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(54) **SEGMENTED CORE CAP SYSTEM FOR TOROIDAL TRANSFORMERS**

SEGMENTIERTES KERNKAPPENSYSTEM FÜR TOROIDALE TRANSFORMATOREN

SYSTÈME À COIFFE DE NOYAU SEGMENTÉ POUR TRANSFORMATEURS TOROÏDAUX

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(56) References cited:
US-A1- 2015 228 401 **US-B1- 6 753 749**
US-B2- 7 312 686 **US-B2- 7 382 075**

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Description

TECHNICAL FIELD

[0001] The present novel technology relates generally to toroidal transformer systems, and, more particularly, to a segmented core cap for use with toroidal transformer cores and a method for using the same.

BACKGROUND

[0002] A transformer is an electrical device that transfers energy between two or more circuits through the phenomenon of electromagnetic induction. Transformers are commonly used to increase (step-up) or decrease (step-down) the voltages of alternating current in electric power applications. This is accomplished by passing a varying current through the primary winding to generate a magnetic flux in the transformer's core. This flux then induces a voltage in the transformer's secondary winding. Depending on the ratio of the primary windings to the secondary windings, the transformers output voltage can be increased or decreased.

[0003] For most transformers designed for small-scale use, such as in devices commonly used in homes or offices, one of two styles of transformers is typically used. These are transformers with either an E-I laminate or a toroidal core (See FIG. A). In a laminate transformer utilizing an E-I structure, the matching "E" and "I" components are stamped from sheets of thin grain oriented electrical steel, and the sheets are then stacked to create the core. Typically, the primary and secondary windings are wound on bobbins. Multiple bobbins are placed on spindles and spun in order to apply the windings. This method of winding the core with wire supplied on bobbins allows for automation, and so reduces the manufacturing times and also provides insulation between the windings and the core. The E-I core laminations are stacked inside the bobbins to complete the transformer.

[0004] In the case of a toroidal core, the core element is typically made from a continuous strip of silicon steel, which is wound like a tight clock spring. The ends are tacked into place with small spot welds, to prevent the coiled steel from unwinding. The core is typically insulated with an epoxy coating or a set of caps or multiple wraps of insulating film, such as MYLAR and/or NOMEX (MYLAR and NOMEX are registered trademarks, reg. no. 0559948 and 86085745, respectively, of the E. I. De Pont de Nemours and Company Corporation, a Delawar Corporation located at 1007 Market Street, Wilmington, DE 19898). The transformer's windings are applied directly onto the insulated core itself. Additional insulation is required to isolate the windings. Since the windings must be wound through the center hole of the core and the core is one piece, bobbins can't be used on toroidal transformers.

[0005] As they do not lend themselves to automation, toroidal transformers are more labor intensive to produce. However, the continuous strip of steel used in the core allows the toroidal transformer to be smaller, lighter, more efficient, and quieter than its E-I laminate counterpart. These qualities are highly desirable in many applications and justify the additional expense.

[0006] US2015/0228401 discloses a preformed insulation structure for arrangement between a first and second winding of a toroidal transformer. US7312686B discloses a housing for a toroidal transformer core, wherein the housing comprises two half shells 34, 36. US6753749B discloses a toroidal transformer enclosure having two annular housing members.

[0007] Thus, there is a need for a toroidal transformer that enjoys the advantages of be smaller size, lighter weight, increased efficiency, and quieter operation while overcoming the drawbacks of being labor intensive and more expensive to produce. The present novel technology addresses these needs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a better understanding of the nature and objects of the present novel technology, reference should be made to the following drawings, in which:

FIG. A is a schematic diagram generally illustrating E-I and toroidal transformer designs of the PRIOR ART.
FIG. 1A is a first perspective view of a toroidal cap segment according to a first embodiment of the present novel technology.
FIG. 1B is a top plan view of FIG. 1A.
FIG. 1C is a second perspective view of FIG. 1A.
FIG. 1D is a third perspective view of FIG. 1A.
FIG. 2A is a first perspective view of a toroidal cap segment according to a second embodiment of the present novel technology.
FIG. 2B is a top plan view of FIG. 2A.
FIG. 2C is a second perspective view of FIG. 2A.
FIG. 2D is a third perspective view of FIG. 2A.
FIG. 3 is a perspective view of a toroidal cap segment according to a third embodiment of the present novel technology.
FIG. 4 is a perspective view of a toroidal cap segment according to a fourth embodiment of the present novel technology.
FIG. 5A is a top perspective view of a plurality of segments forming a toroidal core cap ring according to a fifth embodiment of the present novel technology.
FIG. 5B is a bottom perspective view of FIG. 5B.
FIG. 6A is a top perspective view of a plurality of segments forming a toroidal core cap ring according to a sixth embodiment of the present novel technology.
FIG. 6B is a bottom perspective view of FIG. 6B.
FIG. 7 A is a bottom perspective view of a winding tool according to a seventh embodiment

FGI. 7B is a perspective view of a wire lock tool for use with FIG. 7A.

FIG. 8A is a perspective view of a partially wound core using the present novel technology.

FIG. 8B is another perspective view of another partially wound core.

FIG. 9 is a perspective view of a toroidal transformer including the segmented core caps of the present novel technology.

FIG. 10A is a perspective view of an eighth embodiment not forming part of the present invention

FIG. 10B is a second perspective view of FIG. 10A.

FIG. 11A is a top plan view of a ninth embodiment of the present novel technology.

FIG. 11B is a bottom plan view of FIG. 11A.

FIG. 11C is a perspective view of FIG. 11A.

DETAILED DESCRIPTION

[0009] For the purposes of promoting an understanding of the principles of the novel technology, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the novel technology is thereby intended, such alterations and further modifications in the illustrated device, and such further applications of the principles of the novel technology as illustrated therein being contemplated as would normally occur to one skilled in the art to which the novel technology relates.

[0010] Embodiments of the present novel technology are illustrated in FIGs. 1-11B, and relate to segmented or modular electrically insulating core caps 10 for supporting primary and secondary windings, typically in alternate sectors, to reduce leakage current. Pluralities of individual modular electrically insulating segments 15 typically snap, or otherwise join, together to define annular or semi-annular modular core caps 10 for covering or partially covering a (typically steel) ring-type toroidal transformer core 20. The segments or modules 15 are typically made from an insulating material, such as nylon, ZYTEL, or the like (ZYTEL is a registered trademark, reg. no. 71666270, of the E.I. Du Pont De Nemours and Company Corporation, 1007 Market Street, Wilmington, Delaware 19898).

[0011] The core cap modules 15/completed core caps 10 insulate windings from the core 20 over the full range of the windings, and allow for double wall insulation between adjacent windings, significantly reducing leakage current over the prior art systems. The core cap modules 15/completed core caps 10 also provide for direct cooling of the core 20 by ambient or forced air without intervening insulation. The core 20 may be assembled from component modules 15 over a completed, wound toroidal core 20.The core caps 10 allow for winding 25 of the transformer 30 using standard winding equipment while maintaining a direct path for waste heat to escape, as there is no need for interwinding insulation that can trap heat. Further, the core caps 10 eliminate the need for center fill epoxy and/or mounting washers, so the weight of the transformer 30 is reduced.

[0012] In most embodiments, the segments 15 each include a pair of spaced, typically electrically insulating, wall members 35 between which a core covering panel portion 40 is connected. The wall members 35 are disposed at a predetermined angle relative to each other, typically 30 degrees, 45 degrees, 60 degrees, or the like so that each modular segment 15 spans an arc of about 30 degrees, 45 degrees, 60 degrees or the like. The respective spaced walls 35 include removably engagable, typically male and a female, connector portions 45A, 45B, respectively, such that adjacently disposed segments 15 may be repeatedly removably engaged with one another, with sufficient connected segment portions 15 defining an annular core cap 10. The number of segments 15 required to complete a core cap 10 is predetermined and is typically a function of the predetermined angle between the wall s 35; for example, if the angle is 45 degrees, eight segments 15 will be required to be connected together to define a ring 10. If the angle is sixty degrees, only six segments 15 will be required to define a ring 10. While core caps 10 are typically built from identical core cap modules 15 core caps 10 may alternately include combinations of core cap modules 15 spanning different arcs, such as four core cap modules 15 spanning forty-five degrees each and six core cap modules 15 spanning thirty degrees each. While identically sized and shaped modules 15 are typically more convenient, there are no practical restrictions on the combinations of core cap module 15 sizes and shapes that may be combined to yield a custom core cap 10 having desired properties and characteristics.

[0013] Typically, the wall s 35 engage the panel 40 to define a relatively flat or flush core-engaging side or surface (defining the bottom or underside 70 of the segment 35 and ring 10, located in the downward direction) and disposed opposite the barriers 75 established by two joined or locked together wall s 35 (defining by the wire-segmenting or topside 80 of the ring 10, located in the upward direction). The barriers 75 define the parameters between which alternating wire windings are restricted, typically alternating primary and secondary windings.

[0014] In some embodiments, the segments 15 include one or more separation or wall members 50 positioned to partially or completely extend across the topside 75 of the panel 40 to further define parameters between which wire windings are directed. The one or more separation members 50 are typically positioned equidistantly between the wall s 35 and/or each other 50, respectively. The one or more separation members 50 are typically oriented to extend radially outwardly from the center of the core 20 and/or the annulus 10 defined by the joined segments 15; in other words, each respective separation member 50 typically lies on a radius of the annulus 10, although the separation walls 50 may have other convenient shapes and contours as desired.

