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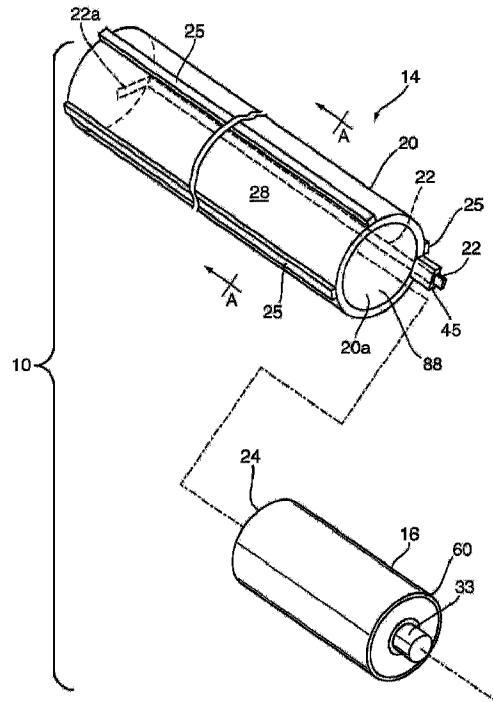
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(54) Titre : BATTERIE AUX VIBRATIONS AMORTIES, COMPARTIMENT DE BATTERIE ET BLOC-BATTERIE DESTINE
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(54) Title: VIBRATION-DAMPED BATTERY, BATTERY CONTAINER, AND BATTERY PACK FOR USE DOWNHOLE



(57) Abrégé/Abstract:

A battery, a battery container, and a battery pack, for use downhole in MWD operations, one or more of which incorporates lateral vibration damping. In a preferred embodiment each comprise specialized lateral vibration damping in the form of a plurality of

(57) Abrégé(suite)/Abstract(continued):

longitudinally-extending resiliently-deformable ridges extending substantially a length of each and circumferentially spaced about an outer periphery. The resiliently-deformable ridges on the battery may be integrally formed and extend radially outwardly from a hollow resiliently-deformable sleeve, and formed of the same resiliently-deformable material of which the sleeve is comprised. The resiliently-deformable ridges on the battery container may extend radially inwardly or outwardly from a periphery thereof. Advantageously, the battery container can thus be free of potting material and thus be reusable when the batteries thereof need be replaced. In all instances the so-configured resiliently-deformable ridges serve to damp severe lateral vibratory forces exerted downhole on such batteries.

ABSTRACT

A battery, a battery container, and a battery pack, for use downhole in MWD operations, one or more of which incorporates lateral vibration damping. In a preferred embodiment each comprise specialized lateral vibration damping in the form of a plurality of longitudinally-
5 extending resiliently-deformable ridges extending substantially a length of each and circumferentially spaced about an outer periphery. The resiliently-deformable ridges on the battery may be integrally formed and extend radially outwardly from a hollow resiliently-deformable sleeve, and formed of the same resiliently-deformable material of which the sleeve is comprised. The resiliently-deformable ridges on the battery container may extend radially inwardly or
10 outwardly from a periphery thereof. Advantageously, the battery container can thus be free of potting material and thus be reusable when the batteries thereof need be replaced. In all instances the so-configured resiliently-deformable ridges serve to damp severe lateral vibratory forces exerted downhole on such batteries.

VIBRATION-DAMPED BATTERY, BATTERY CONTAINER, AND BATTERY PACK FOR USE DOWNHOLE

FIELD OF THE INVENTION

5 The present invention broadly relates to batteries, battery containers, and battery packs for use in downhole equipment such as measurement-while-drilling (“MWD”) drilling equipment.

BACKGROUND OF THE INVENTION AND DESCRIPTION OF THE PRIOR ART

10 Drilling of wells, and in particular the drilling of directional /deviated wells, requires continuous measuring of sensed information as to the location of the drill bit, such as inclination of the drill string and drill bit, and the angular orientation (azimuth) thereof, so that this critical information may then be conveyed uphole in real time to the drill operator at surface to allow instantaneous adjustments to be made that will ensure the well is being drilled in a direction and into a formation as desired.

15 For such so-called “measurement while drilling” (“MWD”) drilling applications, particularly where the drill bit is rotary steerable, sophisticated battery-powered electronics located in “subs” threadably inserted in the drill string proximate the drill bit sense the desired directional parameters in relation to the drill bit, encode such data, and transmit same a drilling operation located at surface .

20 Electro-mechanical devices such as mud pulsers situated downhole in the drill string and operatively electrically coupled to the downhole electronics, encode the sensed data into a series of pressure pulses. These pressure pulses travel uphole where they are sensed by additional electronic equipment and decoded into the relevant data for the operator to view in real time.

25 High-energy density batteries are typically needed in measurement-while-drilling operations to power mud pulsers which in turn open and close valves downhole in a particular coded sequence so as to create corresponding encoded pressure pulses to thereby transmit directional drilling information uphole to a drilling operation.

Typically, batteries for use in such applications, in order to achieve the high energy density and longevity needed, are required to be of the lithium metal anode type, to provide the needed high energy density in comparison to conventional primary batteries (i.e. lead acid type batteries).

5 Such lithium batteries typically comprise a helically wound “sandwich” of oxidative and reductive materials in sheet form, such sheets separated by electrically non-conductive thin sheets.

Disadvantageously, however, lithium batteries, in part due to the inherent high imparted vibratory stresses in downhole hostile environments, are frequently prone to failure, and in
10 particular internal failure of the integrity and arrangement of the sheets of oxidative and reductive materials therein, resulting in expensive and frequent “tripping out” of the drill string to replace structurally-compromised or failed batteries.

Specifically, in oil drilling operation, such lithium batteries are located downhole in end-to end juxtaposed relation due to the dimensional restrictions of the wellbore, and are
15 situated proximate the drill bit.

Accordingly and disadvantageously, due to being situate in close proximity to the drill bit, significant vibration and vibratory forces are exerted on such batteries during drilling and rapid cycling of high-pressure drilling fluids in order to be able to transmit drilling data uphole. As a result, internal structural failure of such lithium batteries due to induced vibration
20 frequently occurs, which disadvantageously often leads to electrical “shorting” of the battery thereby rendering it inoperative or only capable of reduced electrical output.

Even more disadvantageously, however, electrical “shorting” of a high energy lithium battery due to internal structural failure caused by lateral vibratory forces imparted thereon often directly leads to rapid and build-up of heat within the battery. Such results in liquefaction
25 and/or gasification of certain of the contents of the lithium battery and consequent extremely sudden and forceful explosion.

Indeed, downhole explosion of lithium batteries arising from structural failure of the

battery components and resultant electrical shorting is a known and serious problem in directional drilling, particularly in MWD drilling.

5 The force of an exploding lithium battery or batteries downhole of the type and energy density currently used in MWD mud pulsers is comparable to the explosive force of an equivalent weight of dynamite. Such typically results in total destruction of downhole MWD pulsers and associated electronic sensors and circuitry therefor. This has the highly undesirable consequences of increased drilling expense not only to replace expensive wrecked tooling and equipment as well as exploded batteries and battery packs, but further as regards significant lost time and increased costs in “tripping out” the drill string, to say nothing of the hourly cost of
10 mud pump trucks and men working such equipment which need be idle during tripping out and running in of the drill string when actual drilling is not occurring.

Accordingly, a real and serious need exists in the MWD drilling industry for high energy density batteries which can not only provide the required electrical power, but which can be prevented from structural failure and thus otherwise exploding downhole with the
15 aforesaid highly undesirable consequences.

Some prior art “packaging” systems for MWD electronics have been created to attempt to isolate downhole MWD electronics from vibration and shock forces during drilling which act on the housing within the drill string .

For example, US 4,547,833 entitled “*High Density Electronics Packaging System for Hostile Environment*” is one such packaging system which utilizes annular shoe supports
20 provided on a chassis to isolate electronics from axial vibrations and axial forces. Such is a bulky solution, however, and is not targeted *per se* at isolating the batteries from vibrations but rather at isolating the downhole electronics from vibration, which as noted above, if only the electronics and not the batteries are isolated from vibration, such is an ineffective solution to
25 the exploding battery problem.

Likewise, US 2016/0053557 entitled “*Torsional Isolator*” teaches a device which attempts to reduce (axial) vibration and shock during directional drilling inflicted on downhole electronics. Such device, however, is not directed at reducing lateral acceleration forces

specifically, nor specifically reducing acceleration forces on downhole batteries but rather merely on the associated electronics powered by such batteries.

Still further, US 7,749,643 entitled "*Protective Battery Holding Structure*" teaches for example in Fig. 10 and at col. 4, lines 10-20 a battery holder 2 for a cylindrical battery, such
5 battery holder 2 having at least one rib 216 which extends inwardly from rectangular-shaped holder 2 so as to contact an outer surface of the battery. The point contact of the battery with such ribs 216 on the rectangular heat-resistant battery holder prevents heat produced by the battery during operation from transferring to and thereby damaging an outer case enclosing the battery holder. No elongate battery container for holding batteries in an end-to-end juxtaposed
10 position is disclosed, nor are ribs 216 ever taught or suggested as being resiliently-deformable to reduce or damp any lateral *vibration* forces imparted on the batteries, since vibration of the batteries was not foreseen to be a problem in the specification, perhaps because lithium batteries were not in existence, or at least prevalent, at the date of this publication.

US 4,309,818 entitled "*Preformed Flex-Rib Battery Case*" teaches a battery container
15 for a typical lead-acid battery, the walls of which include integrally moulded resilient ribs extending at acute angles from the walls, to retain the battery's electrochemical innards in place. Although the ribs are plastically deformable, they exist entirely within the lead-acid solution of the battery and are not on the exterior of the battery, and accordingly do not reduce lateral vibratory forces applied to the battery.

US 6,376,126 entitled "*Composite Battery Container with Integral Flexible Ribs*"
20 teaches a battery having plate-rest ribs integrally formed on the sides and bottom of the cell compartments of the battery, such ribs formed of a thermoplastic elastomer which elastically deforms when a cell element is disposed within the cell compartment. Again, the ribs as taught in this patent are located within an interior of the battery and accordingly do not reduce lateral
25 vibratory forces applied to the battery.

As regards present uses of lithium batteries and battery packs, battery containers and battery packs presently inserted in drilling string equipment for powering MWD equipment are presently typically injected with a "potting" material. Such potting material is initially a

flowable liquid which is flowed into the battery container containing the batteries, but which quickly solidifies to a substantially rigid state. In doing so such potting material becomes permanently bonded to both the batteries within the battery compartment and to the battery container itself. The purpose of injecting such potting material is to attempt to isolate the batteries from movement and thus potential additional excessive high “g” forces and thus possibly prevent structural damage to the battery and thus its electrical shorting. However, injection of such potting material, depending on the composition, typically does not provide for effective lateral *damping* of the batteries, and thus fails to address what is now believed by the inventors to be the root cause of battery explosions, namely excessive and repetitive lateral vibratory forces which the inventors believe induces structural failure within the batteries. Moreover, as explained below, injection of such potting material into the battery containers thereafter renders such battery containers non-reusable, and such battery containers must be discarded along with the batteries therein once the electrochemical potential of the batteries is depleted through usage.

Specifically, not only is such injected potting material due to its rigidity when hardened, not particularly effective in *damping* of lateral vibratory forces exerted on the batteries within the longitudinal battery container and thus largely ineffective in consistently reducing structural failure of the batteries within the battery container, even more disadvantageously such potting material due to its solidification within the battery container permanently bonds and seals the batteries within the battery container. Such thereby necessitates that not only the batteries but the entire battery container be replaced when the batteries’ life has been exhausted.

The aforementioned prior art methods and usages using potting material thus further increase the cost of maintenance when replacing batteries, let alone being largely ineffective in consistently reducing structural failure of the batteries and thus failing to reduce incidences of battery explosions.

Accordingly, for the aforementioned additional reason, a real and serious need exists in the MWD drilling industry for high energy density batteries and battery packs which can not only provide the required electrical power and have decreased tendency to fail when subjected to vibratory forces, but which are less costly to maintain and allow reuse of the battery container

in order to reduce maintenance costs.

The above background information and description of publications and current prior art battery compartment construction and manner of deployment is provided herein to give context to the advantages of the present invention over the prior art. No admission is intended nor
5 should be construed that any of the above publications or information provided with respect to current practices and usages constitutes prior art against the present invention.

SUMMARY OF THE INVENTION

The inventors have accordingly caused to be invented a battery, battery container, and a battery pack for use downhole in a drilling environment, which is configured in all of its
10 various embodiments to damp lateral acceleration forces which may otherwise be applied to the batteries and otherwise cause internal structural failure and resulting electrical “shorting” and potential consequent explosion of such battery (ies).

The invention is particularly suited for use with batteries of the lithium type, as more particularly described in US 9,118,045 to Engineered Power Inc. entitled “*High Temperature*
15 *Lithium Battery, having initial Low Temperature Use Capability*, which may be exposed to vibratory forces of the magnitude encountered in Measurement While Drilling (MWD) operations.

In a preferred embodiment, the configuration of each of the battery, the battery compartment, and/or the battery pack individually and jointly may contribute to damping of
20 lateral vibratory forces exerted on the batteries when used downhole in MWD drilling operations, so as to reduce incidence of vibration-induced shorting and thus violent explosion of such batteries when used downhole.

Advantageously, the present invention allows for incorporation of the number of resiliently-flexible elongate deformable rib members and their placement on one or more of the
25 battery, the battery container, or an inner sleeve, to allow, for a single resiliently-deformable material of a given modulus of elasticity, a means of varying the amount of stiffness and thus the degree of vibration resistance.

