetic coil assembly (10) of claim 9, wherein the armature plate (40), pole plate (20) and coil assembly (30) define an empty cavity in the first configuration.

15. The electromagnet coil assembly (10) of claim 9, wherein the annular outer side wall (26) includes a recessed portion (26A) that is angled from the annular outer side wall (26) such that the pole piece (20) is V-shaped.

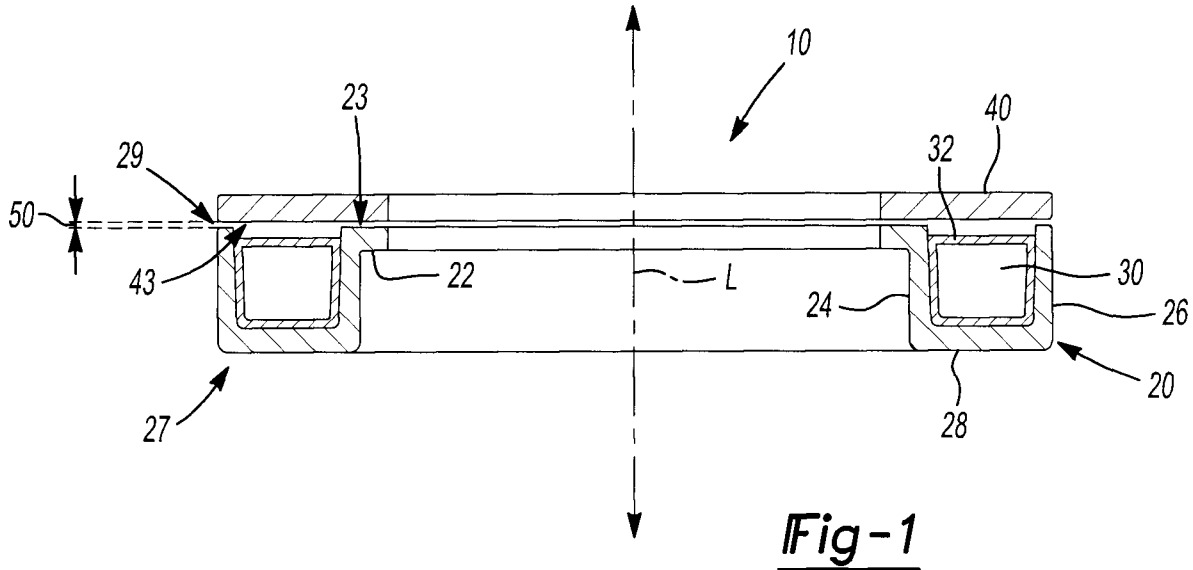


Fig-1

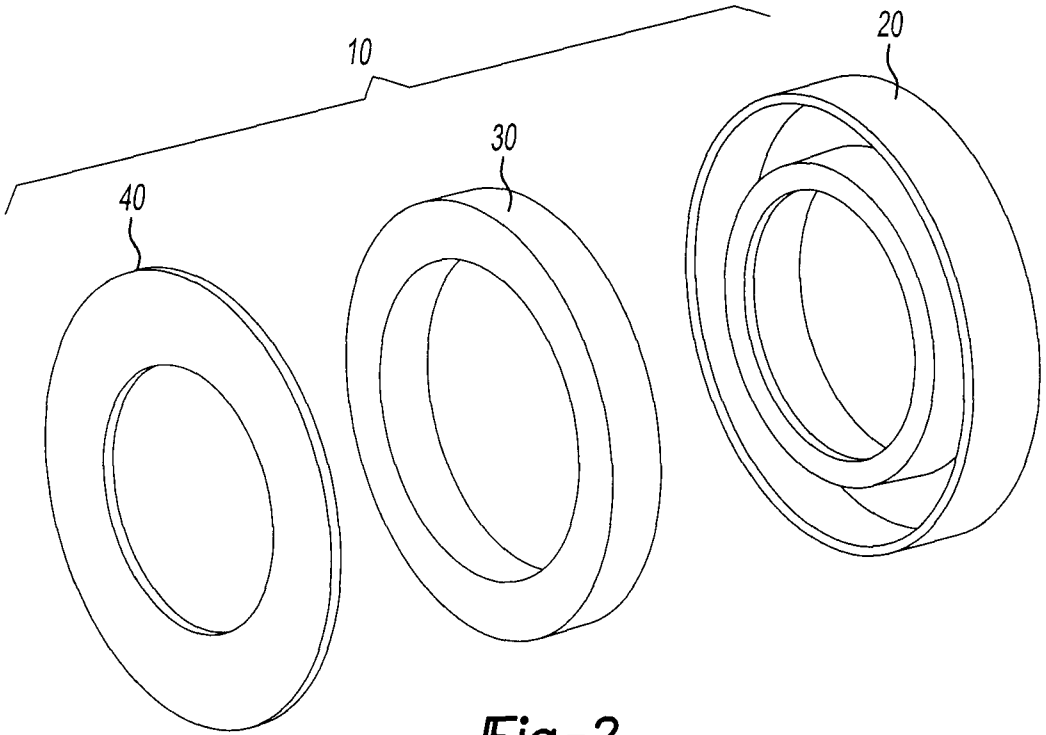


Fig-2

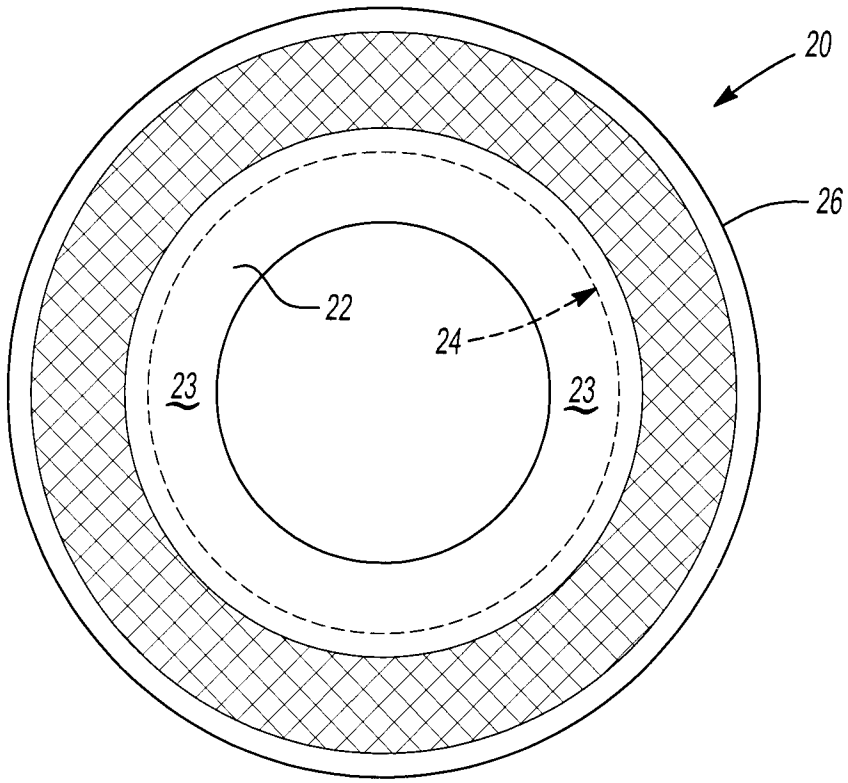


Fig-3

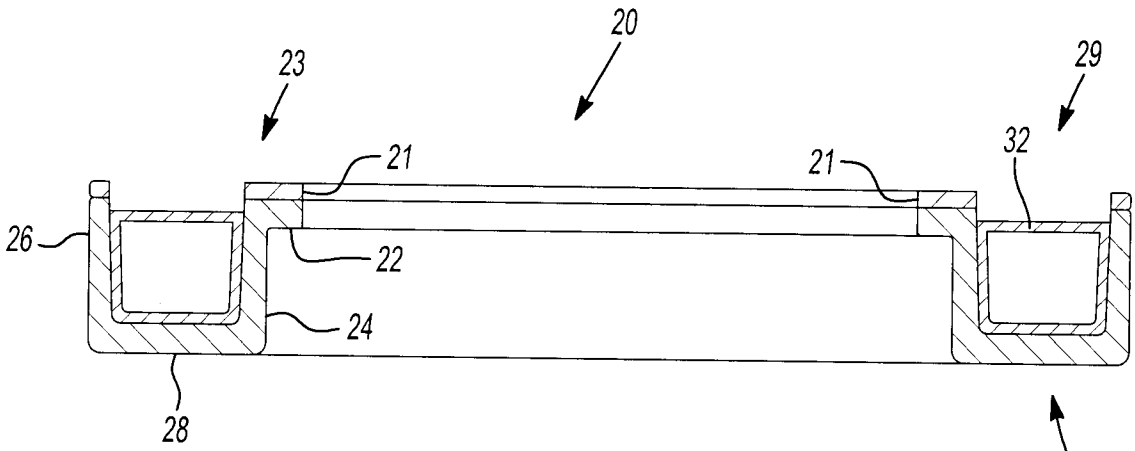


Fig-4

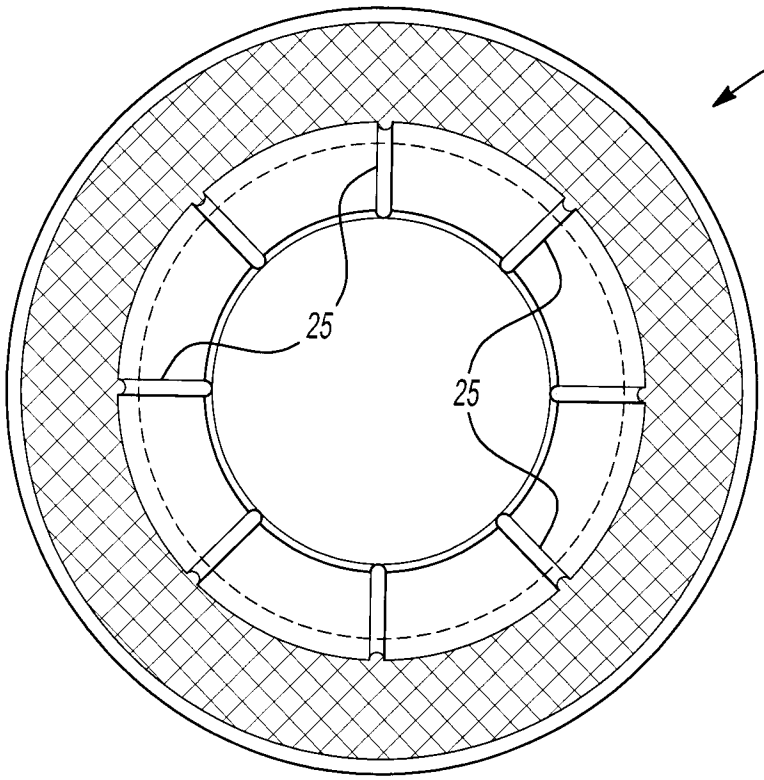


Fig-5

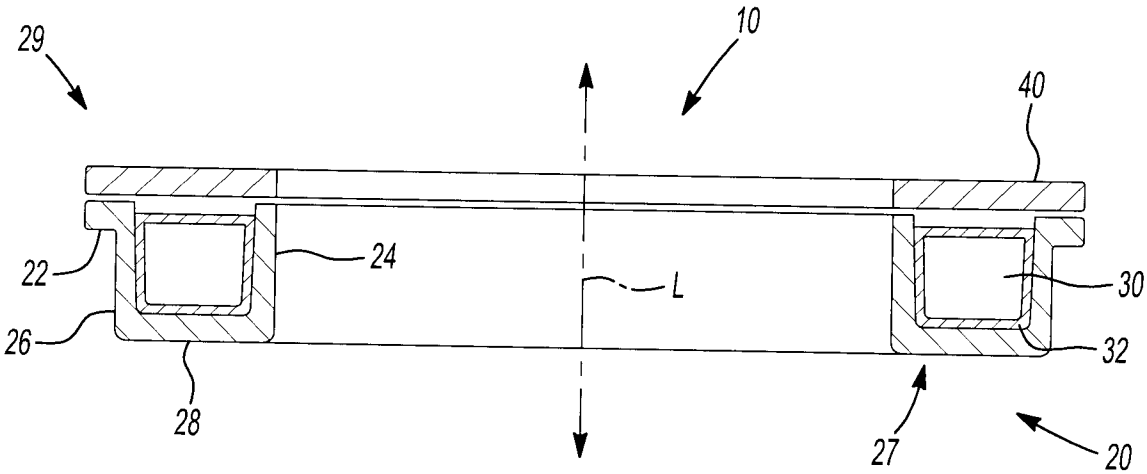