[0015] In some embodiments, the segments 35 further include a core outer diameter or OD cover panel 55 and/or a core inner diameter or ID cover panel 60, both extending downwardly so as to at least partially cover the OD and ID, respectively, of a toroidal core ring placed against the core cover panels 40 of a partially or completely formed annulus 10. These panels 55, 60 may be flat for covering a core ring 20 having flat outer and inner diameter sides, or curved to follow a core ring 20 having a rounded or curved inner and outer diameter portions (see FIGs. 10A-B)

[0016] In some embodiments, the wall members 35 are truncated and do not extend across the panels 40. In some of these embodiments, lower wall members 65 are positioned opposite the panel 40 from the respective wall members 35. The lower wall members 65 may likewise include matable connectors for co-joining.

[0017] In some embodiments, the segments 35 include ribs positioned on the upper side of the panels 40, so as to generate an air gap between wire windings and the topside 80 of the ring 10. The production of an air gap facilitates air cooling of windings by allowing air to circulate between windings and the topside 80 of the cap 10.

[0018] In some embodiments, a winding tool 100 is included to facilitate the winding of a capped core from a single bobbin. The winding tool 100 is typically a flat ring 105 having a projecting rim or flange 110 extending from the outer diameter thereof. The ring 100 typically includes a slot 115 formed there through, such that the ring 110 has a C-shape. The ring 110 is sized to accept a segment 15 therein, with the slot 115 sized to pass wire onto a segment 15 aligned therewith. Winding tool 100 further typically includes an elongated arced wire lock member 120 having a plurality of slots 125 formed partially therethrough and one or more locking apertures 127 formed therethrough for connecting the wire lock member 120 to one or more segments 15 during the wire winding process.

[0019] In operation, a plurality of segments 15 are connected to one another to define a ring 10. The ring 10 includes an annular core top cover portion 140 defined by the panels 40 of the individual segments 15. In most embodiments, the ring 10 also includes (typically) equidistantly spaced radial protrusions 145, defined by mutually engaged connectors 45A, B, extending outwardly from the ring 10. Each radial protrusion 145 is typically part of an elongated wall member 135 positioned on the topside 80 of the ring 10 and extending radially inwardly partway or completely across the topside surface 80. Some of the wall s 135 terminate in radial protrusions 165 extending inwardly from the ring 10. These radial protrusions 165 are typically formed from the joinder of two lower wall s 65, although they may be formed separately.

[0020] The ring 10 may also include an annular core outer diameter cover member 155 and/or an annular core inner diameter cover member 160, each cover member 155, 160 positioned generally perpendicular to the core top cover portion 140 and extending downwardly away therefrom. The respective cover members 155, 160 are typically composed of adjacent cover panels 55, 60 when the segments 15 are connected to define the ring 10.

[0021] Typically, a pair of cap rings 10 are constructed from connected segments 15 and positioned on opposite sides of a toroidal core 20 with outward protrusions 145 aligned. Typically, an even number of segments 15 are connected to make each ring 10. Wire is wound contiguously around alternating segments 15 to define the primary windings 161, with N windings per segment 15. Wire is wound contiguously around the remaining segments 15, in multiples of N windings per segment 15, to define the secondary windings 163. Typically, all of the windings 161, 163 may be accomplished from a single bobbin or shuttle in one contiguous bobbin winding 25 operation, with wire guided from one segment 15 to the next through the groove or gap 170 between the two opposite core caps 10. The wire is typically cut or severed to isolate the primary windings 161 from the secondary windings 163, and the wound core 175 may then be wrapped in insulation 180 to define a toroidal transformer 200. In some embodiments, the winding tool 100 may be utilized to facilitate core winding. Coils 20 so wound retain the advantages of toroidal transformers while enjoying the benefits of being lighter, smaller, more efficient and quieter than E-I laminate cores. Cores 20 so wound exhibit reduced interwinding leakage current when compared with standard wound toroidal transformer cores.

[0022] Typically, the primary windings 161 will occupy the odd numbered segments 15, starting with the first segment wound, and the secondary windings 163 will occupy the even numbered segments 15. In some embodiments, each ring 10 may contain multiples of three segments 15, such as six, nine, or twelve, and the core 20 may be wound with primary 161, secondary 163 and tertiary (not shown) windings as above to yield a three-phase transformer. In other embodiments, the ring may contain segments 15 having different configurations (see FIGs. 11A-11C).

[0023] In some embodiments, an insulating material, such as a MYLAR strip, is positioned to cover the portion of the core 20 exposed by the gap 170. In other embodiments, the core 20 is partially or completely wrapped in an insulating material prior to the positioning of the cap(s) 10 thereupon. In still other embodiments, wall members 35 are spaced and oriented relative each other to define an annulus, but are not physically connected to each other. In most embodiments, the wire wrapping the core 20 is sheathed in an insulating layer or film.

[0024] While the novel technology has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character. It is understood that the embodiments have been shown and described in the foregoing specification in satisfaction of the best mode and enablement requirements. It is understood that one of ordinary skill in the art could readily make a nigh-infinite number of insubstantial changes and modifications to the above-described embodiments and that it would be impractical to attempt to describe all such embodiment variations in the present specification. Accordingly, it is understood that changes and modifications may be possible within the scope of the present invention defined by the present set of claims.

Claims

1. A modular core cap system (10) for a toroidal transformer (20), the system comprising:

a plurality of cap segments (15), wherein each respective cap segment comprises:

first and second spaced elongated wall members (35);
a first connector member (45A, 45B) connected to the first elongated wall member;
a second connector member (45A, 45B) operationally connectable to a first connector member of another one of the plurality of cap segments and connected to the second elongated wall member;
a generally flat panel member (40) connected to and extending between the first and second elongated wall members;
wherein the first and second wall members are disposed at a predetermined angle relative one another; and
wherein the first and second elongated wall members and the panel member are electrically non-conducting; and

wherein an integral number of the plurality of cap segments are configured to be joined together in use, to define an annular core cap (10) of which each respective cap segment spans an arc in annular direction.

2. The modular core cap system of claim 1 wherein the angle between the first and second elongated wall members is:

a) 30 degrees; or
b) 60 degrees; or
c) 45 degrees.

3. The modular core cap system of claim 1, further comprising a first elongated curved cover member (155, 160) extending between the first and second elongated wall members and a second spaced elongated curved cover member (155, 160) extending between the first and second elongated wall members, wherein the respective cover members are oriented generally perpendicular to the panel member and wherein the panel member is disposed between the respective spaced cover members.

4. The modular core cap system of claim 1 wherein the segments are made of nylon.

5. The modular core cap system of claim 1 wherein each respective segment further comprises a respective elongated raised rib extending from each respective panel member for providing an air gap under wire windings, when such wire windings are provided to the modular core cap system.

Patentansprüche

1. Modulares Kernkappensystem (10) für einen toroidförmigen Transformator (20), wobei das System Folgendes umfasst:

mehrere Kappensegmente (15), wobei jedes entsprechende Kappensegment Folgendes umfasst:

ein erstes und ein zweites langgestrecktes Wandelement (35), die voneinander beanstandet sind;
ein erstes Verbinderelement (45A, 45B), das mit dem ersten langgestreckten Wandelement verbunden ist;
ein zweites Verbinderelement (45A, 45B), das mit einem ersten Verbinderelement eines weiteren der mehreren Kappensegmente funktionstechnisch verbunden werden kann und mit dem zweiten langgestreckten Wandelement verbunden ist;
ein im Allgemeinen flaches Plattenelement (40), das mit dem ersten und dem zweiten langgestreckten Wandelement verbunden ist und sich zwischen ihnen erstreckt;
wobei das erste und das zweite Wandelement unter einem vorgegebenen gegenseitigen Winkel angeordnet sind; und
wobei das erste und das zweite langgestreckte Wandelement und das Plattenelement nicht elektrisch leitend sind; und

wobei eine ganze Zahl der mehreren Kappensegmente konfiguriert sind, im Gebrauch miteinander verbunden zu werden, um eine ringförmige Kernkappe (10) zu definieren, wobei jedes entsprechende Kappensegment in Winkelrichtung einen Bogen überspannt.

2. Modulares Kernkappensystem nach Anspruch 1, wobei der Winkel zwischen dem ersten und dem zweiten langgestreckten Wandelement

a) 30 Grad; oder
b) 60 Grad; oder
c) 45 Grad

beträgt.

3. Modulares Kernkappensystem nach Anspruch 1, das ferner ein erstes langgestrecktes gekrümmtes Abdeckelement (155, 160), das sich zwischen dem ersten und dem zweiten langgestreckten Wandelement erstreckt, und ein hiervon beabstandetes zweites langgestrecktes gekrümmtes Abdeckelement (155, 160), das sich zwischen dem ersten und dem zweiten langgestreckten Wandelement erstreckt, umfasst, wobei die jeweiligen Abdeckelemente im Allgemeinen senkrecht zu dem Plattenelement orientiert sind und wobei das Plattenelement zwischen den jeweiligen beabstandeten abdeckt Elementen angeordnet ist.

4. Modulares Kernkappensystem nach Anspruch 1, wobei die Segmente aus Nylon hergestellt sind.

5. Modulares Kernkappensystem nach Anspruch 1, wobei jedes entsprechende Segment ferner eine entsprechende langgestreckte aufrecht stehende Rippe aufweist, die sich von jedem entsprechenden Plattenelement erstreckt, um unter Drahtwicklungen einen Luftspalt bereitzustellen, wenn für das modulare Kernkappensystem solche Drahtwicklungen bereitgestellt sind.