In addition, by virtue of the configuration, the battery container of the present invention and a battery pack utilizing such battery container are advantageously now re-usable and need not be disposed of when the batteries' electrochemical potential is depleted through use.

Accordingly, in a first broad embodiment of the present invention as regards a battery
5 container, the present invention provides for an elongate cylindrical battery container for use in downhole in measurement-while-drilling operations which provides electrical power to a mud pulser and which battery container damps lateral vibration of at least one substantially cylindrical battery contained therein, and which comprises:

10 (i) an elongate, cylindrical hollow tube adapted to contain therewithin said at least one cylindrical battery;

(ii) at least one elongate electrically-conductive member extending longitudinally along a length of said elongate hollow tube, adapted at one end thereof to be in electrical communication with one electrical contact of said at least one cylindrical battery when said at least one cylindrical battery is
15 inserted in said elongate hollow tube; and

(iii) a plurality of resiliently-deformable protruding rib members uniformly disposed about or positioned along a cylindrical periphery of said elongate hollow tube, each of said rib members of a thickness so as to extend uniformly radially outwardly or inwardly from said cylindrical periphery of said elongate
20 hollow tube and spaced about or along said cylindrical periphery of said elongate hollow tube;

wherein when said at least one cylindrical battery is inserted in said elongate hollow tube and said elongate hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib members absorb and damp lateral vibratory
25 forces exerted on said at least one battery contained in said battery container.

In one embodiment, the resiliently-deformable rib members are molded and formed integrally with said elongate hollow tube.

In an alternative embodiment, the resiliently-deformable rib members are separate from and non-integral with the elongate hollow tube.

In a refinement of the battery container, the elongate electrically-conductive member is integrally moulded within said elongate hollow tube along said length of said elongate hollow tube.

In a further refinement, the plurality of resiliently-deformable rib members comprise a plurality of elongate longitudinally-extending members extending substantially a length of said elongate hollow tube and which are each in mutual parallel arrangement with each other and uniformly spaced about said cylindrical periphery of said elongate hollow tube. In a still-further refinement, the resiliently-deformable rib members are situated on an exterior of said cylindrical periphery of said elongate hollow tube, and an interior cylindrical periphery of said elongate hollow tube is in direct contact with each of said at least one cylindrical battery.

In an alternative embodiment, the plurality of resiliently-deformable rib members comprise a plurality of annular rings which are spaced longitudinally along substantially a length of said elongate hollow tube and in mutual parallel arrangement to each other .

In an alternative configuration, each of said at least one cylindrical batteries are circumferentially surrounded about said cylindrical periphery thereof by a thin resiliently-deformable sleeve. The resiliently-deformable rib members are integrally formed within said thin resiliently-deformable sleeve and disposed about or along an outer or inner cylindrical periphery of said thin resiliently-deformable sleeve. When a plurality of cylindrical batteries and associated sleeves are inserted in said elongate hollow tube and said elongate hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib members and said thin resiliently-deformable sleeves in a region of said resiliently-deformable rib members together absorb and damp lateral vibratory forces exerted on said elongate hollow tube and said cylindrical batteries contained therewithin.

In a further refinement, the electrically-conductive member comprises a thin, flat, elongate ribbon member having a width substantially greater than a thickness thereof and said

width disposed within a portion of said cylindrical periphery of said elongate hollow tube. In a still further refinement, the thin resiliently-deformable material and said resiliently-deformable rib members are together formed from a two- part silicone rubber composition comprising a base and a curing agent, said base when mixed with said curing agent forming a resiliently-deformable, waterproof, electrically non-conductive flexible material. In one embodiment, the two-part silicone rubber composition is formed from ZIAMETER™ RTV-4130-J base and ZIAMETER¹ RTV-4130-J curing agent.

In a still-further refinement of the battery container of the present invention, a biasing member may be situated at one end of said elongate tube for exerting a force against said at least one battery for damping longitudinal vibrations exerted on said at least one battery when located in said battery container, and in a refinement the biasing member is a helical spring.

In an alternative aspect of the battery container of the present invention, such may comprise:

- (i) an elongate, substantially cylindrical, hollow tube adapted to contain therewithin at least one substantially cylindrical battery;
 - (ii) at least one elongate electrically-conductive member extending substantially longitudinally along a length of said elongate hollow tube, adapted at one end thereof to be in electrical communication with one electrical contact of said at least one cylindrical battery when said at least one cylindrical battery is inserted in said elongate hollow tube; and
 - (iii) a helical protruding rib member disposed around a cylindrical periphery of said battery container, of a thickness so as to extend uniformly radially outwardly or inwardly from said cylindrical periphery of said elongate hollow tube ;
- wherein when said at least one cylindrical battery is inserted in said elongate hollow

¹ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

tube and said elongate hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib member absorbs and damps lateral vibratory forces exerted on said at least one battery contained in said battery container.

5 In a further aspect of the present invention, the present invention relates to a cylindrical battery pack containing therewithin a plurality of elongate cylindrical batteries in end-to-end juxtaposed position for use downhole in measurement-while-drilling operations, which battery pack provides vibration reduction to said plurality of cylindrical batteries contained therein. The battery pack comprises:

10 (i) an elongate, substantially cylindrical hollow tube, containing therewithin said plurality of elongate substantially cylindrical batteries arranged end-to-end;

 (ii) a flat, elongate, electrically conductive ribbon member integrally formed within said hollow tube, extending substantially the length of said hollow tube and in electrical communication with at least one of said plurality of cylindrical batteries when said plurality of cylindrical batteries are inserted in said hollow tube; and

15

 (iii) a plurality of elongate, resiliently-deformable longitudinally-extending rib members extending substantially along a longitudinal length of a periphery of said elongate hollow tube and/or along a longitudinal length of an outer cylindrical periphery of each of said plurality of cylindrical batteries contained therein, protruding radially from said cylindrical periphery of said elongate hollow tube and/or protruding radially from said outer cylindrical periphery of each of said cylindrical batteries, circumferentially spaced about said cylindrical periphery of said elongate hollow tube and/or said outer cylindrical periphery of each of said plurality of cylindrical batteries;

20

25

 wherein when battery pack is inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib members absorb and damp lateral vibratory forces exerted on said batteries contained therewithin.

In a further refinement of the aforementioned battery pack, the plurality of elongate, resiliently-deformable longitudinally-extending rib members extending substantially along a longitudinal length of an outer periphery of said elongate hollow tube. Alternatively, the plurality of elongate, resiliently-deformable longitudinally-extending rib members extending substantially along a longitudinal length of an inner periphery of said elongate hollow tube. In a preferred embodiment, the plurality of elongate, resiliently-deformable longitudinally-extending rib members extending substantially along a longitudinal length of both an outer and an inner periphery of said elongate hollow tube.

In a further or alternative refinement, the plurality of elongate, resiliently-deformable longitudinally-extending rib members of said battery pack extend substantially along a longitudinal length of each of said plurality of cylindrical batteries thereof.

Accordingly, in a further embodiment of the present invention, such invention comprises a battery for use downhole in measurement-while-drilling operations which provides lateral vibration damping. The battery of the present invention will typically be a lithium type, which is particularly prone and susceptible to vibration-caused shorting and failure, but is not limited to lithium batteries, and may be incorporated into any type of battery where significant downhole vibratory forces may denigrate battery performance or induce structural failure.

Accordingly, in such further aspect of the present invention, the battery of the present invention comprises an elongate substantially-cylindrical encapsulating tube surrounding oxidative and reductive metals, compounds or compositions, and at least three elongate, resiliently-deformable, longitudinally-extending rib members, each extending substantially along a longitudinal length of an outer periphery of said and circumferentially uniformly spaced about said outer cylindrical periphery of said encapsulating tube. When said battery is inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib members absorb and damp lateral vibratory forces exerted on said battery.

In a further refinement of the battery of the present invention, such battery may comprise a thin hollow sleeve substantially uniformly and circumferentially surrounding said encapsulating tube, and the plurality of elongate, resiliently-deformable, longitudinally-extending mutually parallel rib members extend substantially along a longitudinal length of an

outer periphery of said thin hollow sleeve and radially outwardly from an outer cylindrical periphery thereof. In a further refinement, the thin hollow sleeve is also resiliently deformable. Thus when said battery is inserted in measurement-while-drilling equipment and then inserted downhole, the resiliently-deformable rib members and said thin sleeve in a region of said
5 resiliently-deformable rib members thereon together both absorb and damp lateral vibratory forces exerted on said battery.

In one embodiment, the longitudinally-extending rib members are each adhered to and extend outwardly from said encapsulating tube.

In a preferred embodiment, the battery of the present invention is further utilized within
10 a battery container of the present invention, and in and forming a battery pack of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and permutations and combinations of the invention will now appear from the above and from the following detailed description of the various particular
15 embodiments of the invention, taken together with the accompanying drawings each of which are intended to be non-limiting, in which:

Fig. 1 is an exploded perspective view of a downhole battery environment in a tubing string for the battery pack, battery container, and battery of the present invention;
20

Fig. 2A is an exploded perspective view of a battery container and battery pack of the present invention, containing at least one battery and having lateral damping means to reduce lateral vibrational energy imparted on the battery;

Fig. 2B is a cross-section through the battery container, taken along plane A-A of Fig.
25 2A;

Fig. 3 is an exploded perspective view of another alternative battery container of the present invention, containing at least one battery and having lateral damping means to reduce lateral vibrational energy imparted on the battery;

Fig. 4A is an exploded perspective view of another alternative battery container and battery pack of the present invention, containing at least one battery and having lateral damping means to reduce lateral vibrational energy imparted on the battery, wherein the lateral damping means comprises elongate resiliently-deformable rib members adhered to the encapsulating tube of the battery;

Fig. 4B is a cross-section through the battery container, taken along plane A-A of Fig. 4A:

Fig. 5 is an exploded perspective view of another alternative battery pack of the present invention, containing at least one battery and having lateral damping means to reduce lateral vibrational energy imparted on the batter, wherein the lateral damping means consists of a plurality of annular rings spaced along a periphery of the battery;

Fig. 6A is an exploded perspective view of another alternative battery pack of the present invention, containing at least one battery and having lateral damping means to reduce lateral vibrational energy imparted on the battery;

Fig. 6B is a cross-section, taken along plane B-B of Fig. 6A, where the resiliently-deformable (elastomeric) ribs are integral with the battery container which is also elastomeric;

Fig. 6C is a cross-section, taken along plane B-B of Fig. 6A, where the resiliently-deformable (elastomeric) ribs are integral with the sleeve member which is also elastomeric and which surrounds the battery;

Fig. 7A is an exploded perspective view of another alternative cross-section of an alternative embodiment of the battery pack;

Fig. 7B is a cross-section, taken along plane D-D of Fig. 7A, where the resiliently-deformable (elastomeric) ribs are integral with the battery container which is also elastomeric;

Fig. 7C is a cross-section, taken along plane C-C of Fig. 7A, where the resiliently-deformable (elastomeric) ribs are integral with the sleeve member which is also elastomeric;

Fig. 8 is a perspective exploded view of an alternative battery pack and battery

compartment of the present invention, containing at least one battery and having lateral damping means to reduce lateral vibrational energy imparted on the battery;

Fig. 9A is a cross-section, taken along plane **X-X** of **Fig. 8**, where the resiliently-deformable (elastomeric) ribs are integral with the tube member;

5 **Fig. 9B** is a cross-section of an alternative embodiment of the battery pack of the present invention shown in **Fig. 7**, taken along plane **Y-Y** of **Fig. 8**, where the resiliently-deformable (elastomeric) ribs are adhered to the sleeve member which surrounds the battery;

10 **Fig. 10** is a perspective exploded view of an alternative battery pack and battery container of the present invention, containing at least one battery, said battery pack and battery container having lateral damping means to reduce lateral vibrational energy imparted on the battery;

Fig. 11 a perspective exploded view of an alternative battery pack and battery container of the present invention, containing at least one battery and having lateral damping means to reduce lateral vibrational energy imparted on the battery;

15 **Fig. 12** is a cross-section, taken along plane **E-E** of **Fig. 11**, where the resiliently-deformable (elastomeric) ribs are integral with the tube member, which is also elastomeric

Fig. 13 is a cross-section, taken along plane **F-F** of **Fig. 11**, where the resiliently-deformable (elastomeric) ribs are integral with the tube member, which is also elastomeric and which surrounds the battery;

20 **Fig. 14** is a partial phantom side elevation view of one embodiment of a battery pack of the present invention (elastomeric ribs not shown);

Fig. 15 is a similar partial-phantom side elevation view of the battery pack of the present invention (elastomeric ribs not shown);

25 **Fig. 16A** is a cross-section , taken along plane **G-G** of **Fig. 15**, of an embodiment of the invention where the resiliently-deformable (elastomeric) ribs are on the exterior of the tube member which surrounds the battery, and are situated in the battery compartment;

Fig. 16B is a cross-section , taken along plane **G-G** of **Fig. 15**, of an embodiment of the invention where the resiliently-deformable (elastomeric) ribs are on the exterior of the tube member which surrounds the battery, and are also situated on the exterior of the battery container;

5 **Fig. 16C** is a cross-section, taken along plane **G-G** of **Fig. 15**, of an embodiment of the invention where the resiliently-deformable (elastomeric) ribs are on the exterior of the tube member which surrounds the battery, and are also situated on the interior of the battery container;

10 **Fig. 16D** is a cross-section, taken along plane **G-G** of **Fig. 15**, of an embodiment of the invention where the resiliently-deformable (elastomeric) ribs are situated on the interior of the battery container;

15 **Fig. 16E** is a cross-section , taken along plane **G-G** of **Fig. 15**, of an embodiment of the invention where the resiliently-deformable (elastomeric) ribs are situated on both the exterior and interior of the tube member which surrounds the battery, and are also situated on the interior of the battery container;

Fig. 16F is a cross-section, taken along plane **G-G** of **Fig. 15**, of an embodiment of the invention where the resiliently-deformable (elastomeric) ribs are situated on the exterior of the battery;

20 **Fig. 17** is a perspective exploded view of an alternative battery pack and battery container of the present invention, containing at least one battery, said battery pack and battery container having lateral damping means to reduce lateral vibrational energy imparted on the battery, wherein the lateral damping means consists of a plurality of annular resiliently-deformable rings situated about a periphery of a tubular member and longitudinally spaced therealong;

25 **Fig. 18** is a perspective exploded view of an alternative battery pack of the present invention, containing at least one battery, said battery pack and battery container having lateral damping means to reduce lateral vibrational energy imparted on the battery, wherein the lateral

damping means consists of a helical ring spirally wound about a periphery of a tubular member and longitudinally spaced therealong;

Fig. 19 is a perspective exploded view of an alternative battery pack and battery container of the present invention, said battery container thereof having lateral damping means to reduce lateral vibrational energy imparted on the battery, wherein the lateral damping means consists of a plurality of annular rings spaced along an interior periphery of the battery container; and

Fig. 20 is a cross-section, taken along plane H-H of Fig. 19, showing in cross-section the plurality of annular rings spaced along an interior periphery of the battery container.