Fig-6

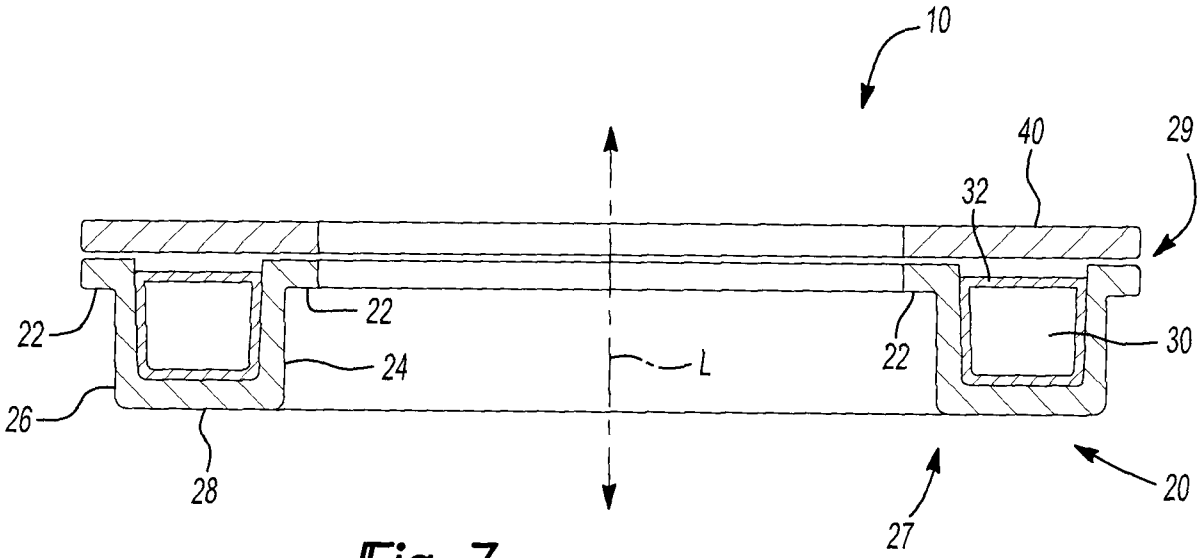

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Fig-7

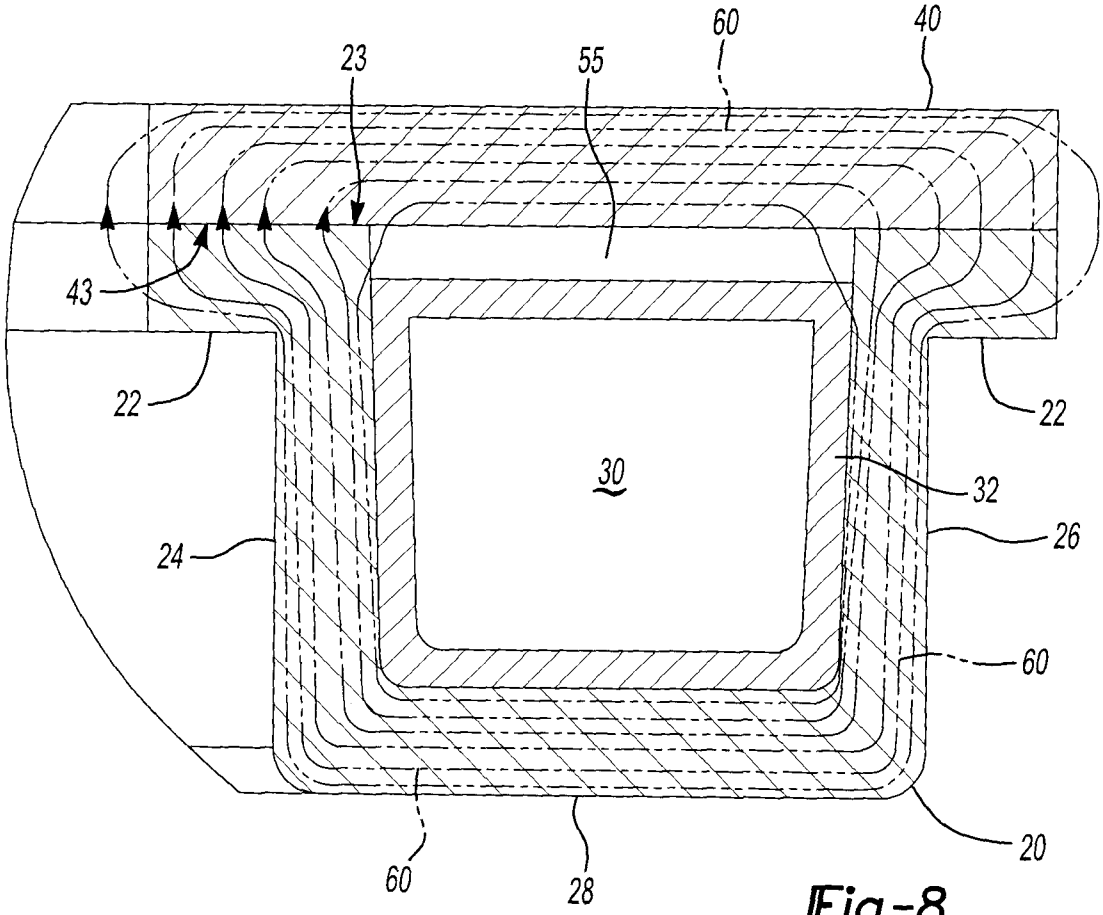

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26
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28
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Fig-8