Revendications

1. Système modulaire (10) à coiffe de noyau pour un transformateur toroïdal (20), le système comportant :

une pluralité de segments (15) de coiffe, chaque segment de coiffe respectif comportant :

des premier et second éléments (35) de paroi allongés espacés ;
un premier élément (45A, 45B) de connecteur lié au premier élément de paroi allongé ;
un second élément (45A, 45B) de connecteur pouvant être lié opérationnellement à un premier élément de connecteur d'un autre segment de la pluralité de segments de coiffe et lié au second élément de paroi allongé ;
un élément (40) de panneau généralement plat lié aux premier et second éléments de paroi allongés et s'étendant entre ceux-ci ;
les premier et second éléments de paroi étant disposés à un angle prédéterminé l'un par rapport à l'autre ; et
les premier et second éléments de paroi allongés et l'élément de panneau étant électriquement non conducteurs ; et

un nombre entier de la pluralité de segments de coiffe étant configurés pour être joints ensemble en couts d'utilisation, pour définir une coiffe annulaire (10) de noyau dont chaque segment respectif de coiffe couvre un arc dans une direction annulaire.

2. Système modulaire à coiffe de noyau selon la revendication 1, l'angle entre les premier et second éléments de paroi allongés étant de :

a) 30 degrés ; ou
b) 60 degrés ; ou
c) 45 degrés.

3. Système modulaire à coiffe de noyau selon la revendication 1, comportant en outre un premier élément (155, 160) de couvercle incurvé allongé s'étendant entre les premier et second éléments de paroi allongés et un second (155, 160) élément de couvercle incurvé allongé espacé s'étendant entre les premier et second éléments de paroi allongés, les éléments de couvercle respectifs étant orientés généralement perpendiculairement à l'élément de panneau et l'élément de panneau étant disposé entre les éléments de couvercle espacés respectifs.

4. Système modulaire à coiffe de noyau selon la revendication 1, les segments étant constitués de nylon.

5. Système modulaire à coiffe de noyau selon la revendication 1, chaque segment respectif comportant en outre une nervure surélevée allongée respective s'étendant à partir de chaque élément de panneau respectif pour ménager un entrefer sous des enroulements de fil, lorsque ces enroulements de fil équipent le système modulaire à coiffe de noyau.

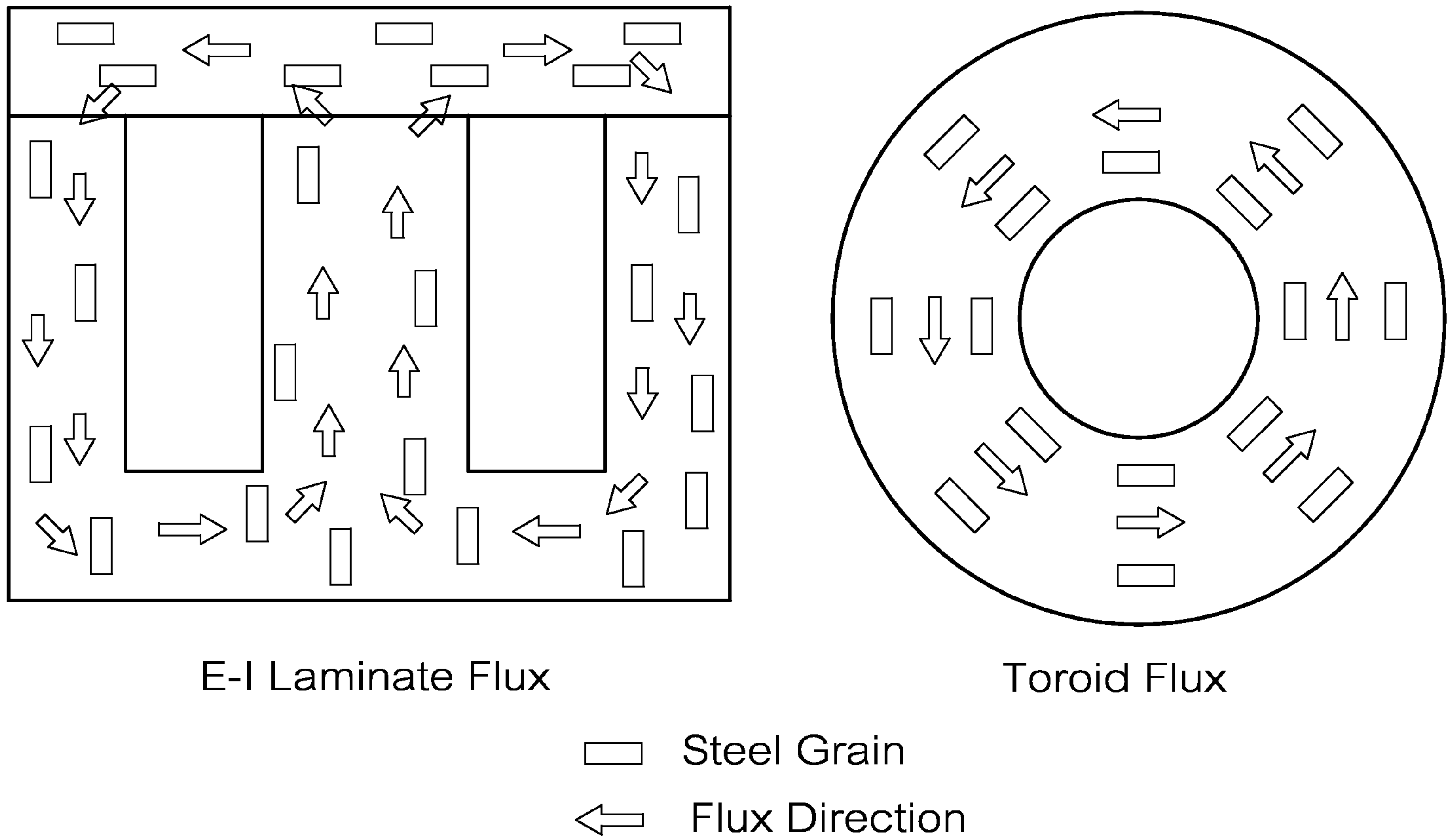

Fig. A
(Prior Art)