10

DETAILED DESCRIPTION OF SOME PREFERRED EMBODIMENTS

Battery power assemblies 12 are typically incorporated downhole in drill strings 15 for directional drilling, for the purpose of providing electrical energy to operate a stepper motor for operating a downhole mud pulser (not shown). The mud pulser, and in particular the stepper motor thereof, operates a servo valve (not shown) in a linear –back and forth direction so as to thereby open and close in coded sequence a main pressure valve (not shown) to thereby create pressure pulses for transmitting data received from downhole sensors, such as azimuth and inclination of the drill bit, uphole to a drilling operator to allow “steering” of the drill bit.

Battery packs 10 within said battery power assemblies 12 provide electrical power to power downhole electronic equipment for the mud pulser, namely electrical power for receiving data and encoding data sensed by various downhole sensors during drilling, such as azimuth and inclination of the drill bit, and converting same such to a series of electrical pulses to the stepper motor of the mud pulser. The stepper motor of the mud pulser then causes encoded pressure pulses containing such data to travels uphole where it is sensed and decoded and provided in real time to the drill operator.

Fig. 1 shows an exploded perspective view of one such battery power assembly 12 in a drill/tubing string 15, for containing the battery pack 10 of the present invention, located downhole in a wellbore.

As may be seen from **Fig. 1**, the battery pack 10 of the present invention [which may further contain therewithin a specialized battery container 14 (not visible in **Fig. 1**, but clearly shown in exploded view in **Fig. 2**) and/or one or more specially-configured batteries 16 (not visible in **Fig. 1** but see for example **Fig. 4**)] is typically located co-axially in a drill string 15.

During drilling operations, pressurized fluid such as drilling mud 6 typically flows downhole in drill string 15 via the interstitial area between the exterior of a cylinder 9 (in which the battery pack 10 is inserted) and the interior of drill string 15, to a drill bit motor (not shown) to hydraulically power such drill bit motor. Centralizers 11 on both the uphole and downhole side of cylinder 9 are typically used to maintain the battery power assembly 12 co-axial within drill string 15.

Due to the rapid opening and closing of main pressure valve and created pressure pulses, and also due to action of the drill bit and oscillatory lateral movement of the drill string within a wellbore (not shown), battery power assemblies 12 and in particular batteries 16 contained within a battery pack 10 are continually subject to high lateral vibratory forces, the vertical and horizontal force components thereof referred to as V_{FH} and V_{FV} respectively and as shown in **Fig. 1**.

Fig's 2A & 2B show a first embodiment of the battery container 14 of the present invention, which with battery 16 forms a first embodiment of the battery pack 10 of the present invention.

In this embodiment, battery container 14 comprises an elongate, cylindrical hollow tube 20 adapted to contain therewithin said at least one cylindrical battery 16. Elongate hollow tube 20 possesses at least one elongate electrically-conductive member 22 extending longitudinally along a length of elongate hollow tube 20. As shown in **Fig. 2A**, electrically-conductive member 22 is adapted at a distal end 22a thereof to be in electrical communication with one electrical contact 24 of said at least one cylindrical battery 16 when said at least one cylindrical

battery 16 is inserted in elongate hollow tube 20.

Electrically-conductive member 22 may be adhered to the interior or exterior of tube 20, or may be integrally molded therewith, as shown in Fig. 2A. Electrically conductive member 22, and distal electrical contact 22a thereof, allows the positive or negative charge of the battery 16, as the case may be, at a distal end 24 of battery 16 to be conveyed to a common end of the battery container 20, such as proximal end 33 of battery 16 and proximal end 20a of tube 20 (typically the downhole end of such battery compartment 20), where such positive and negative charges may then be together conveyed via an insulated "bayonet" type electrical connector 45 or the like, to downhole componentry within the drill string, such as to the stepper motor of a mud pulser.

Distal electrical contact 22a may further exerting a force against said at least one battery 16 for damping longitudinal vibrations exerted on said at least one battery 16 when located in said battery container 20. Distal electrical contact 22a may further be a helical spring.

In the embodiment shown in Fig. 2A, electrically-conductive member 22 comprises a thin, flat, elongate ribbon-like member formed from a flat sheet of conductive metal, which is particularly suited to taking up a small height and is thus suited to be integrally moulded into tube member 20. Other configurations for the electrically-conductive member 22, such as an elongate wire adhered to or moulded within tube 20, may be used, and will now occur to persons of skill in the art.

Significantly, a plurality of resiliently-deformable protruding rib members 25 are provided.

In the embodiment shown in Fig's 2A & 2B resiliently-deformable protruding rib members 25 are uniformly disposed about or positioned along the exterior cylindrical periphery 28 of elongate hollow tube 20, each of said rib members 25 being of a thickness so as to extend uniformly radially outwardly from cylindrical periphery 28 of elongate hollow tube 20 and spaced about cylindrical periphery 28 of elongate hollow tube 20 as best shown in Fig. 2B. In the embodiment of Figs. 2A & 2B, three(3) resiliently-deformable protruding rib members 25

are provided, but more may be provided, with each preferably extending substantially a length of elongate hollow tube **20** and in mutual parallel arrangement with each other and uniformly spaced about the exterior cylindrical periphery **28** of elongate hollow tube **20**. By having resiliently-deformable protruding rib members **25** extend longitudinal (i.e. in the same direction
5 as the batteries **16** are inserted in battery container **20**, such configuration allows longitudinal venting of air when the batteries **16** are inserted in tube **20** and thus has the benefit of allowing easier installation of battery **16** within tube **20** by avoiding “swabbing” of the battery and trapping of air which would otherwise occur if the resiliently-deformable protruding rib members **25** were annular rings, as shown in **Fig. 3**, which trapping of air would impede
10 insertion of the batteries **16** within tube **20** unless air vent holes were further included in periphery of tube **20**.

The resiliently-deformable protruding rib members **25** are preferably formed from a two-part silicone rubber composition comprising a base and a curing agent. In a preferred embodiment, a material therefor which has been found suitable is a two-part silicone rubber
15 composition formed from ZIAMETER² RTV-4130-J base and ZIAMETER³ RTV-4130 curing agent, which when mixed forms a resiliently-deformable, waterproof, electrically non-conductive flexible material.

As more fully explained below and as depicted in various embodiments, the resiliently-deformable protruding rib members **25** may be applied to for formed on the exterior
20 encapsulating tube **60** of the battery **16**, the interior and/or exterior of an external sleeve **30** which may surround battery **16**, and/or to the exterior or interior of tube **20**, to provide the required lateral vibrational damping of batteries **16** forming part of battery pack **10**.

Fig. 3 shows an alternative arrangement of the battery container **14** of the present invention, which with battery **16** forms a second embodiment of the battery pack **10** of the
25 present invention.

² Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

³ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

In such embodiment, a series of resiliently-deformable protruding rib members 25, in the form of a plurality of annular rings 26, are disposed about the cylindrical periphery 28 of elongate tube 20, and extend uniformly radially outwardly from cylindrical periphery 28 of tube 20, and spaced longitudinally along cylindrical periphery 28. As noted above, air vent holes (not shown) may further be included in periphery of tube 20, to ease the insertion of so-formed batteries 16 within tube 20 and prevent swabbing of interior of tube 20.

Again, an electrically-conductive member 22 is provided as shown, which may be adhered to the interior or exterior of tube 20 or may be integrally molded therewith. Such allows the positive or negative charge of the battery 16, as the case may be, to be conveyed to a common end of the battery container 20, typically a downhole end of such battery compartment 20, where such positive and negative charges may then be conveyed, by means of an insulated "bayonet" type electrical connector or the like, to downhole componentry within the drill string, such as to the stepper motor of the mud pulser.

Again, electrically-conductive member 22 is provided at a distal end with an electrical contact 22a to be in electrical communication with one electrical contact 24 of at least one cylindrical battery 16 when such cylindrical battery 16 is inserted in elongate hollow tube 20.

In a further alternative embodiment to the embodiments of the battery compartment shown in Fig.'s 2A and Fig. 3, a single resiliently-deformable rib member 25, in the form of a helical member spirally around a cylindrical periphery of said battery container 20, of a thickness so as to extend uniformly radially outwardly or inwardly from said outer or inner cylindrical periphery 28, 88 respectively of battery container 20 (i.e. hollow elongate tube 20) may be provided.

Fig. 4A shows another permutation of the present invention. Instead of resiliently-deformable longitudinally-extending protruding rib members 25 being situated on an interior and/or exterior of battery container (i.e. tube 20) as shown in Fig. 2A, Fig. 6A, Fig. 7A, Fig. 8 and Fig. 11, in the embodiment shown in Fig. 4A a plurality of and preferably three(3) or more) resiliently-deformable protruding rib members 25 are directly adhesively secured to the

metal encapsulating tube **60** which surrounds the oxidative and reductive spiral layers **70** of each battery **16**, as shown in **Fig. 4B**. So-modified battery **16** or batteries, when inserted in battery container **20** and thereby forming battery pack **10** and inserted downhole, will then have the resiliently-deformable longitudinally-extending protruding rib members **25** effectively
5 damping lateral vibratory forces exerted on one or of batteries **16**, thereby reducing incidence of structural damage or explosion of battery (ies) **16**.

Fig. 5 shows another permutation of the present invention. Instead of resiliently-deformable protruding rib members **25** which are longitudinally extending and situated on an interior and/or exterior of battery container (tube **20**) as shown *inter alia* in **Fig. 2A**, **Fig. 6A**,
10 **Fig. 7A**, **Fig. 8** and **Fig. 11**, resiliently-deformable protruding rib members **25** are in the form of a plurality of elastomeric annular rings **27** which may fitted around and/or adhesively secured to the encapsulating tube **60** of battery **16**. So-modified battery **16** or batteries, when inserted in battery container **20** and thereby forming battery pack **10** and inserted downhole, will then have the elastic annular rings **27** effectively damping lateral vibratory forces exerted on one or
15 of batteries **16**, thereby reducing incidence of structural damage or explosion of battery (ies) **16**.

Fig. 6A (together with cross-sections **Fig.'s 6B,6C**), **Fig. 7A** (together with cross-sections **Fig.'s 7B,7C**), **Fig. 8** (together with cross-sections **Fig.'s 9A,9B**), **Fig. 11** (together with cross-sections **Fig.'s 12&13**), and **Figs. 17-19** all show various additional embodiments
20 of the battery pack **10** of the present invention where in each case a thin cylindrical hollow sleeve **30** having resiliently- deformable protruding rib members **25** thereon is provided which is adapted in an assembled battery pack **10** to be situated between an exterior of each of the one or more batteries **16** and the interior cylindrical periphery **88** of battery container (i.e. tube) **20**.

25 Hollow tubular sleeve **30** extending a length of battery container **20**, or alternatively or a plurality of tubular sleeves **30** each adapted when inserted in battery container **20** to overlie respective batteries **16**, may be advantageously employed where one or more of the following scenarios apply: i) a field service company may wish to retrofit an existing battery pack where neither the pre-existing battery container **20** or battery **16** are provided with resiliently-

deformable protruding rib members 25, so as to thereby provide such battery pack with lateral damping capability to provide resistance to lateral vibrations; (ii) additional damping capability is desired to be provided in addition to whatever resiliently- deformable protruding rib members 25 having been provided on battery container 20 and/or battery 16, to provide additional vibration-withstanding capability for an existing battery pack; and/or (iii) fabrication of exterior or interior resiliently-deformable protruding rib members 25 on a separate component such as thin hollow sleeve 30 may be easier and less time consuming than alternatively forming said resiliently-deformable protruding rib members 25 on the interior cylindrical periphery 88 of elongate battery container 20 and/or adhesively applying said resiliently-deformable protruding rib members 25 on an exterior of encapsulating tube 60 of battery 16.

Other and additional advantages of utilizing a separate thin hollow sleeve component 30 as part of battery pack 10 will further now occur to persons of skill in the art.

Hollow sleeve 30 may be of a separate cast or formed material , with resiliently-deformable protruding rib members 25 adhesively applied thereto, either to the exterior of thin tubular sleeve 30 (as shown in Figs. 6A & 6C) and/or the interior thereof (as shown in Fig. 7A & Fig. 8).