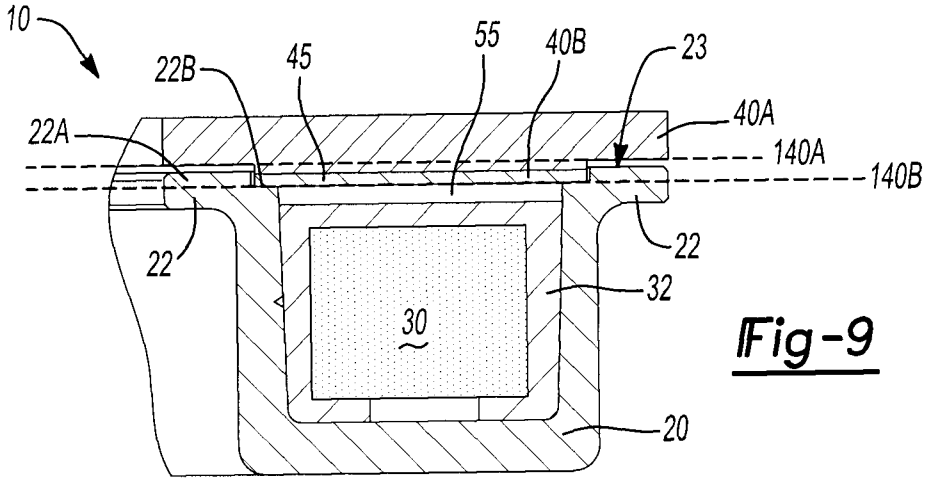


Fig-9

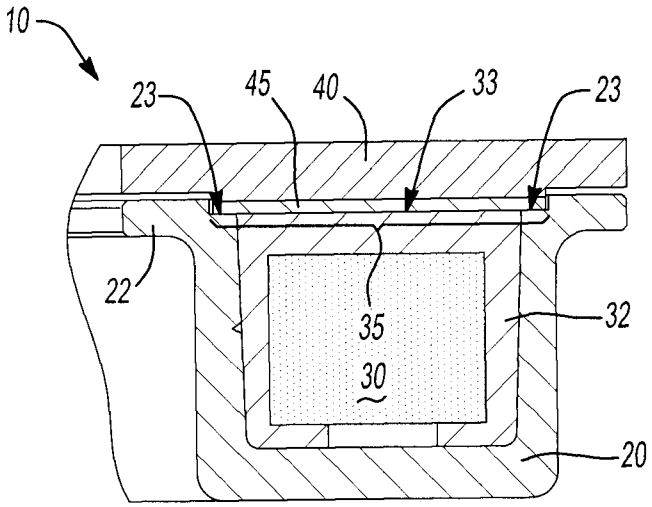


Fig-10

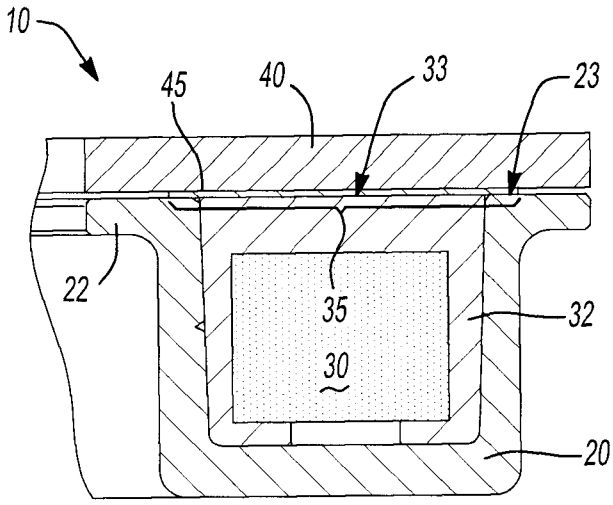


Fig-11

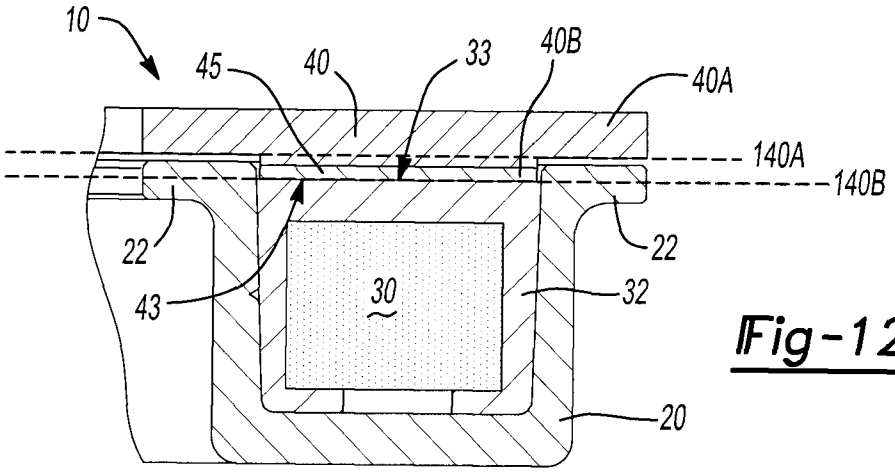


Fig-12