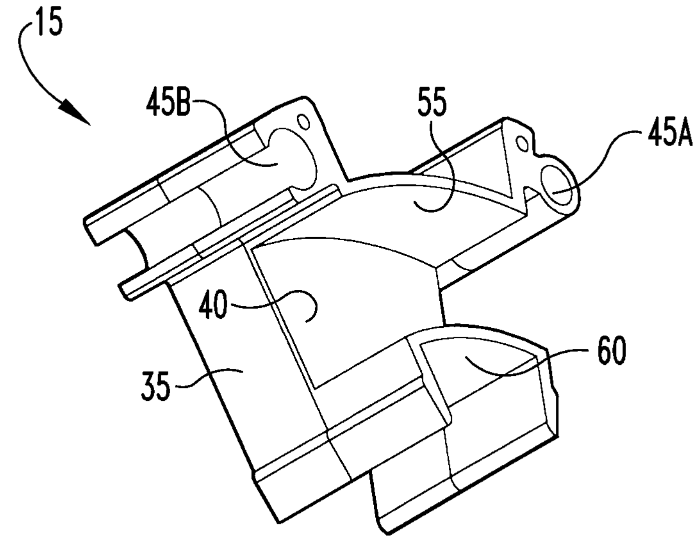

Fig. 1A

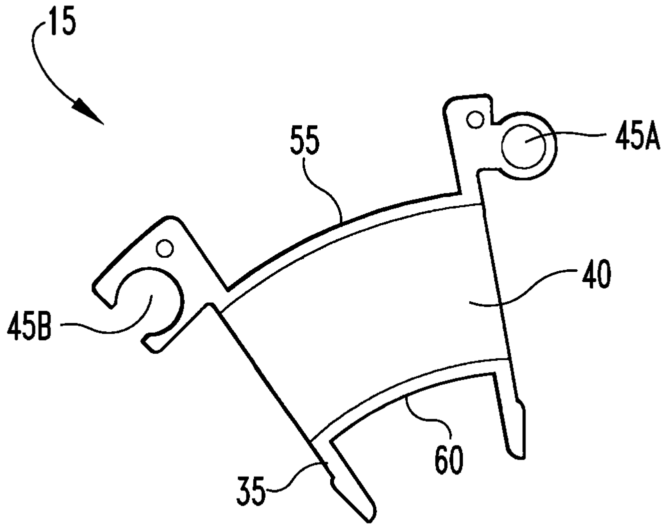

Fig. 1B

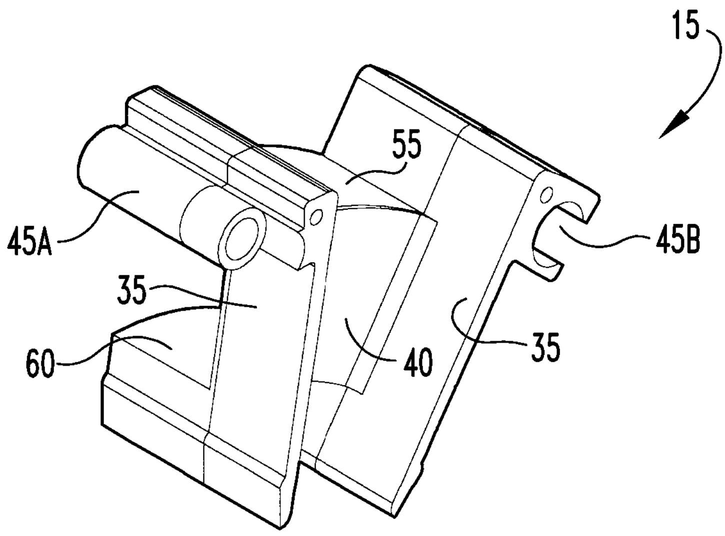

Fig. 1C

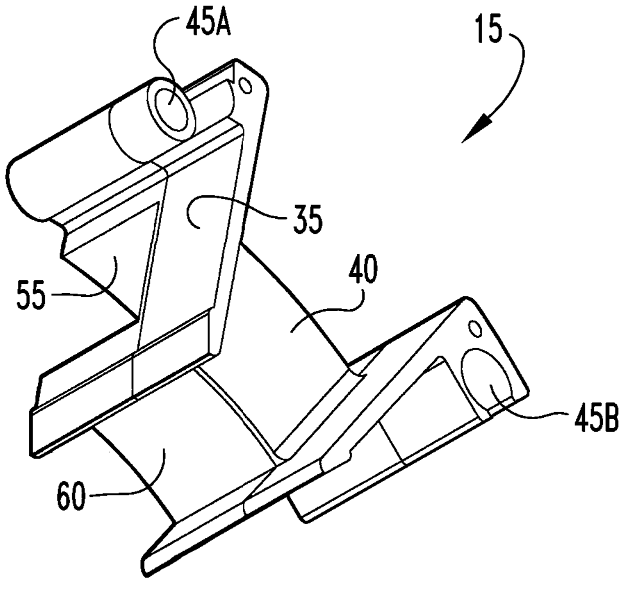

Fig. 1D

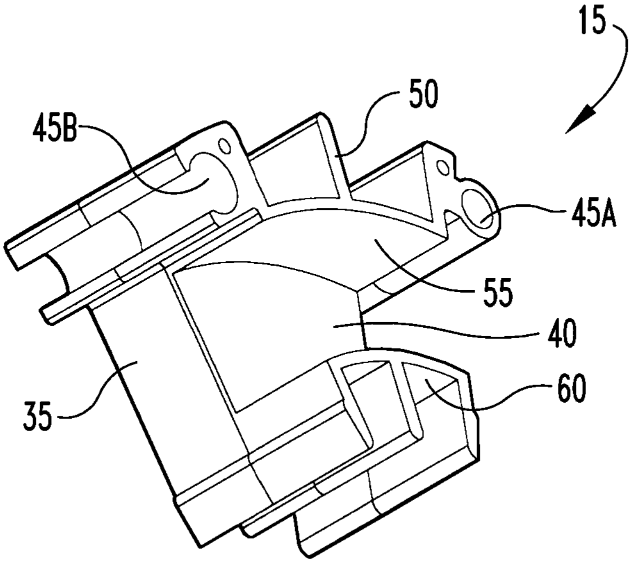

Fig. 2A