Alternatively, resiliently-deformable protruding rib members 25 may be integrally cast with hollow sleeve 30. Such manner of forming hollow sleeve 30 is preferred, as such offers additional lateral vibration damping in the region of the intersection of the resiliently-deformable protruding rib members 25 with the cylindrical periphery of hollow sleeve 30, and avoids a further manufacturing step of having to otherwise form and secure the resiliently-deformable protruding rib members 25 to hollow sleeve 30. Such is further preferred in that the hollow sleeve 30 and resiliently-deformable protruding rib members 25 may be together formed from a mold, using a two-part silicone rubber composition, such as but not limited to the aforementioned ZIAMETER⁴ RTV-4130-J base and ZIAMETER⁵ RTV-4130 curing agent, which when injected in a mould thereby form a resiliently-deformable, waterproof,

⁴ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

⁵ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

electrically non-conductive flexible hollow sleeve 30, having resiliently-deformable protruding rib members 25 integrally formed thereon of a suitable modulus of elasticity to provide vibration absorption and damping.

Specifically, as regards **Fig. 6A-C**, such shows an embodiment whereby a thin
5 cylindrical sleeve 30 is provided having longitudinally resiliently-deformable protruding rib members 25 thereon. Where tube 20 already has a plurality of resiliently-deformable protruding rib members 25 arranged about the exterior cylindrical periphery 28 thereof as shown, additional resiliently-deformable protruding rib members 25 on cylindrical hollow sleeve 30 provide additional lateral damping of batteries 16 when sleeve 30 and batteries are together
10 placed in battery container 20 and the resulting battery pack 10 placed downhole.

Alternatively, in a further modification, battery container 20 need not possess any resiliently-deformable protruding rib members 25, and instead resiliently-deformable protruding rib members 25 may be situated on or integrally formed in sleeve 30 so as to provide the necessary lateral vibration damping to batteries 16.

15 In the embodiment shown in **Fig. 6A**, resiliently-deformable protruding rib members 25 are adhesively adhered to the outer cylindrical periphery of hollow sleeve 30 as may be seen from **Fig. 6C**, and are integrally formed in the exterior cylindrical periphery 28 of battery container 20, as may be seen from **Fig. 6B**. This configuration may be reversed, or all may be integrally formed, or all may be adhesively attached to the respective battery container 20 or
20 hollow sleeve 30.

Likewise, resiliently-deformable protruding rib members 25, whether integrally or adhesively affixed, may be provided on either or both of the exterior cylindrical periphery 28 and interior cylindrical periphery 88 of battery container 20, and/or on the exterior cylindrical periphery or the interior cylindrical periphery of sleeve 30.

25 For example, as an illustration of one of the aforesaid configurations and as shown in **Fig. 7A**, resiliently-deformable protruding rib members 25 are provided on both the interior cylindrical surface 88 of battery container 20, and on the interior cylindrical surface of sleeve 30. As seen from **Fig. 7C**, resiliently-deformable protruding rib members 25 are integrally

formed with battery container **20**, while as seen from **Fig. 7B**, resiliently-deformable protruding rib members **25** are adhesively secured to sleeve **30**.

Fig. 8 and **Fig.'s 9A,9B** show an alternative embodiment/combination, wherein resiliently-deformable protruding rib members **25** are provided only on interior cylindrical periphery **88** of battery container **20**, and integrally formed therewith. Conversely, resiliently-deformable protruding rib members **25** are further applied to both the interior cylindrical periphery and exterior cylindrical periphery of sleeve **30**, and adhesively affixed thereto, as may be seen from **Fig. 9B**.

Fig.'s 11-13 show an alternative embodiment/combination, wherein resiliently-deformable protruding rib members **25** are provided on both the interior cylindrical periphery and exterior cylindrical periphery of sleeve **30**, and adhesively adhered to such peripheries as shown in **Fig. 13**. Likewise, resiliently-deformable protruding rib members **25** are further applied to both the interior cylindrical periphery **88** and exterior cylindrical periphery of battery container **20** and integrally formed therewith, as may be seen from **Fig. 12**.

Fig. 10 shows yet another embodiment of the invention, where no sleeve **30** is employed. Instead, battery container **20** has resiliently-deformable protruding rib members **25** on both the interior cylindrical periphery **88** and exterior cylindrical periphery of battery container **20**. Such resiliently-deformable protruding rib members **25** may be separately formed and adhesively attached to battery container **20**, or alternatively integrally formed therewith in the manner above described. When battery **16** is inserted in battery container **20**, the resultant battery pack **10** provides vibrational damping and vibrational absorption of vibrational energies which would otherwise be exerted on the batteries **16** therein when the battery pack **10** is placed downhole and exposed to vibrations.

Fig. 14 shows a cross-sectional side elevation view of battery container **20**, without batteries **16** located therein, showing to advantage the electrically-conductive member **22** extending longitudinally the length thereof.

Fig. 15 is a similar cross-sectional side elevation view of battery container **20**, with batteries **16** inserted therein.

Fig.'s. 16A-F show various cross-sectional views along plane **G-G** of battery pack **10** of **Fig. 15** , when the battery pack **10** shown in **Fig. 15** is of various configurations.

For example, **Fig. 16A** shows a cross-section along plane **G-G** of battery pack **10** of **Fig. 15**, wherein a sleeve **30**, with resiliently-deformable protruding rib members **25** on the exterior cylindrical periphery thereof, is interposed between the encapsulating metal exterior tube **60** of battery **16** and the interior cylindrical periphery **88** of battery container **20**.

Fig. 16B shows a cross-section along plane **G-G** of battery pack **10** of **Fig. 15**, wherein a sleeve **30**, with resiliently-deformable protruding rib members **25** on the exterior cylindrical periphery thereof, is interposed between the encapsulating metal exterior tube **60** of battery **16** and the interior cylindrical periphery **88** of battery container **20**. Resiliently-deformable protruding rib members **25** are further provided on the exterior periphery **28** of battery container **20**.

Fig. 16C shows a cross-section along plane **G-G** of battery pack **10** of **Fig. 15**, wherein a sleeve **30**, with resiliently-deformable protruding rib members **25** on the exterior cylindrical periphery thereof, is interposed between the encapsulating metal exterior tube **60** of battery **16** and the interior cylindrical periphery **88** of battery container **20**. Resiliently-deformable protruding rib members **25** are further provided on both the exterior periphery **28** of battery container **20**, as well as on the interior periphery **88** of battery container **20**.

Fig. 16D shows a cross-section along plane **G-G** of battery pack **10** of **Fig. 15**, wherein resiliently-deformable protruding rib members **25** are provided only on the interior periphery **88** of battery container **20**.

Fig. 16E shows a cross-section along plane **G-G** of battery pack **10** of **Fig. 15**, wherein a sleeve **30**, with resiliently-deformable protruding rib members **25** on both the exterior and interior cylindrical periphery thereof, is interposed between the encapsulating metal exterior tube **60** of battery **16** and the interior cylindrical periphery **88** of battery container **20**. Resiliently-deformable protruding rib members **25** are further provided on the interior periphery **88** of battery container **20**.

Fig. 16F shows a cross-section along plane **G-G** of battery pack **10** of **Fig. 15**, wherein resiliently-deformable protruding rib members **25** are provided only on the exterior of encapsulating metal tube **60** of battery **16**.

5 **Fig. 17** shows another variation (exploded view) of the battery pack **10** of the present invention. In such embodiment, a thin hollow tubular sleeve **30** is provided with a plurality of resiliently-deformable protruding rib members **25**. In this embodiment the resiliently-deformable protruding rib members **25** are in the form of annular rings **26** which are disposed and spaced longitudinally along the length and outer cylindrical periphery of sleeve **30**. The
10 annular rings **26** may be separately formed, and applied to the cylindrical periphery of sleeve **30**, which may thus be formed of a different, and no-resiliently deformable material. Alternatively, and preferably, the annular rings **26** and sleeve **30** are integrally formed or moulded, and are formed of a resiliently-deformable material, such as a two-part silicone rubber composition, such as but not limited to the aforementioned ZIAMETER⁶ RTV-4130-J
15 base and ZIAMETER⁷ RTV-4130 curing agent. When one or more cylindrical batteries **16** are inserted in sleeve **30** and such assembly inserted in battery container **20** so as to form a battery pack **10**, annular rings **26** contact interior cylindrical periphery **88** of battery container **20**, and resiliently deform when vibratory forces are applied to battery pack **10** so as to reduce and damp vibratory forces applied to batteries **16**.

20 **Fig. 19** shows another variation (exploded view) of the battery pack **10** of the present invention. In such embodiment, a thin hollow tubular sleeve **30** is provided with a plurality of resiliently-deformable protruding rib members **25**. In this embodiment the resiliently-deformable protruding rib members **25** are in the form of annular rings **26** which are disposed and spaced longitudinally along the length and inner cylindrical periphery of sleeve **30**. The
25 annular rings **26** may be separately formed, and applied to the cylindrical periphery of sleeve **30**, which may thus be formed of a different, and no-resiliently deformable material.

⁶ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

⁷ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

Alternatively, and preferably, the annular rings 26 and sleeve 30 are integrally formed or moulded with sleeve 30, and are formed of a resiliently-deformable material, such as a two-part silicone rubber composition, such as but not limited to the aforementioned ZIAMETER⁸ RTV-4130-J base and ZIAMETER⁹ RTV-4130 curing agent. When one or more cylindrical
5 batteries 16 are inserted in sleeve 30 and such assembly inserted in battery container 20 so as to form a battery pack 10, annular rings 26 contact interior cylindrical periphery 88 of battery container 20 and resiliently deform when vibratory forces are applied to battery pack 10 so as to reduce and damp vibratory forces applied to batteries 16.

Fig. 20 shows a cross section of sleeve 30 taken along plane H-H of **Fig. 19**.

10 **Fig. 18** shows yet another embodiment (exploded view) of the battery pack 10 of the present invention. In such embodiment, thin hollow tubular sleeve 30 is provided with a helical resiliently-deformable protruding rib member 39 disposed around an inner cylindrical periphery of sleeve 30, of a thickness so as to extend uniformly radially inwardly from the cylindrical periphery of sleeve 30. When one or more cylindrical batteries 16 are inserted in sleeve 30 and
15 such assembly inserted in battery container 20 so as to form a battery pack 10, annular rings 26 contact interior cylindrical periphery 88 of battery container 20 and resiliently deform when vibratory forces are applied to battery pack 10 so as to reduce and damp vibratory forces applied to batteries 16.

For a complete definition of the invention and the intended scope thereof, reference is
20 to be made to the specification as a whole.

⁸ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

⁹ Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

We claim:

1. An elongate cylindrical battery container for use in downhole in measurement-while-drilling operations which provides electrical power to a mud pulser and which battery container damps lateral vibration of at least one substantially cylindrical battery contained therein, comprising:

(i) an elongate, electrically insulative cylindrical hollow tube adapted to contain therewithin said at least one cylindrical battery;

(ii) at least one elongate electrically-conductive member extending longitudinally along substantially a length of said elongate electrically insulative cylindrical hollow tube containing therewithin said at least one cylindrical battery, adapted at one end thereof to be in electrical communication with one electrical contact of said at least one cylindrical battery when said at least one cylindrical battery is inserted in said elongate electrically insulative cylindrical hollow tube, wherein said at least one electrically-conductive member comprises a thin, flat, elongate ribbon member having a width substantially greater than a thickness thereof and said elongate ribbon member is integrally molded within and sealed within substantially said length of said elongate electrically insulative cylindrical hollow tube within a cylindrical periphery of said elongate electrically insulative cylindrical hollow tube;

and

(iii) a first plurality of resiliently-deformable protruding rib members uniformly disposed about or positioned along said cylindrical periphery of said elongate hollow tube, each of said rib members of a thickness so as to extend uniformly radially inwardly or outwardly from said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube and spaced about or along said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube;

wherein when said at least one cylindrical battery is inserted in said elongate electrically

insulative cylindrical hollow tube and said elongate electrically insulative cylindrical hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib members absorb and damp lateral vibratory forces exerted on said at least one battery contained in said battery container and said electrically conductive member allows electrical current flow from said at least one cylindrical battery within said battery container.

2. The elongate cylindrical battery container as claimed in claim 1, wherein said first resiliently-deformable rib members are molded and formed integrally with said elongate electrically insulative cylindrical hollow tube.

3. The elongate cylindrical battery container as claimed in claim 1, wherein said first resiliently-deformable rib members are separate from and non-integral with said elongate electrically insulative cylindrical hollow tube.

4. The elongate cylindrical battery container as claimed in claim 1,

wherein said first plurality of resiliently-deformable rib members comprise a plurality of elongate longitudinally-extending members extending substantially along a length of said elongate electrically insulative cylindrical hollow tube and which are each in mutual parallel arrangement with each other and uniformly and circumferentially spaced about said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube.

5. The elongate cylindrical battery container as claimed in claim 4, wherein said first resiliently-deformable rib members are in direct contact with each of said at least one cylindrical battery.

6. The elongate cylindrical battery container as claimed in claim 1,

wherein said first plurality of resiliently-deformable rib members comprise a plurality of annular rings which are spaced longitudinally along substantially a length of said elongate electrically insulative cylindrical hollow tube and in mutual parallel arrangement to each other .