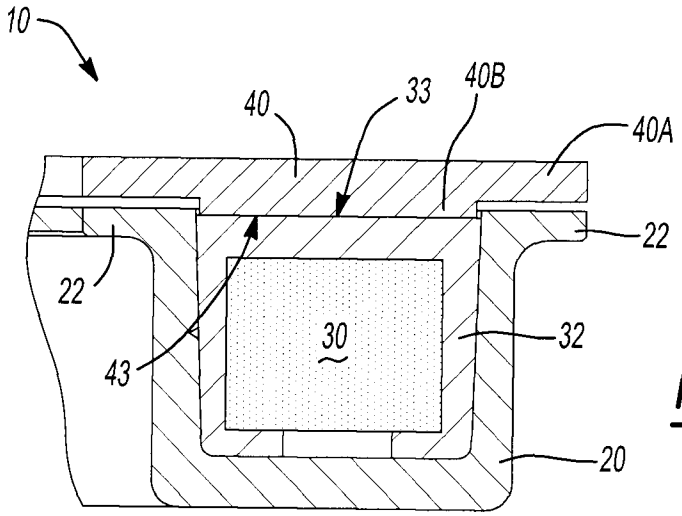


Fig-13

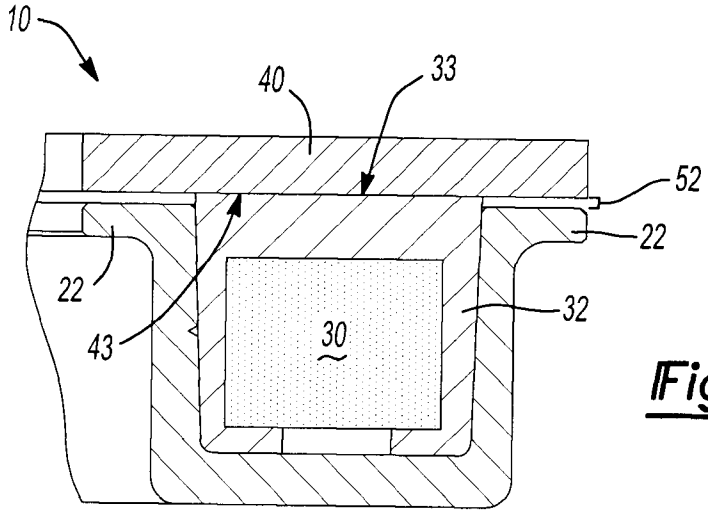


Fig-14

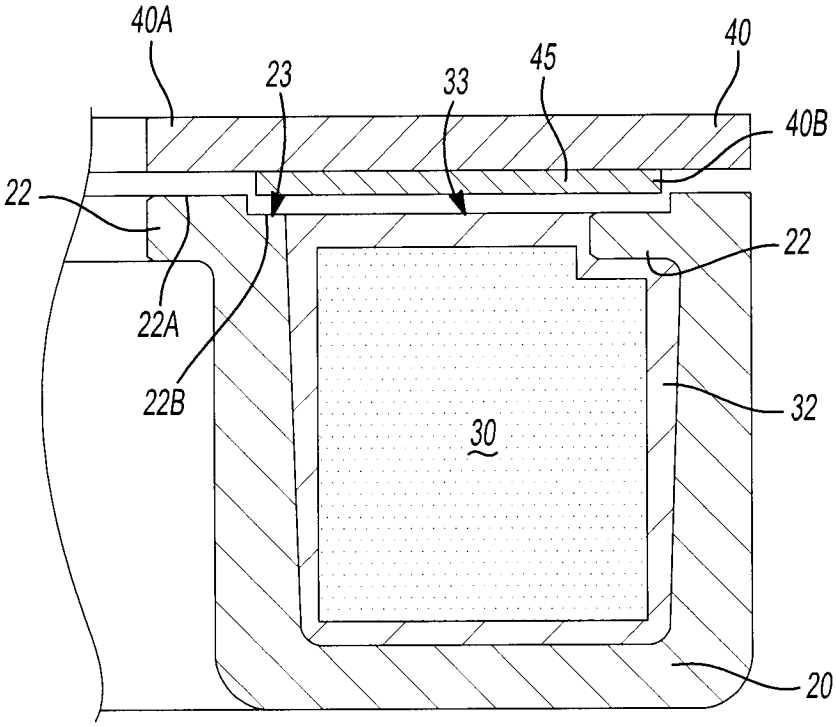

40A
23
33
45
40
40B
22
22
22A
22B
32
30
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Fig-15