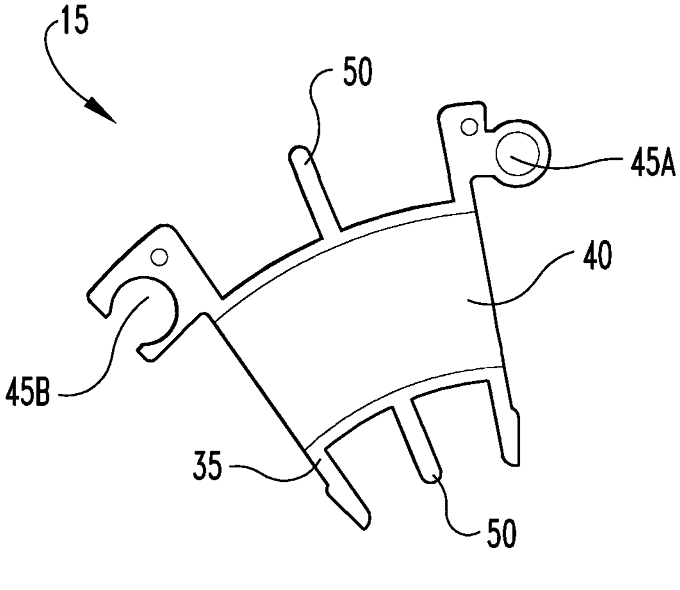

Fig. 2B

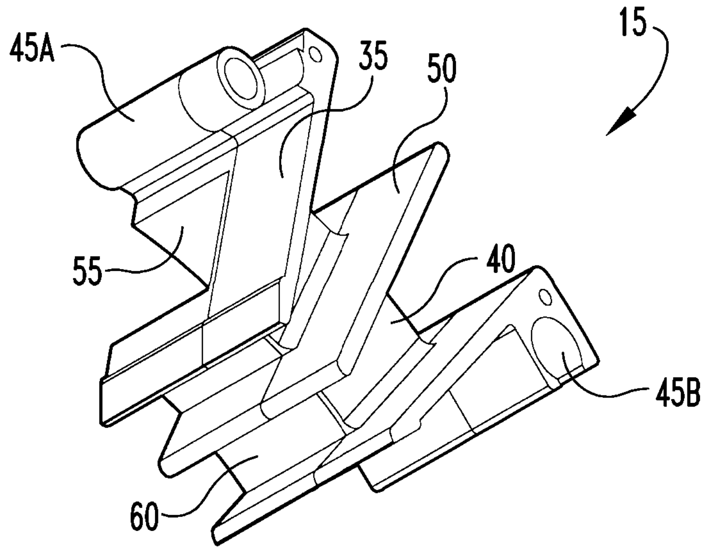

Fig. 2C

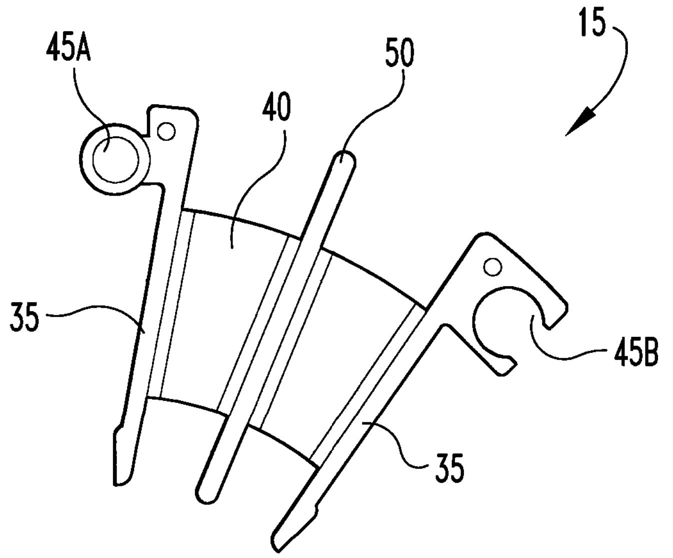

Fig. 2D

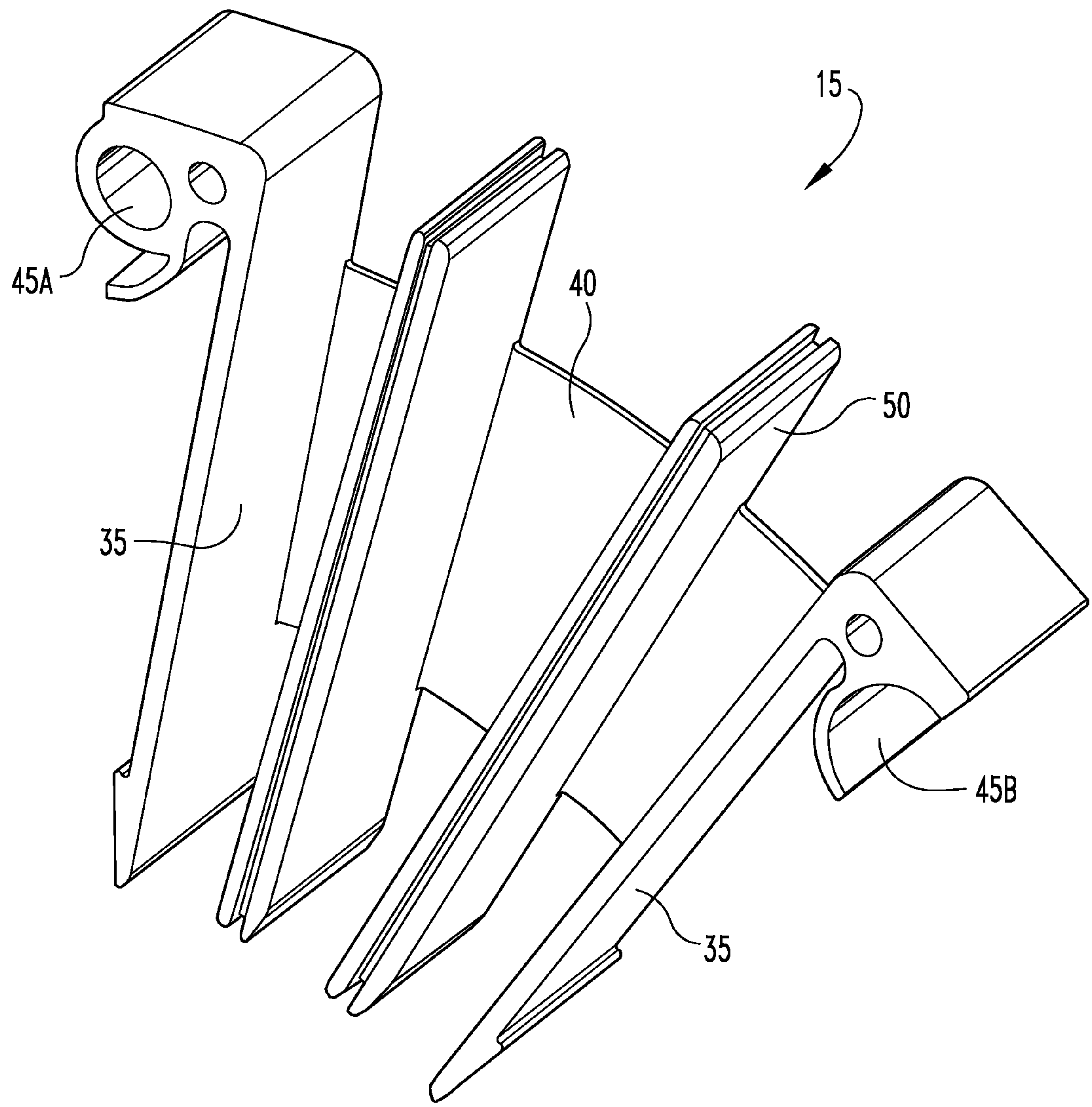

Fig. 3

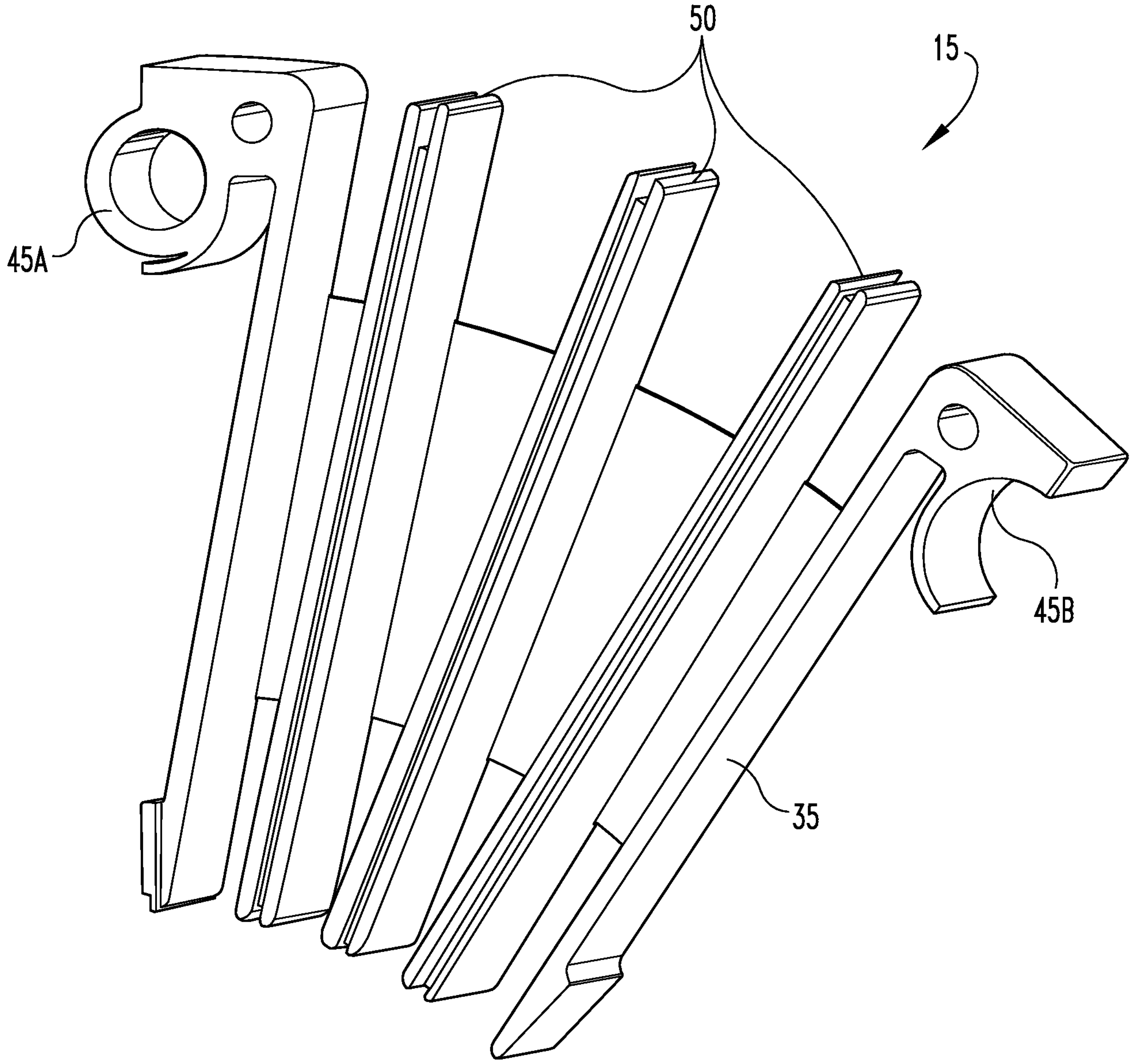

Fig. 4