7. The elongate cylindrical battery container as claimed in claim 1, wherein:

each of said at least one cylindrical batteries are circumferentially surrounded about said cylindrical periphery thereof by a thin resiliently-deformable tubular sleeve;

a further second plurality of resiliently-deformable rib members are integrally formed within said thin resiliently-deformable sleeve and disposed about or along an outer or inner cylindrical periphery of said thin resiliently-deformable sleeve;

wherein when a plurality of cylindrical batteries and associated sleeves are inserted in said elongate hollow tube and said elongate hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said further second plurality of resiliently-deformable rib members and said thin resiliently-deformable sleeve in a region of said first resiliently-deformable rib members together absorb and damp lateral vibratory forces exerted on said elongate electrically insulative cylindrical hollow tube and said cylindrical batteries contained therewithin.

8. The elongate cylindrical battery container as claimed in claim 1,

wherein said electrically-conductive member is situated within said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube proximate one of said first plurality of resiliently-deformable protruding rib members and immediately radially below or above said one of said first plurality of resiliently-deformable protruding rib members thereon.

9. The elongate cylindrical battery container as claimed in claim 7, wherein said thin resiliently-deformable tubular sleeve and said second resiliently-deformable rib members are together formed from a two-part silicone rubber composition comprising a base and a curing agent, said base when mixed with said curing agent forming a resiliently-deformable, waterproof, electrically non-conductive flexible material.

10. The elongate cylindrical battery container as claimed in claim 9, wherein said two-part silicone rubber composition is formed from ZIAMETER™ RTV-4130-J base and ZIAMETER¹ RTV-4130-J curing agent.

11. The elongate cylindrical battery container as claimed in claim 1, further having a biasing member situated at one end of said elongate tube for exerting a force against said at least one battery for damping longitudinal vibrations exerted on said at least one battery when located in said battery container.

12. The elongate cylindrical battery container as claimed in claim 11, wherein said biasing member at one end of said elongate tube is a helical spring.

13. An elongate cylindrical battery container for use downhole in measurement-while-drilling operations which damps lateral vibration of at least one cylindrical battery contained therein, comprising:

(i) an elongate, electrically insulative substantially cylindrical, hollow tube adapted

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to contain therewithin at least one substantially cylindrical battery;

(ii) at least one elongate electrically-conductive member extending longitudinally along substantially a length of said elongate electrically-insulative cylindrical hollow tube, adapted at one end thereof to be in electrical communication with one electrical contact of said at least one cylindrical battery when said at least one cylindrical battery is inserted in said elongate electrically-insulative cylindrical hollow tube, wherein said at least one electrically-conductive member comprises a thin, flat, elongate ribbon member having a width substantially greater than a thickness thereof and said elongate ribbon member is integrally molded within and sealed within substantially said length of said elongate electrically insulative cylindrical hollow tube within a cylindrical periphery of said elongate electrically insulative cylindrical hollow tube;

and

(iii) at least one resiliently-deformable protruding rib member disposed around said cylindrical periphery of said battery container of a thickness so as to extend uniformly radially inwardly or outwardly from said cylindrical periphery of said elongate hollow tube ;

wherein when said at least one cylindrical battery is inserted in said elongate hollow tube and said elongate hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said at least one resiliently-deformable protruding rib member absorbs and damps lateral vibratory forces exerted on said at least one battery contained in said battery container and said electrically conductive member allows electrical current flow from said at least one cylindrical battery within said battery container.

14. The battery container as claimed in claim 13, wherein said at least one resiliently-deformable protruding rib member comprises a resiliently-deformable rib member helically disposed around said cylindrical periphery of said battery container.

15. The elongate cylindrical battery container as claimed in claim 13,

wherein said at least one resiliently-deformable protruding rib member comprises a plurality of elongate longitudinally-extending resiliently-deformable rib members extending substantially a length of said elongate hollow tube and which are each in mutual parallel arrangement with each other and uniformly and circumferentially spaced about said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube.

16. The elongate cylindrical battery container as claimed in claim 13,

wherein said at least one resiliently-deformable protruding rib member comprises a plurality of annular rings which are spaced longitudinally along substantially a length of said elongate electrically insulative cylindrical hollow tube and in mutual parallel arrangement to each other .

17. The elongate cylindrical battery container as claimed in claim 13,

wherein said at least one resiliently-deformable protruding rib member is situated within said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube proximate said at least one resiliently-deformable protruding rib members and radially immediately below or above said at least one resiliently-deformable protruding rib members thereon.

18. An elongate cylindrical battery container for use in downhole in measurement-while-drilling operations which provides electrical power to a mud pulser and which battery container damps lateral vibration of at least one substantially cylindrical battery contained therein, comprising:

(i) an elongate, electrically insulative cylindrical hollow tube adapted to contain

therewithin said at least one cylindrical battery;

(ii) at least one elongate electrically-conductive member extending longitudinally along substantially a length of said elongate electrically insulative cylindrical hollow tube, adapted at one end thereof to be in electrical communication with one electrical contact of said at least one cylindrical battery when said at least one cylindrical battery is inserted in said elongate hollow tube, wherein said at least one electrically-conductive member comprises a thin, flat, elongate ribbon member having a width substantially greater than a thickness thereof and said elongate ribbon member is integrally molded within and sealed within substantially said length of said elongate electrically insulative cylindrical hollow tube within a cylindrical periphery of said elongate electrically insulative cylindrical hollow tube;

and

(iii) a plurality of resiliently-deformable protruding rib members uniformly disposed about or positioned along said cylindrical periphery of said elongate hollow tube, each of said rib members of a thickness so as to extend radially outwardly or inwardly from said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube and spaced about or along said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube;

wherein said plurality of resiliently-deformable protruding rib members comprise a plurality of annular rings which are spaced longitudinally along substantially a length of said elongate electrically insulative cylindrical hollow tube and in mutual parallel arrangement to each other;

wherein said elongate, electrically insulative cylindrical hollow tube comprises one or more vent holes in the periphery thereof; and

wherein when said at least one cylindrical battery is inserted in said elongate electrically insulative cylindrical hollow tube and said elongate electrically insulative cylindrical hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib members absorb and damp lateral vibratory forces exerted on said at least one

battery contained in said battery container and said electrically conductive member allows electrical current flow from said at least one cylindrical battery within said battery container.

19. The elongate cylindrical battery container as claimed in claim 18, wherein said resiliently-deformable rib members are molded and formed integrally with said elongate electrically insulative cylindrical hollow tube.

20. The elongate cylindrical battery container as claimed in claim 18, wherein said resiliently-deformable rib members are separate from and non-integral with said elongate electrically insulative cylindrical hollow tube.

21. The elongate cylindrical battery container as claimed in claim 18, wherein said elongate electrically-conductive member is integrally moulded within said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube proximate one of said plurality of resiliently-deformable protruding rib members and immediately radially beneath or above said one of said plurality of resiliently-deformable protruding rib members thereon.

22. The elongate cylindrical battery container as claimed in claim 18, wherein said resiliently-deformable rib members are situated on an exterior of said cylindrical periphery of said elongate electrically insulative cylindrical hollow tube, and an interior cylindrical periphery of said elongate electrically insulative cylindrical hollow tube is in direct contact with each of said at least one cylindrical battery.

23. The elongate cylindrical battery container as claimed in claim 18, wherein:

each of said at least one cylindrical batteries are circumferentially surrounded about said cylindrical periphery thereof by a thin resiliently-deformable tubular sleeve;

a further plurality of resiliently-deformable rib members are integrally formed within said thin resiliently-deformable tubular sleeve and disposed about or along an outer or inner cylindrical periphery of said thin resiliently-deformable sleeve;

wherein when a plurality of cylindrical batteries and associated sleeves are inserted in said elongate hollow tube and said elongate electrically insulative cylindrical hollow tube inserted in measurement-while-drilling equipment and then inserted downhole, said resiliently-deformable rib members and said thin resiliently-deformable sleeve in a region of said further plurality of resiliently-deformable rib members thereon together absorb and damp lateral vibratory forces exerted on said elongate electrically insulative cylindrical hollow tube and said cylindrical batteries contained therewithin.

24. The elongate cylindrical battery container as claimed in claim 23, wherein said thin resiliently-deformable tubular sleeve and said further resiliently-deformable rib members thereon are together formed from a two- part silicone rubber composition comprising a base and a curing agent, said base when mixed with said curing agent forming a resiliently-deformable, waterproof, electrically non-conductive flexible material.

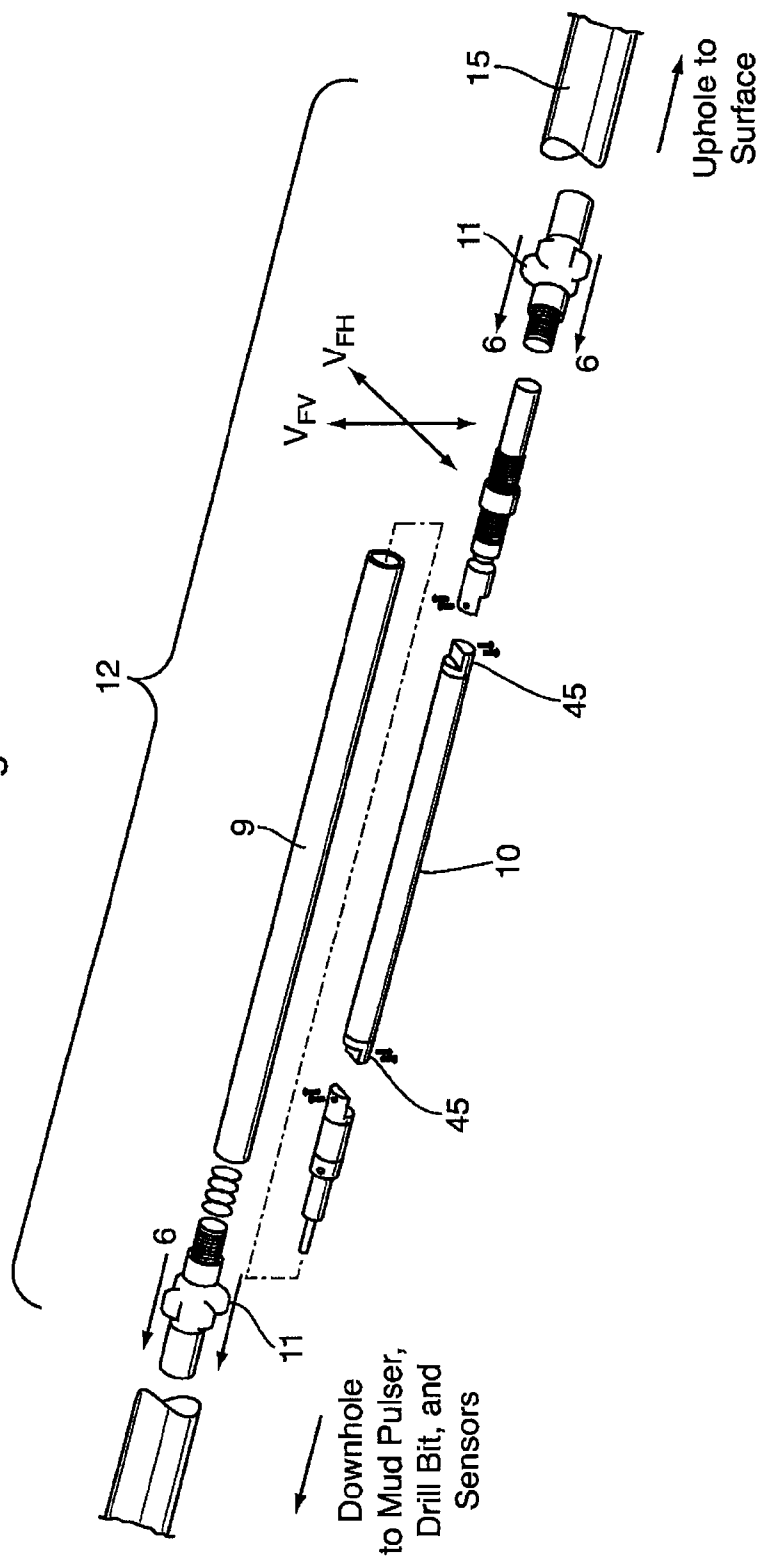
25. The elongate cylindrical battery container as claimed in claim 24, wherein said two-part silicone rubber composition is formed from ZIAMETER™ RTV-4130-J base and ZIAMETER² RTV-4130-J curing agent.

² Registered trademark of Dow Corning Corporation for a two-part silicon rubber supplied as a pourable fluid that cures to a firm flexible elastomer

26. The elongate cylindrical battery container as claimed in claim 18, further having a biasing member situated at one end of said elongate electrically insulative cylindrical hollow tube for exerting a force against said at least one battery for damping longitudinal vibrations exerted on said at least one battery when located in said battery container.

27. The elongate cylindrical battery container as claimed in claim 26, wherein said biasing member at one end of said elongate electrically insulative cylindrical hollow tube is a helical spring.