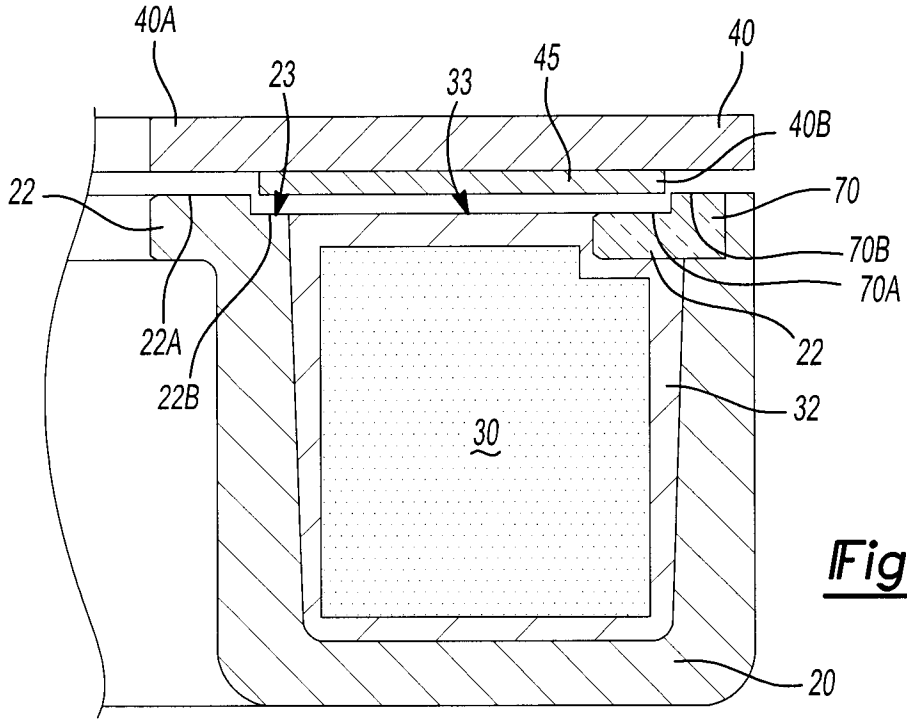

40A
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40B
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70
70B
70A
22
22A
22B
32
30
20