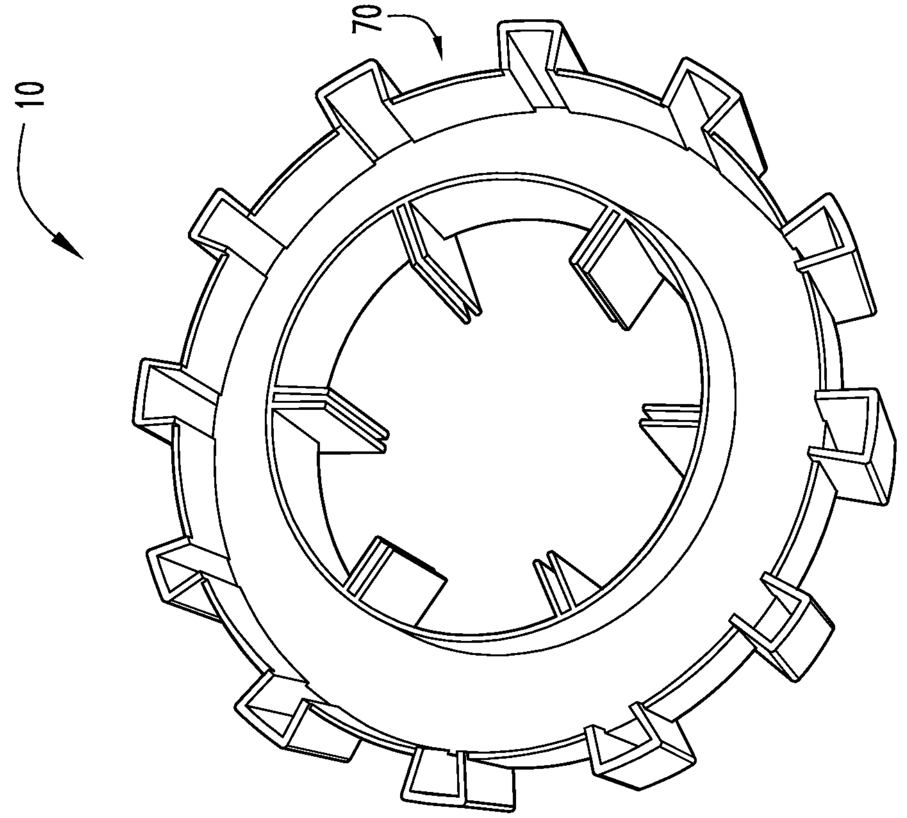

Fig. 5B

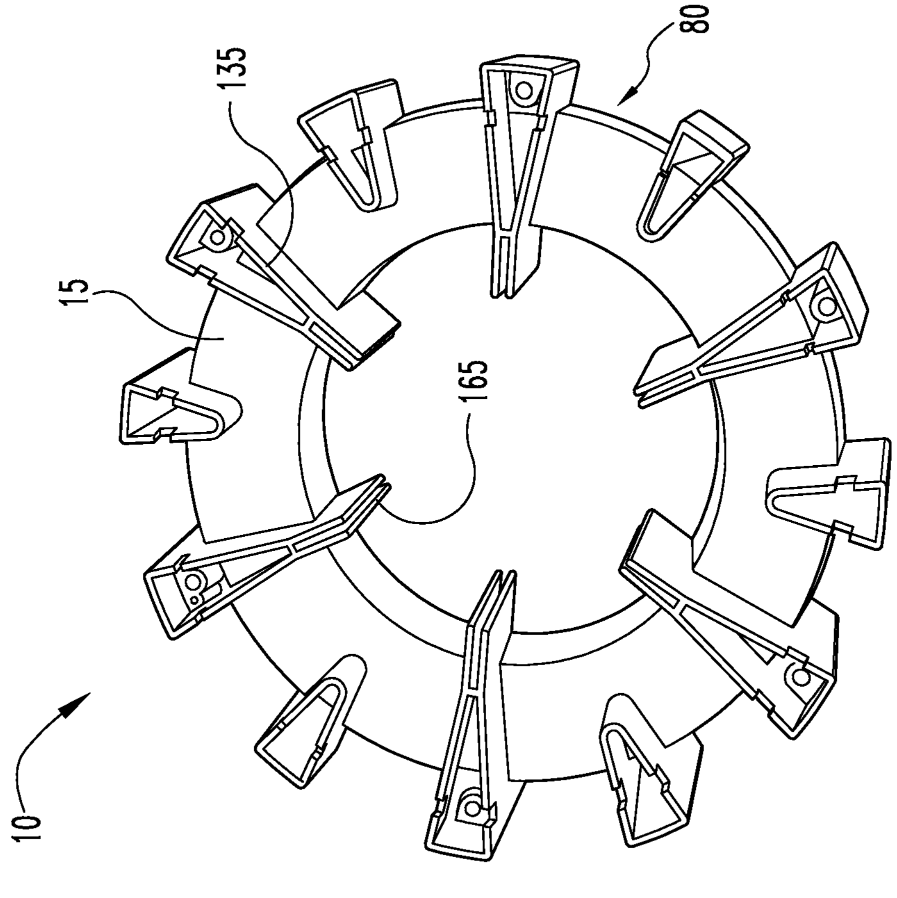

Fig. 5A

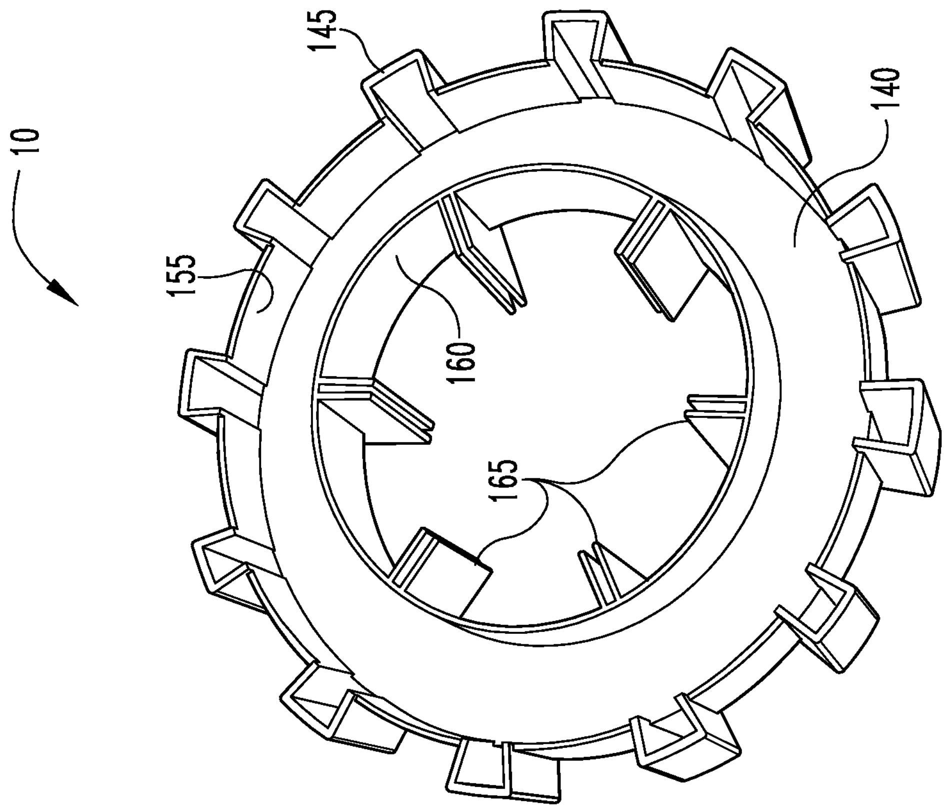

Fig. 6B

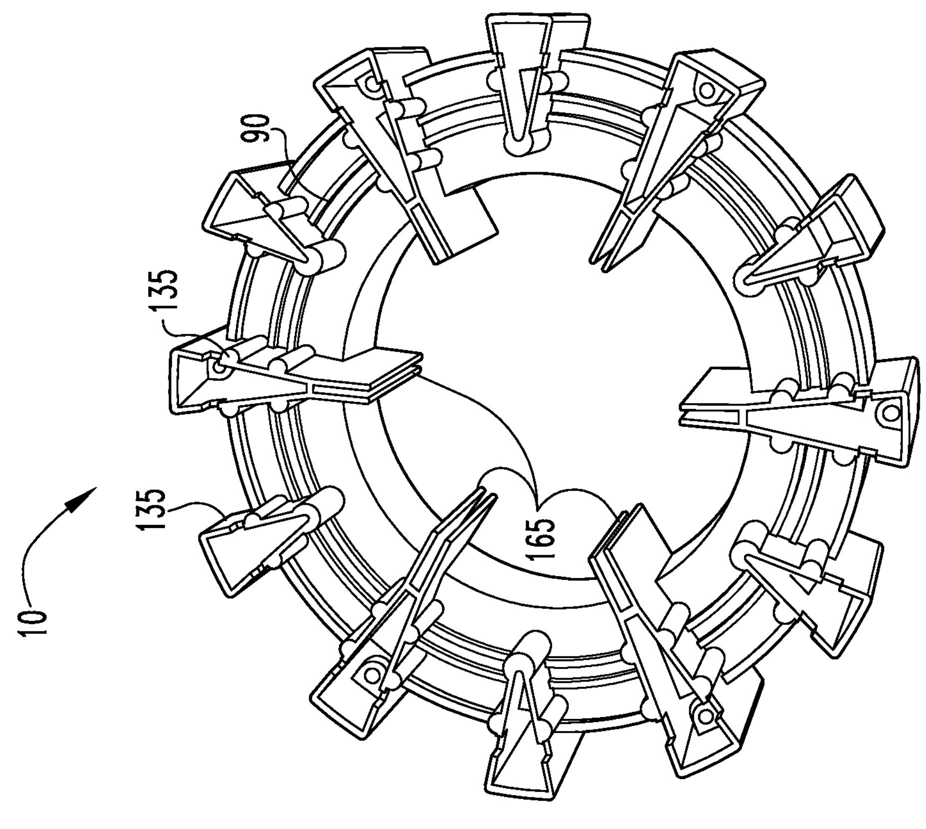

Fig. 6A

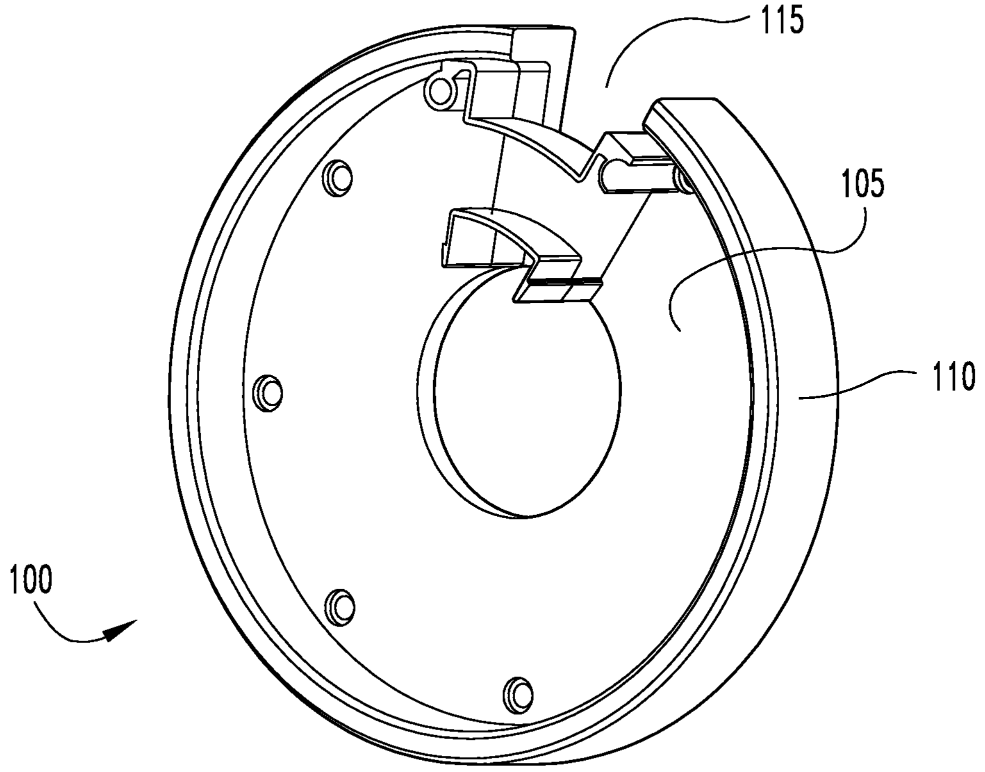

Fig. 7A

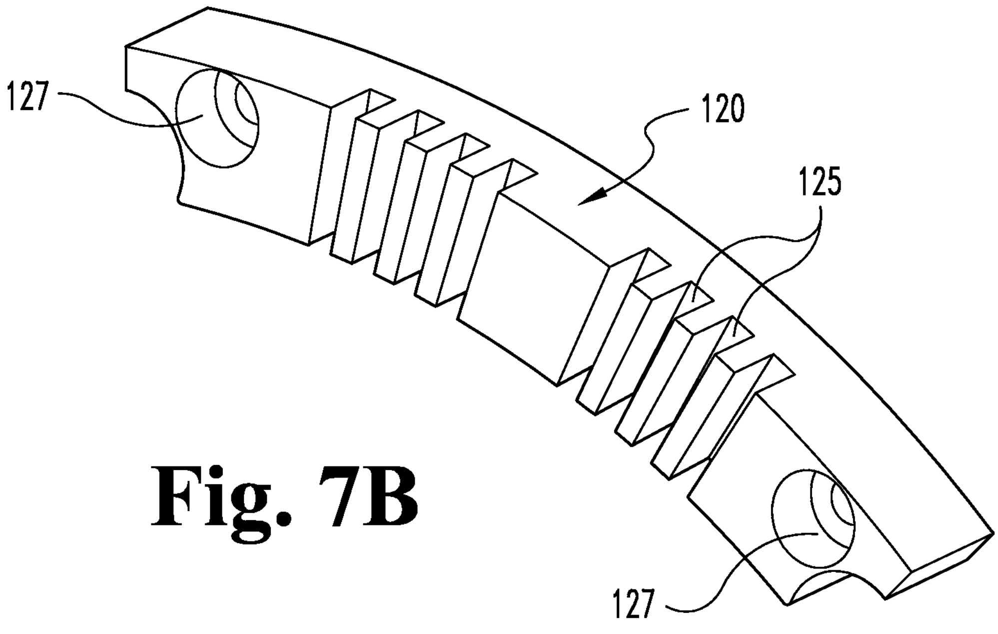