Fig. 1



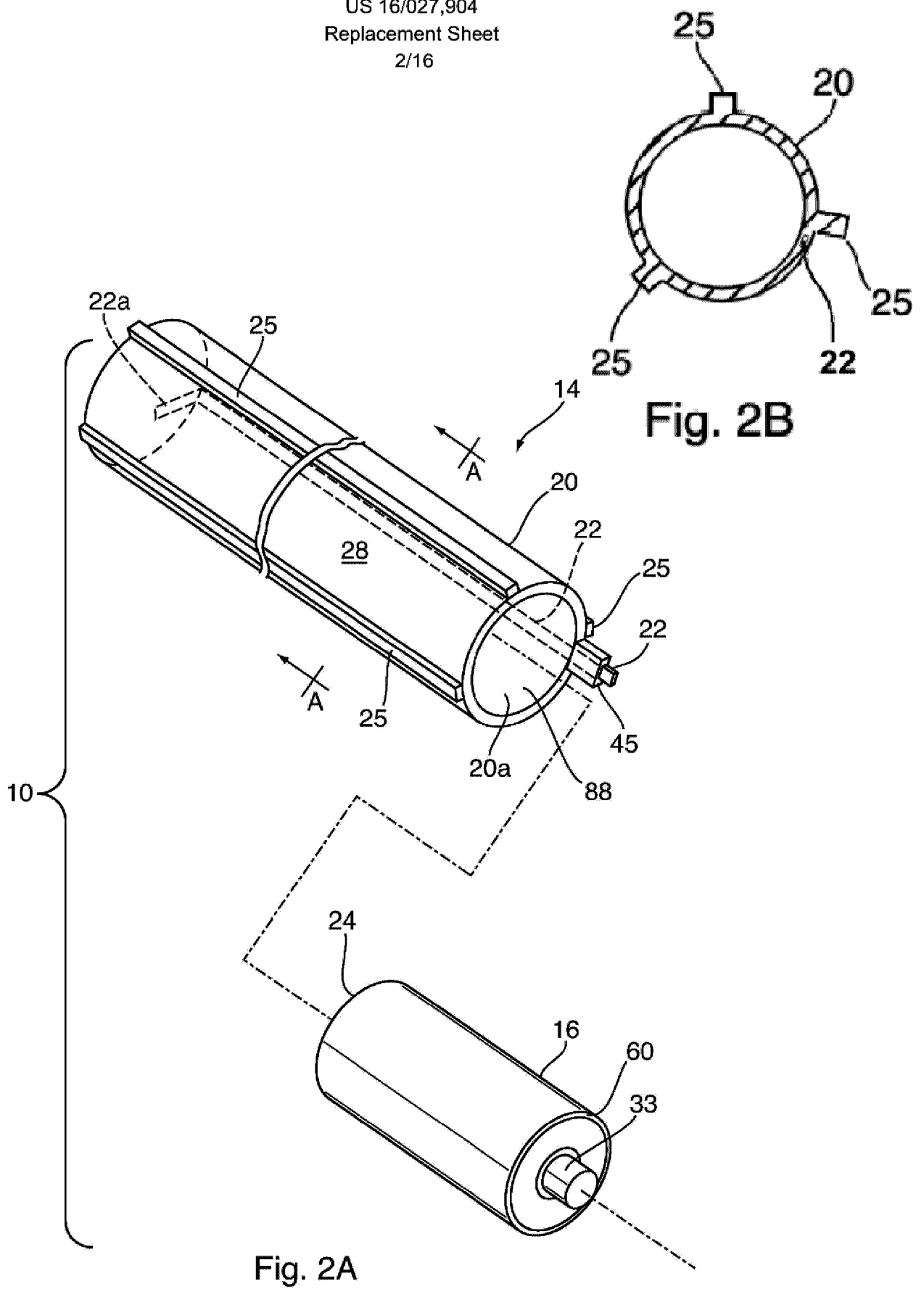
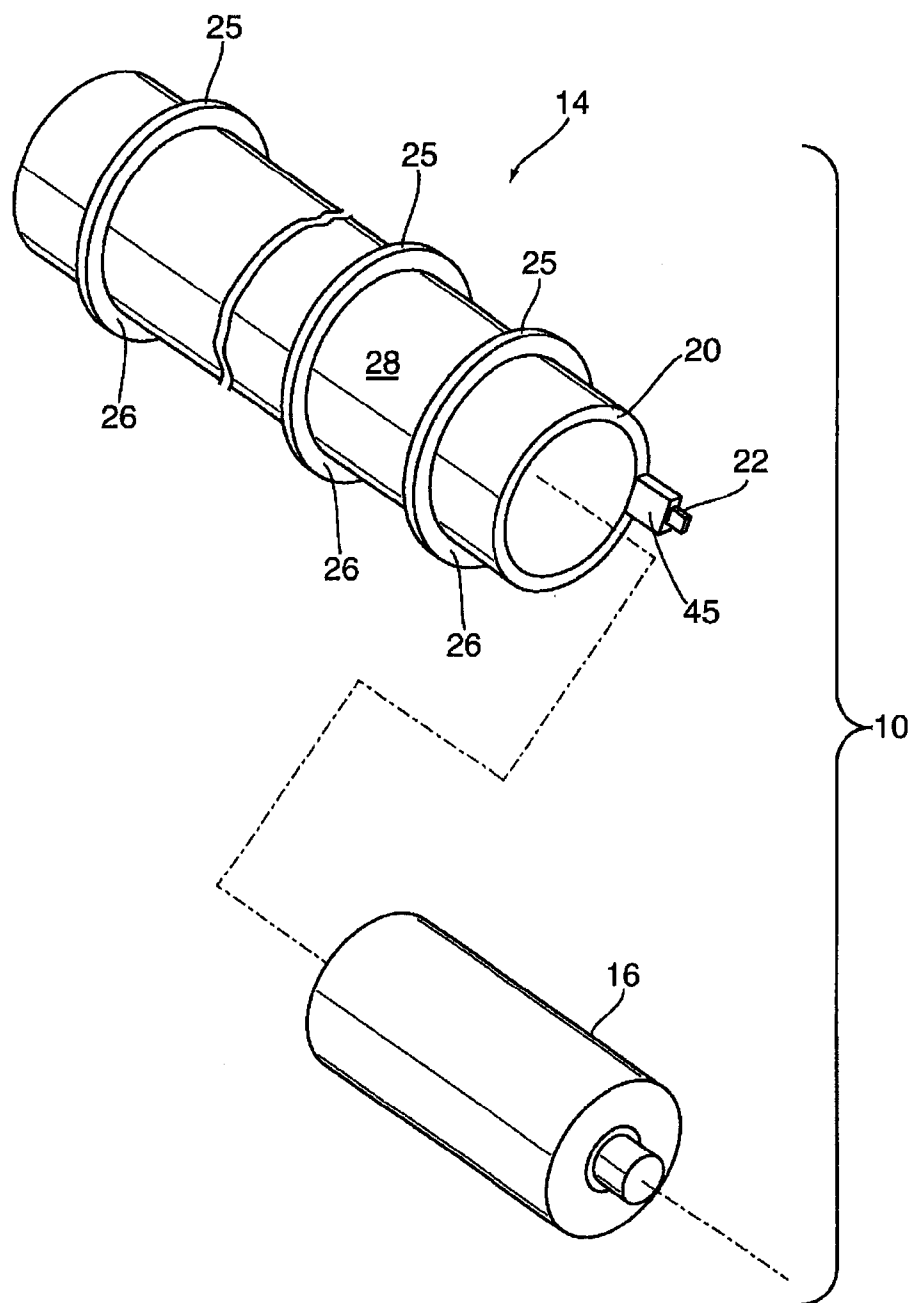
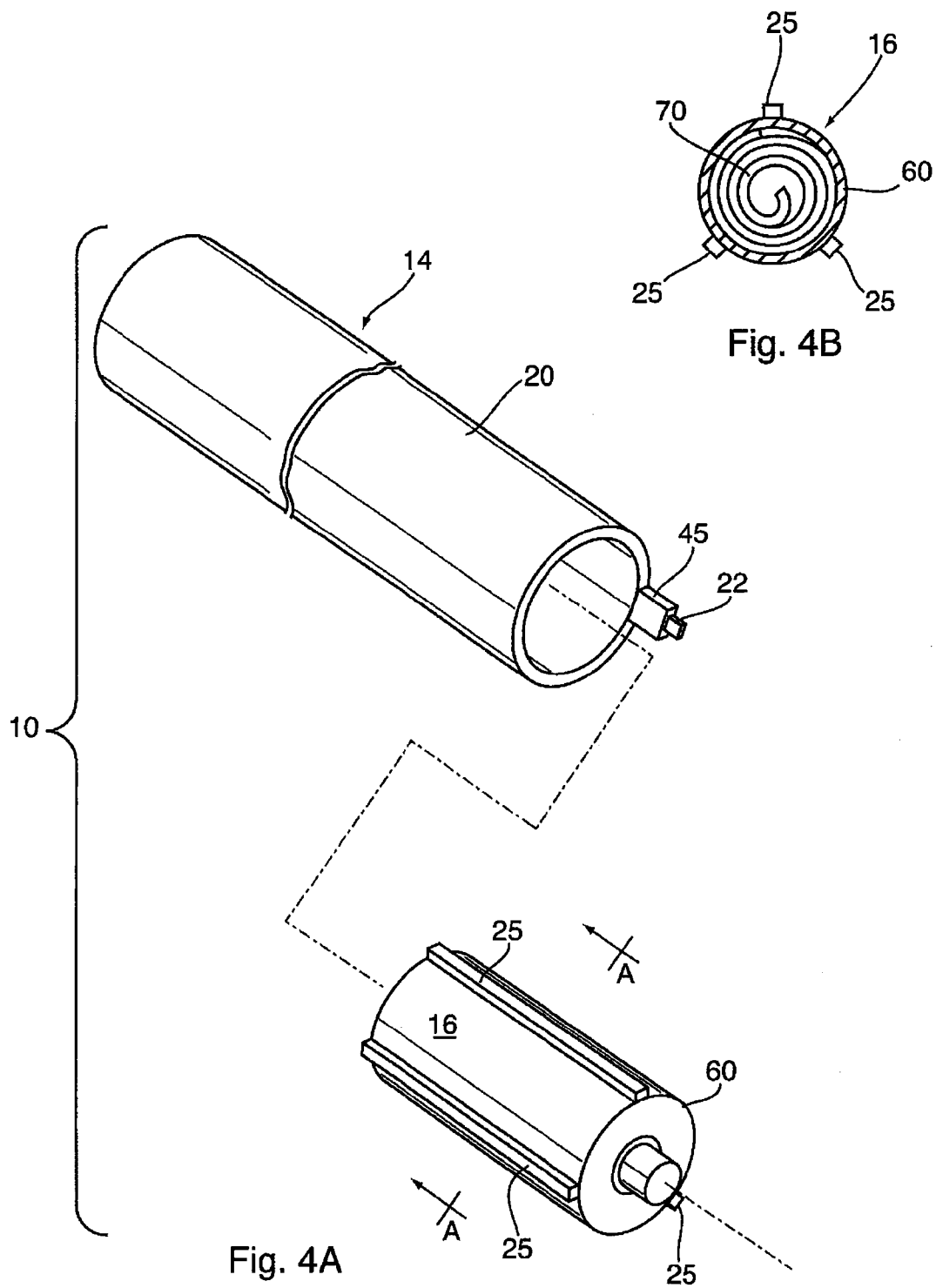