Fig-16

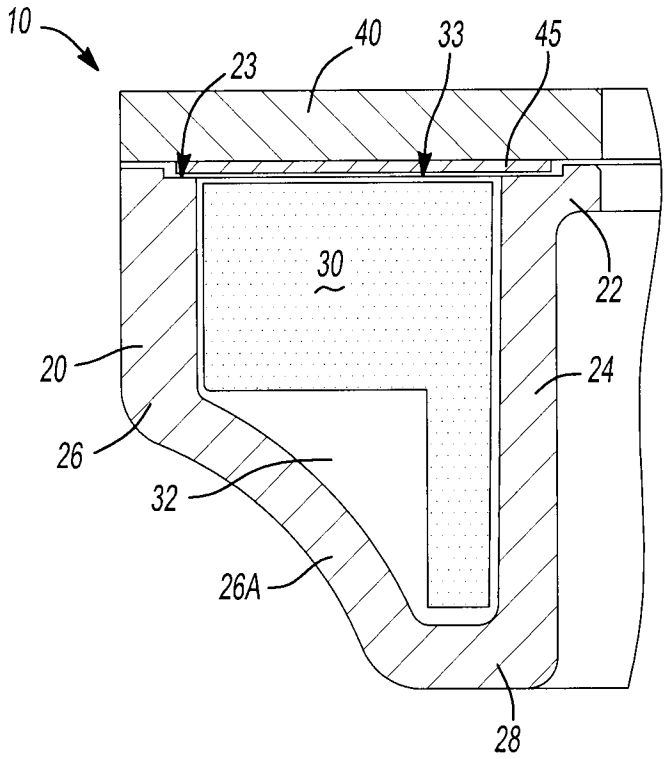


Fig-17

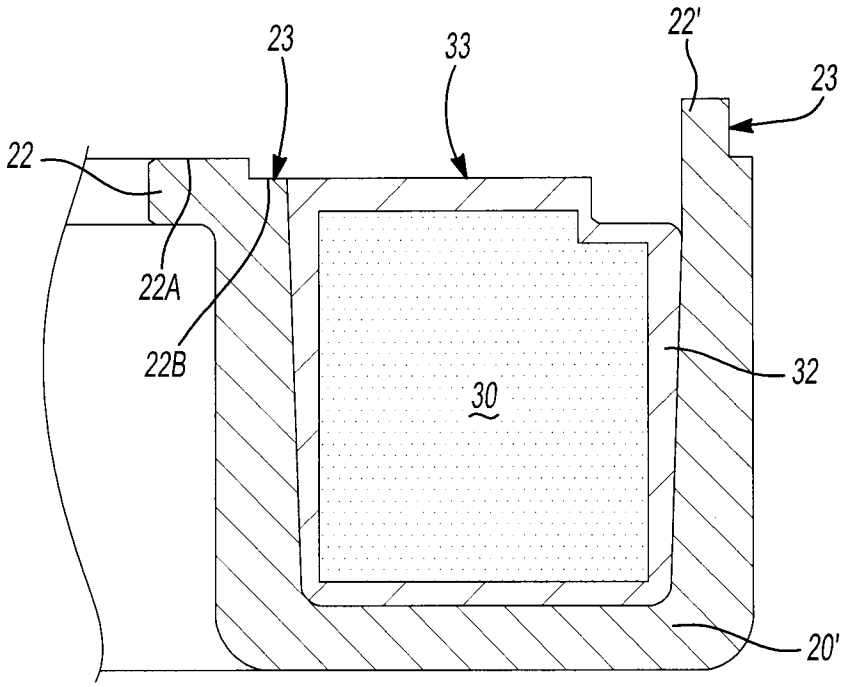


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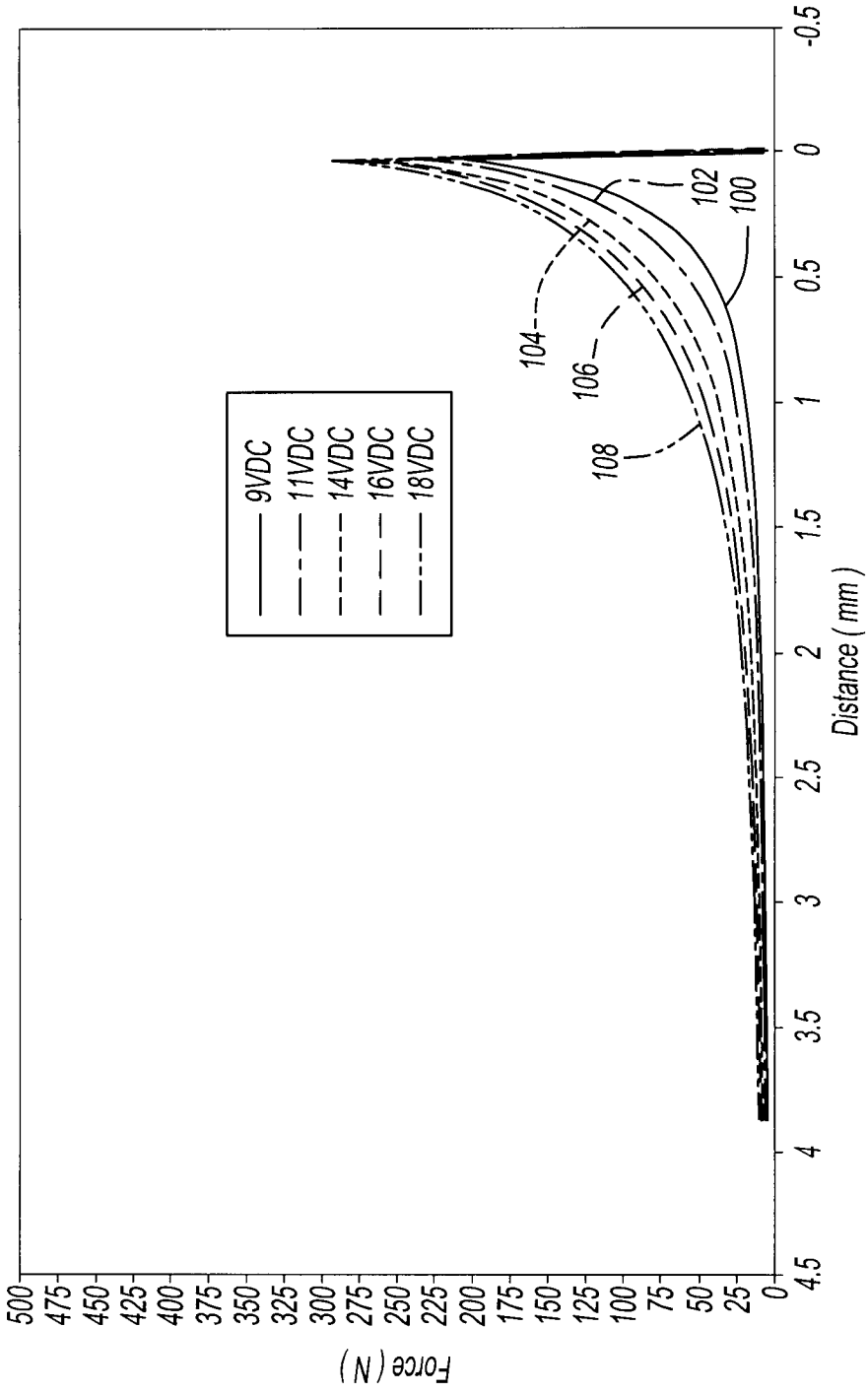

Force (N)
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
Distance (mm)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
9VDC
11VDC
14VDC
16VDC
18VDC
100
102
104
106
108