Fig. 7B

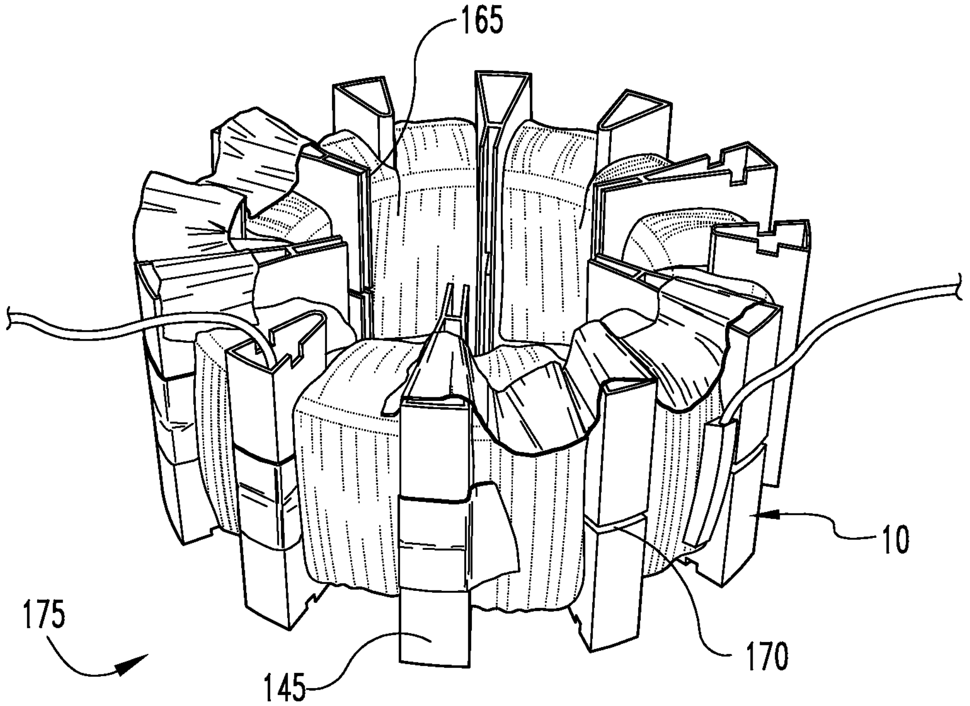

Fig. 8A

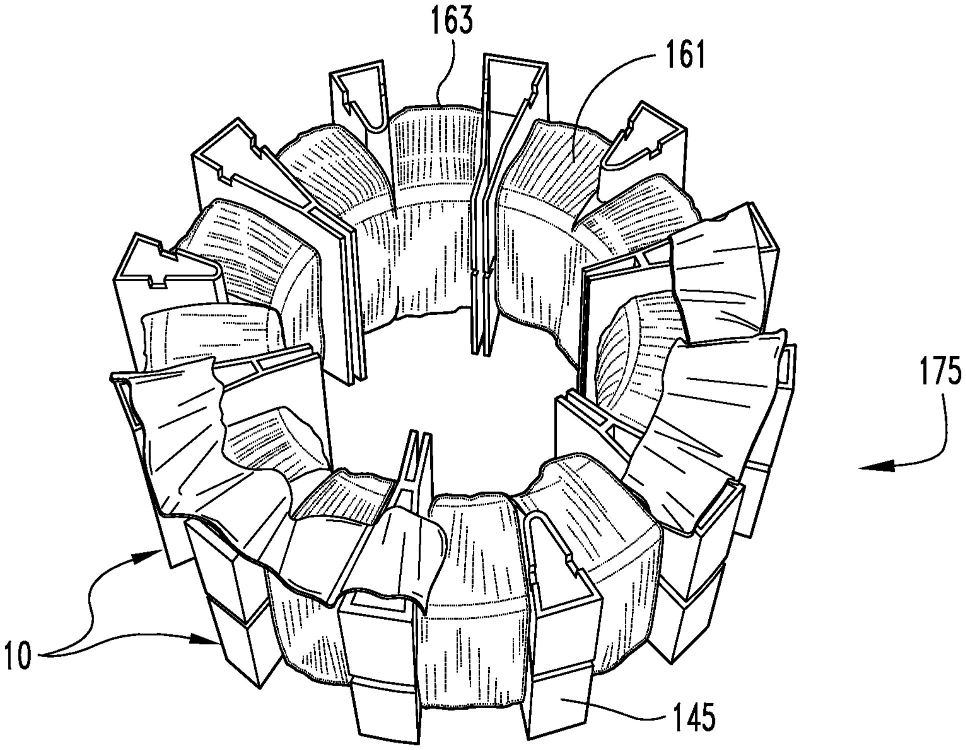

Fig. 8B

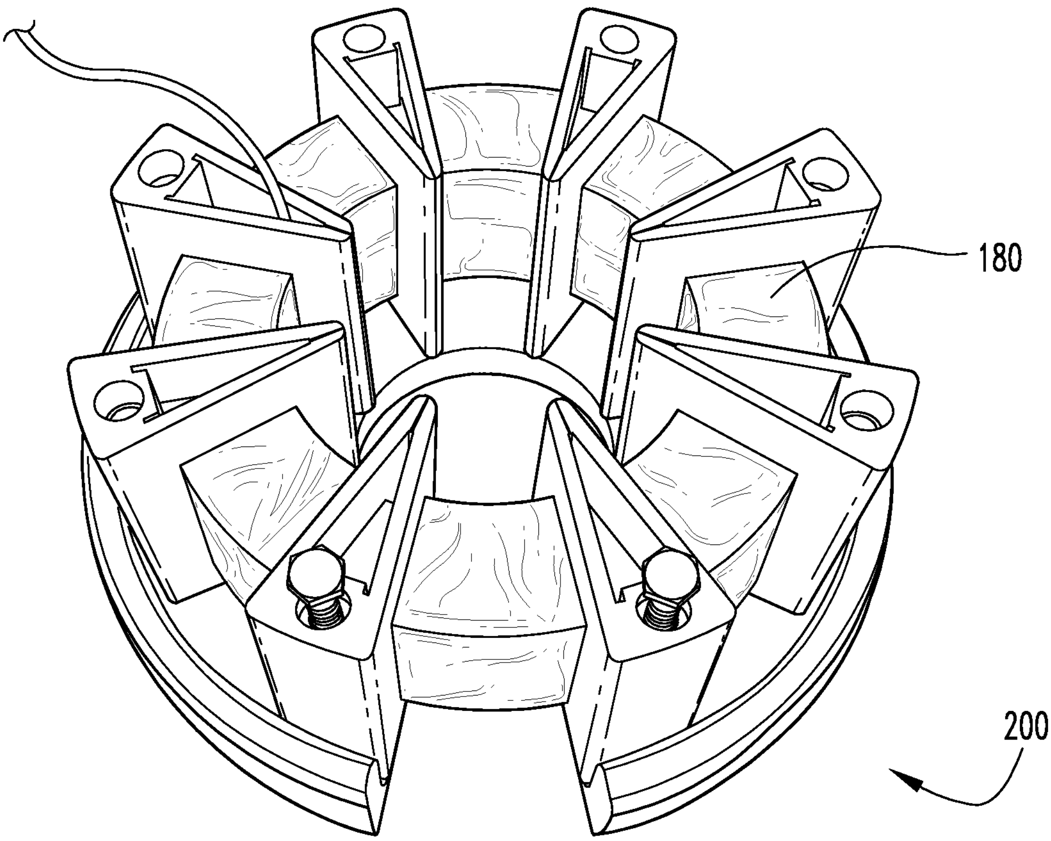

Fig. 9

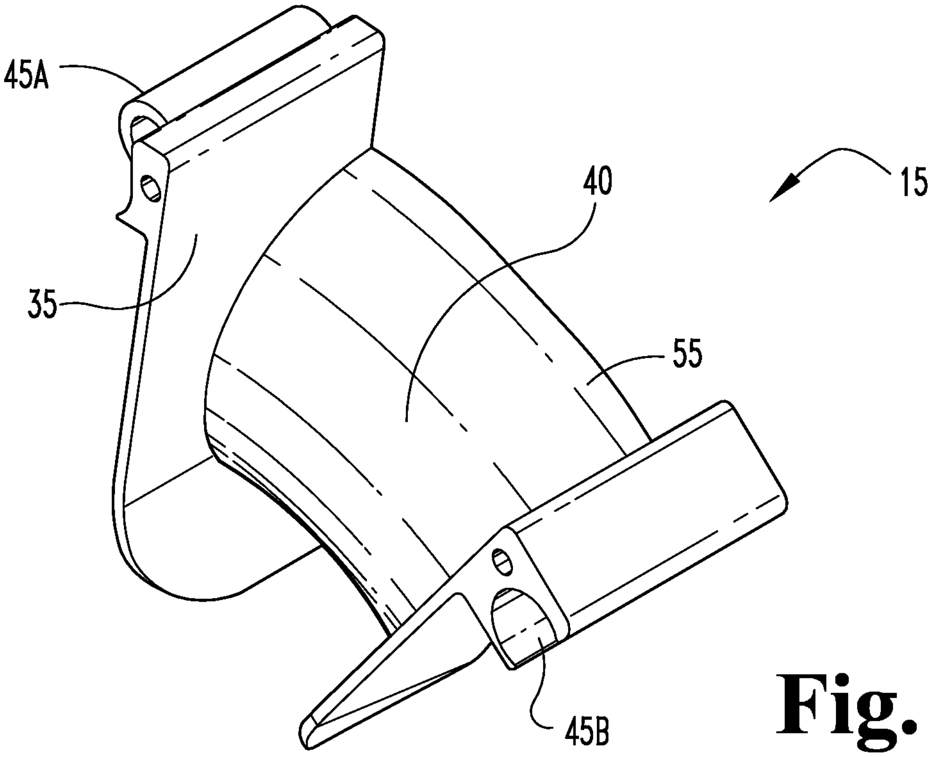

Fig. 10A

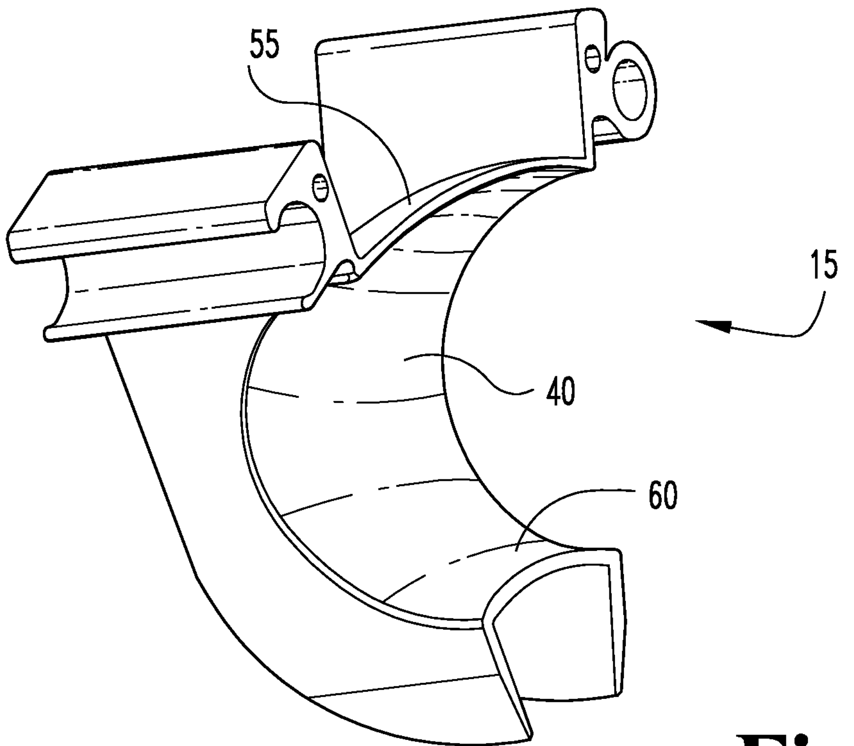