Fig. 3





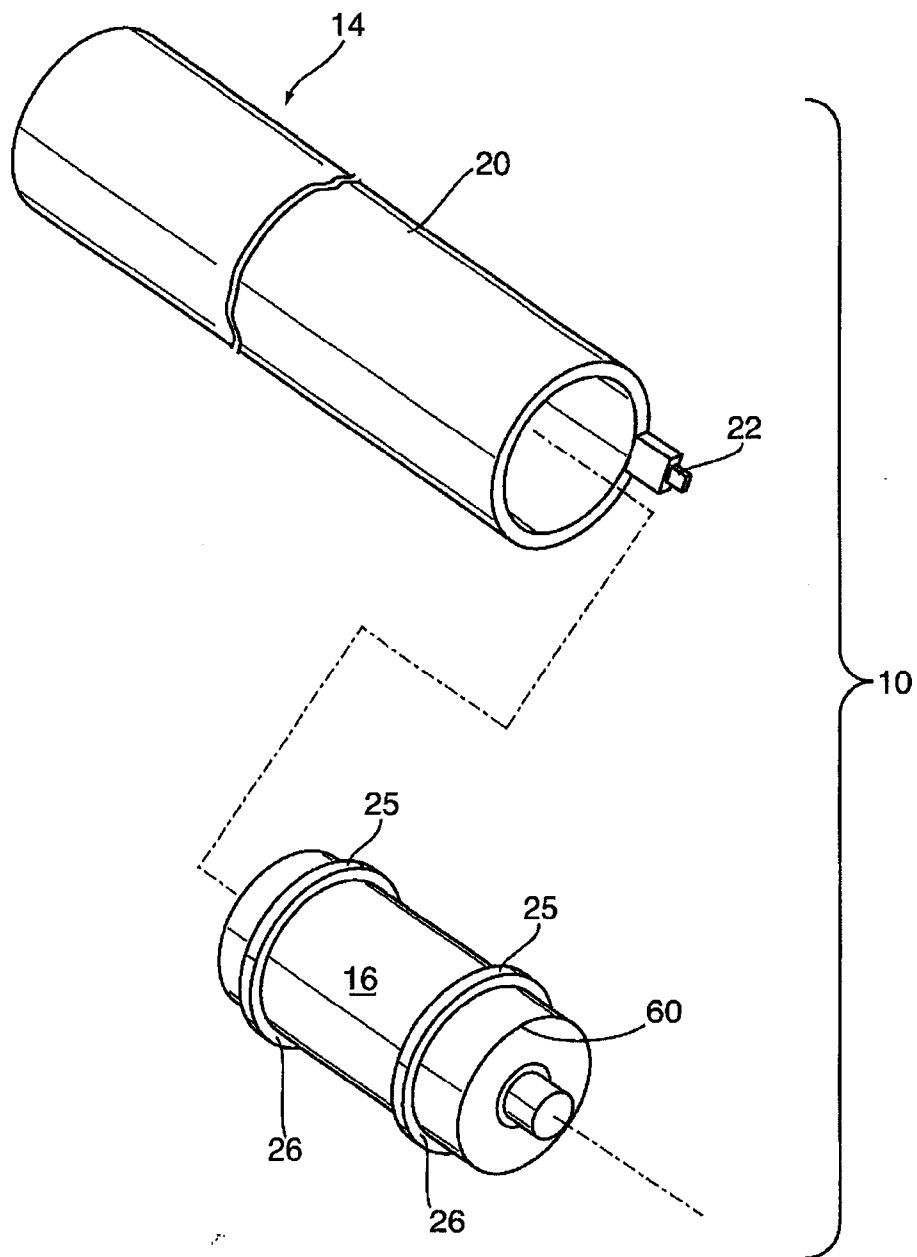
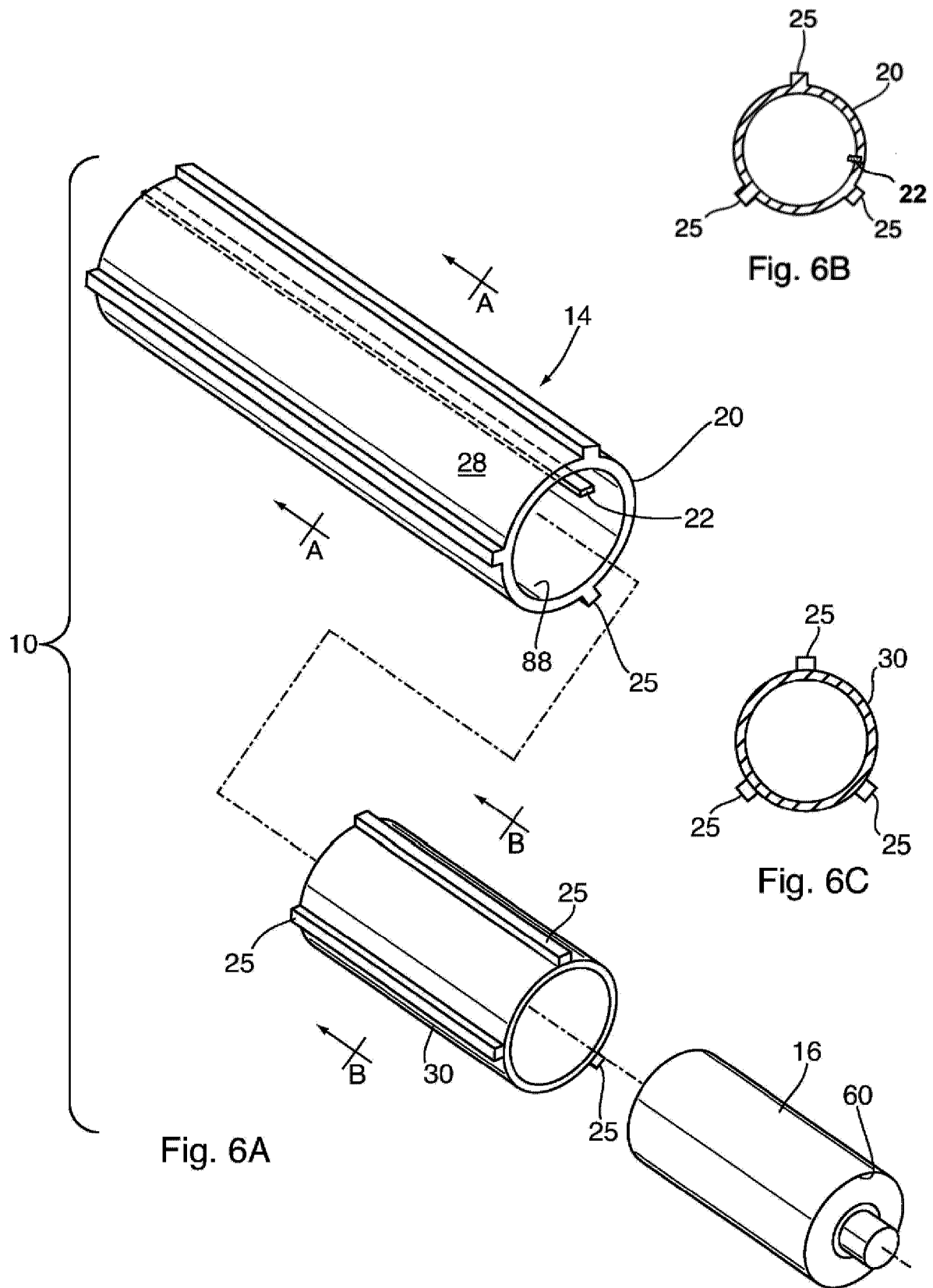
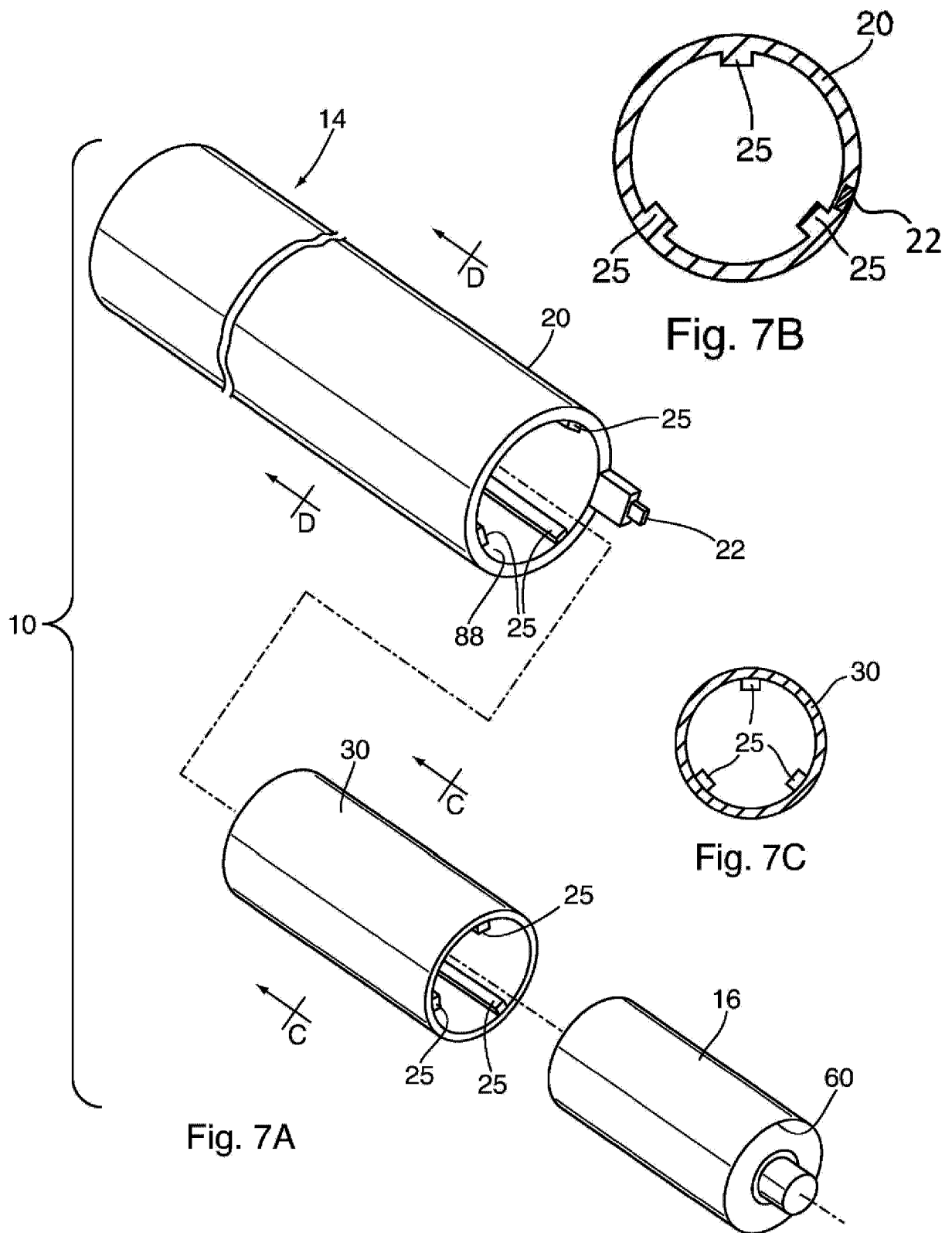