Fig-19

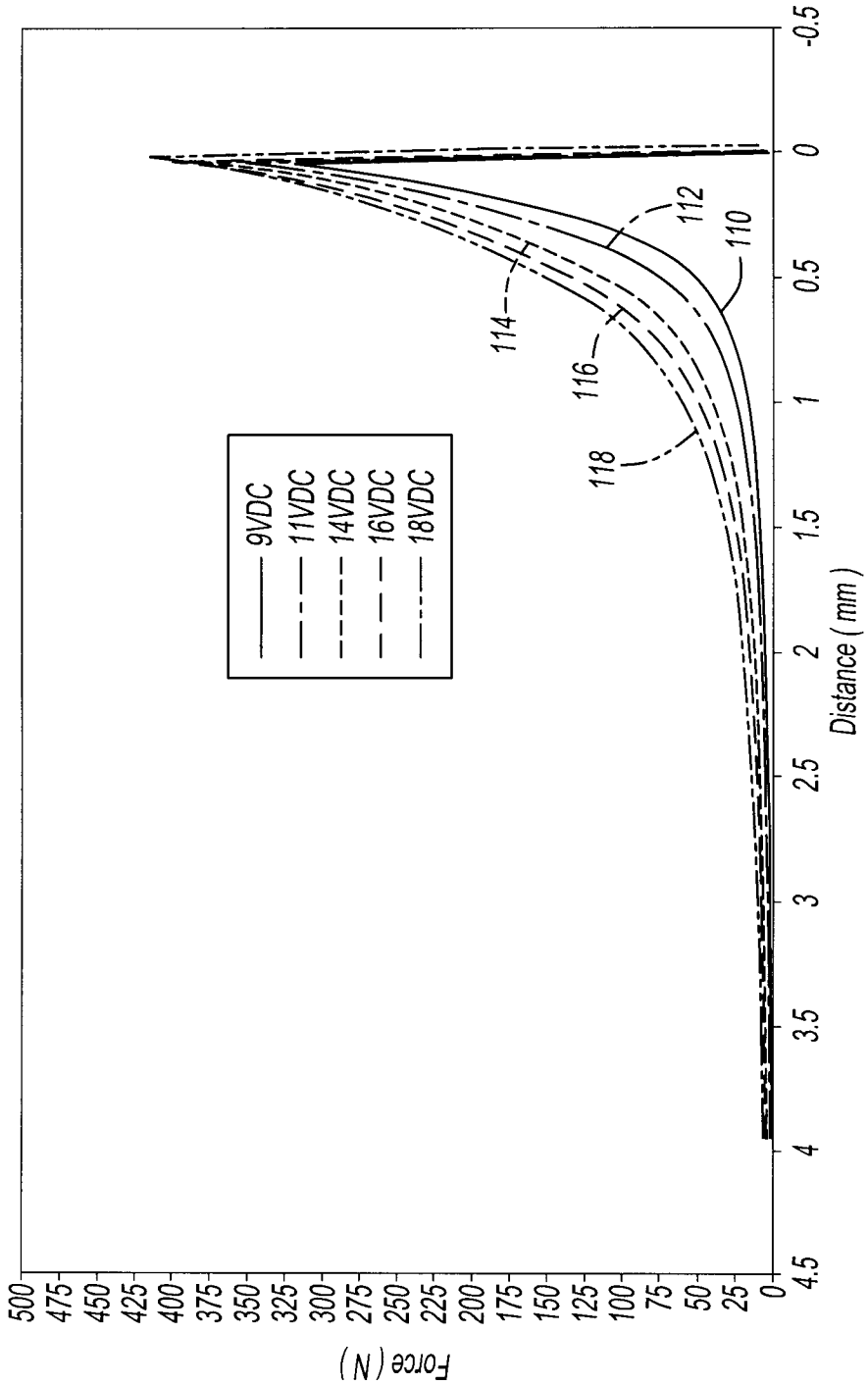

Force (N)
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
Distance (mm)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
9VDC
11VDC
14VDC
16VDC
18VDC
110
112
114
116
118

Fig-20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2011/001057

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***H01F 7/126*** (2006.01)
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)
H01F 7/126 (2006.01), ***H01F 7/08*** (2006.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Databases: Epoque EPODOC, TXTEN, Canadian patent database
Search terms: electromagnet, clutch, rotation, annular, contact, plate, ring, flange, channel, v-shaped, radially, coil

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2006/0061442 A1 (Brooks) 23 Mar. 2006 (23-03-2006) *Figs. 3 and 6; pars. 0116-0118*	1, 8 2-7 and 9-15
Y	US 5320206 A (Maejima) 14 June. 1994 (14-06-1994) *Fig. 1; col. 3, line 47 - col. 4, line 17*	2-7 and 9-15
Y	US 4958712 A (Saganuma et al) 25 Sept. 1990 (25-09-1990) *Fig. 14; col. 7, lines 45-50*	4, 6, 7 and 13
A, P	WO 2011/017811 A1 (Staniewicz et al) 17 Feb. 2011 (17-02-2011) *Figs. 1, 6, 14, pars. 3-7*	1-15

[ ] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 November 2011 (04-11-2011)	9 November 2011 (09-11-2011)

Name and mailing address of the ISA/CA	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	Howard Sandler (819) 994-0483

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2011/001057

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2006061442 A1	23 March 2006 (23-03-2006)	US7777600B2	17 August 2010 (17-08-2010)
		US2009212889A1	27 August 2009 (27-08-2009)
		US2011068884A1	24 March 2011 (24-03-2011)
		WO2006127628A1	30 November 2006 (30-11-2006)
US5320206 A	14 June 1994 (14-06-1994)	None	
US4958712 A	25 September 1990 (25-09-1990)	JP1006525A	11 January 1989 (11-01-1989)
		JP2611991B2	21 May 1997 (21-05-1997)
		JP1145434A	07 June 1989 (07-06-1989)
		JP2713712B2	16 February 1998 (16-02-1998)
WO2011017811 A1	17 February 2011 (17-02-2011)	None	