Fig. 10B

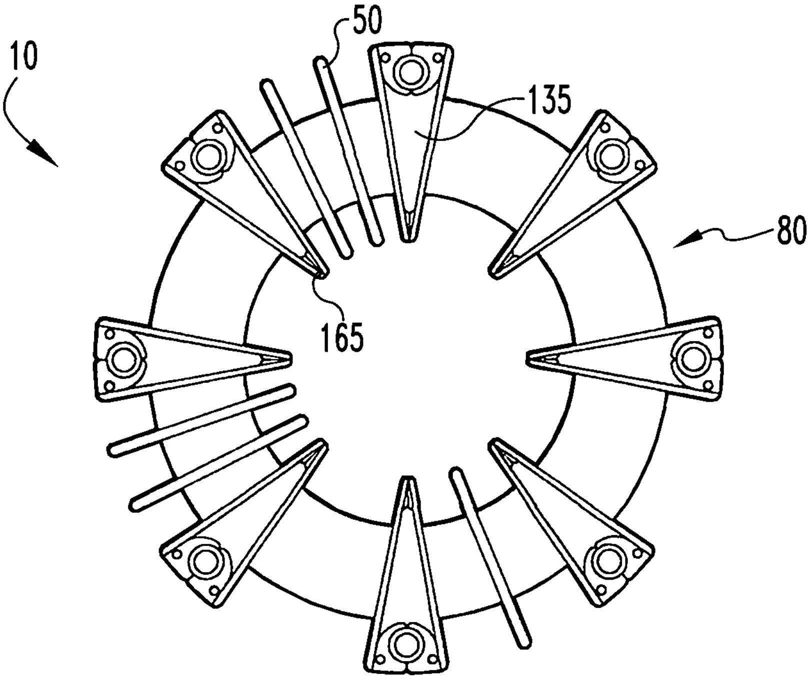

Fig. 11A

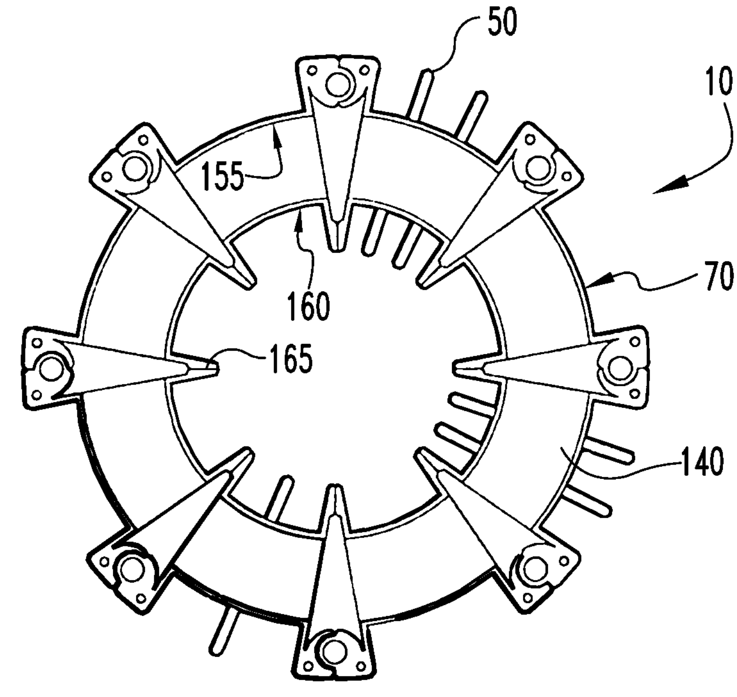

Fig. 11B

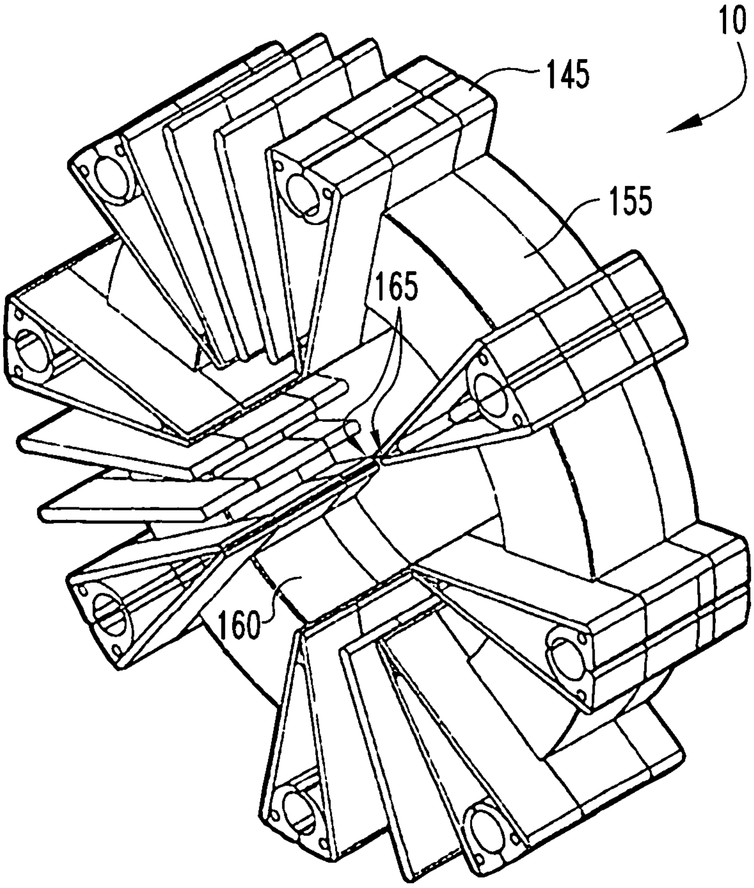

Fig. 11C

REFERENCES CITED IN THE DESCRIPTION

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