Fig. 5





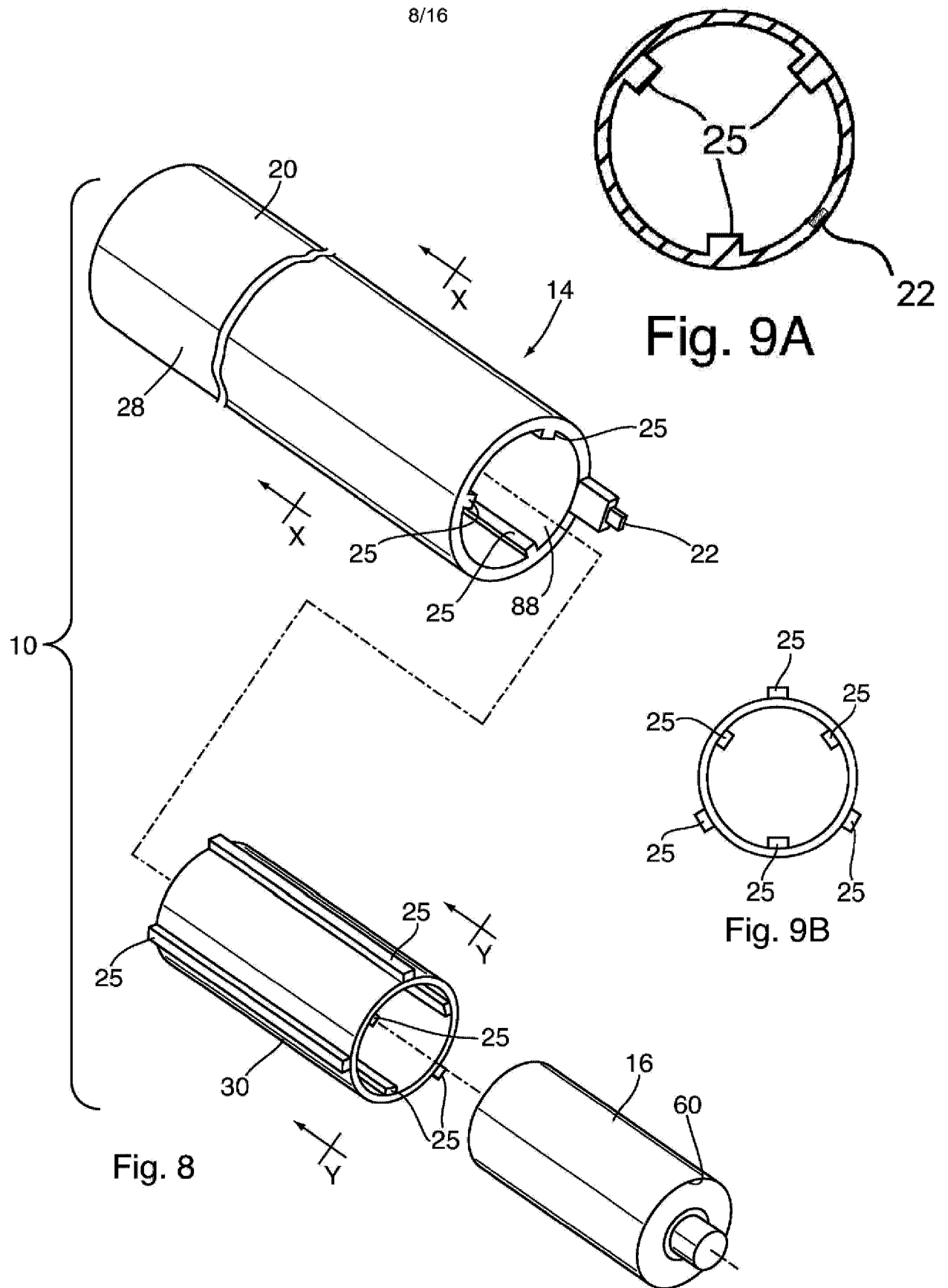


Fig. 10

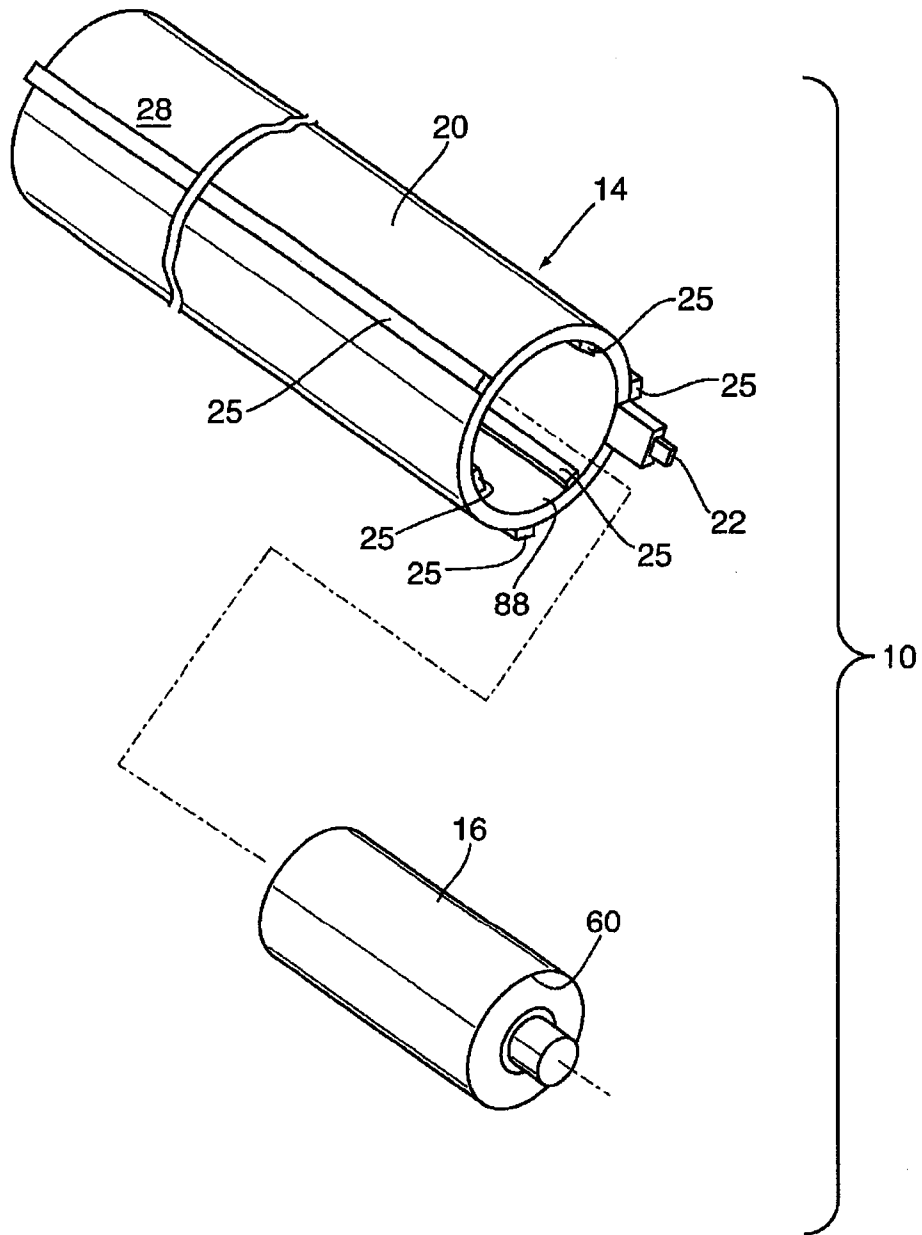


Fig. 11

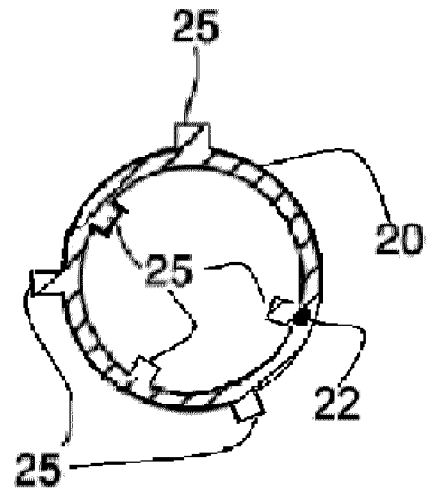
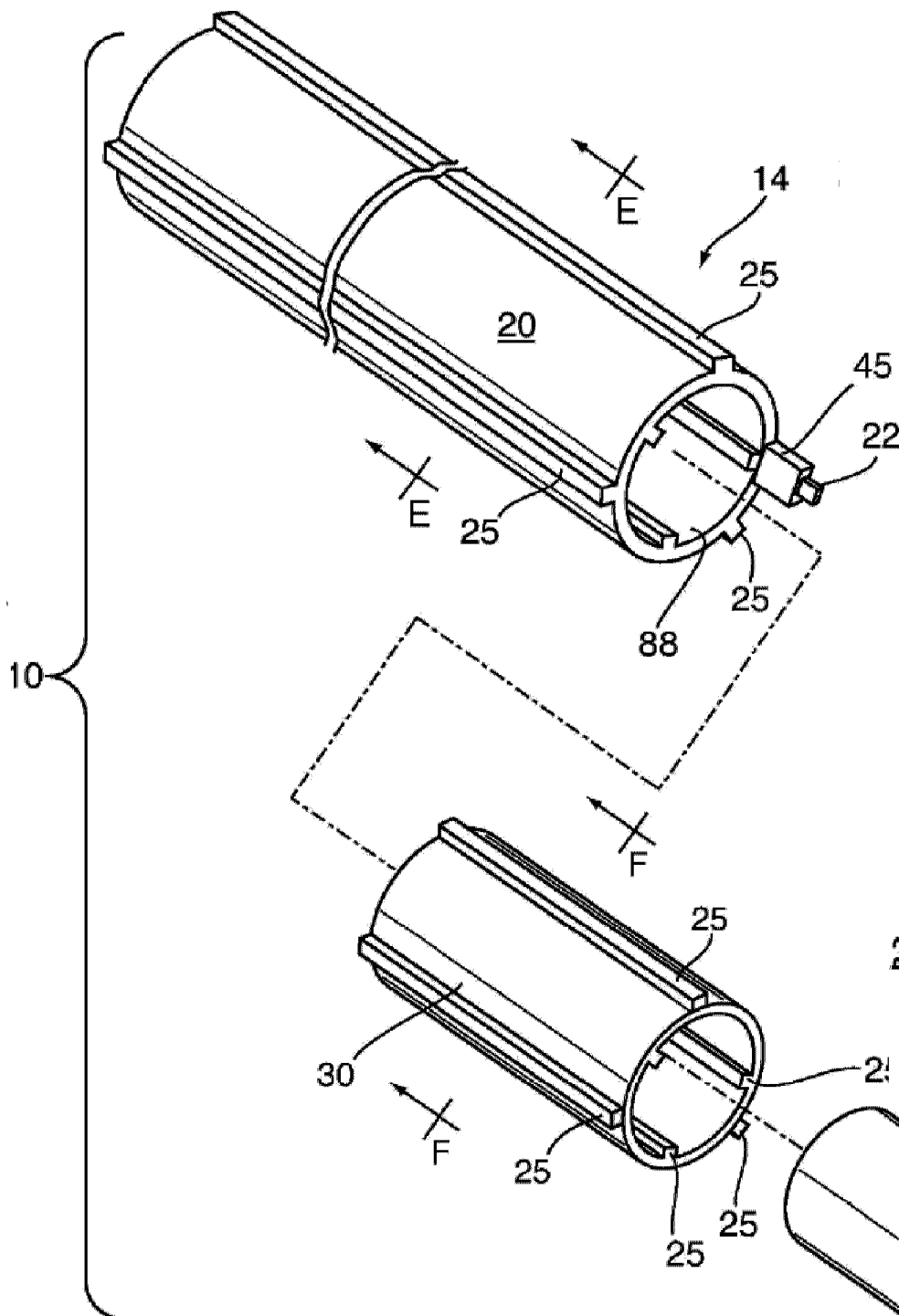


Fig. 12

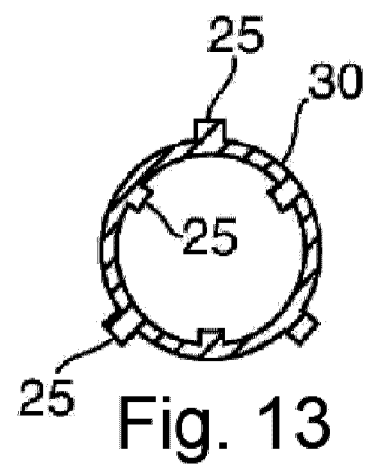


Fig. 13

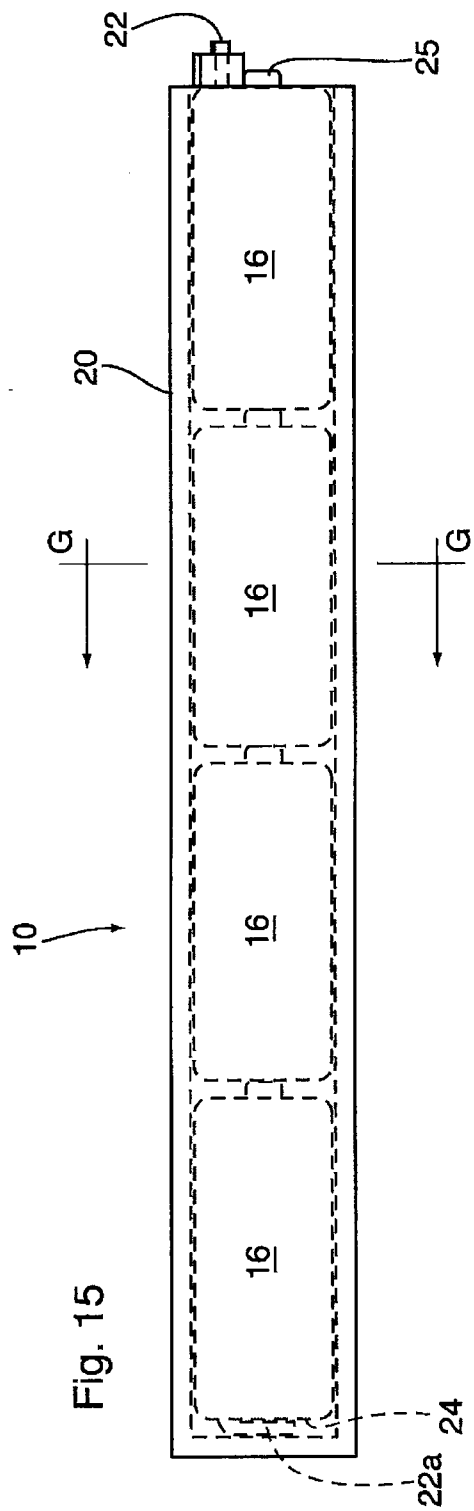
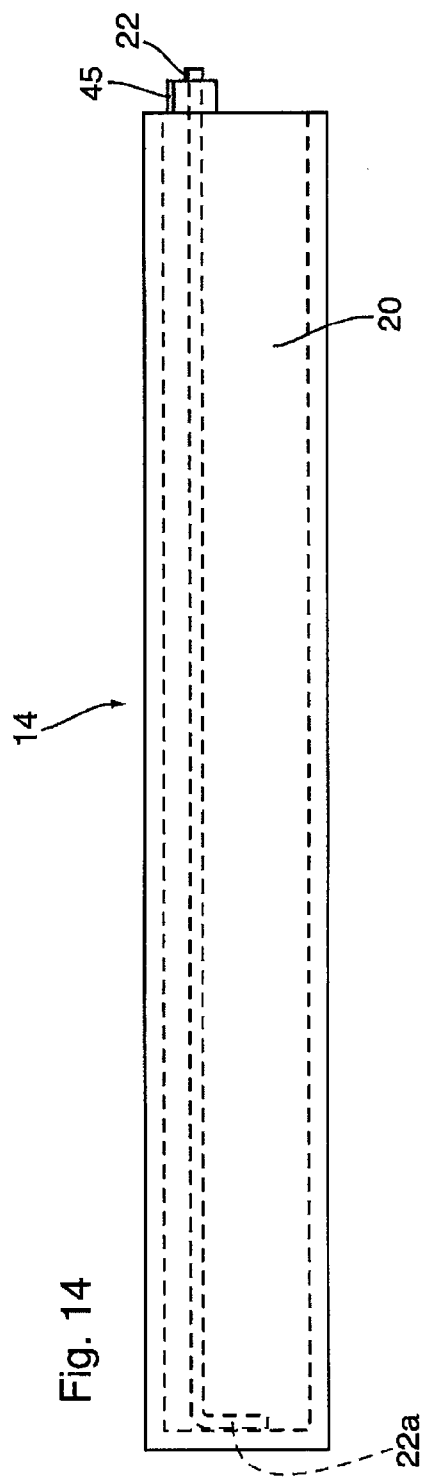


Fig. 16A

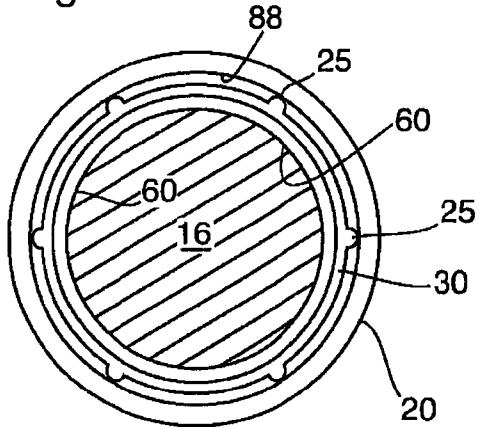


Fig. 16D

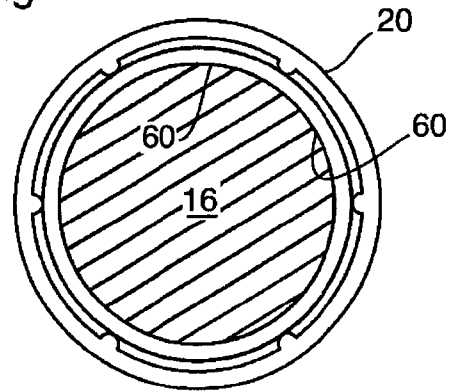


Fig. 16B

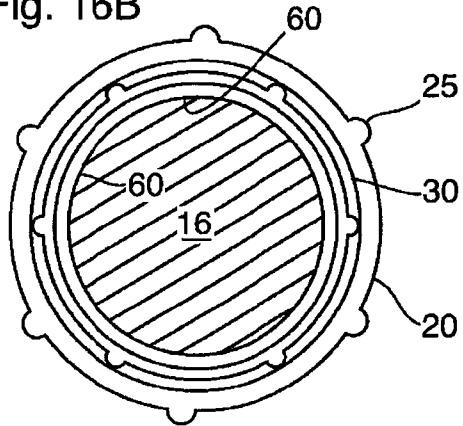


Fig. 16E

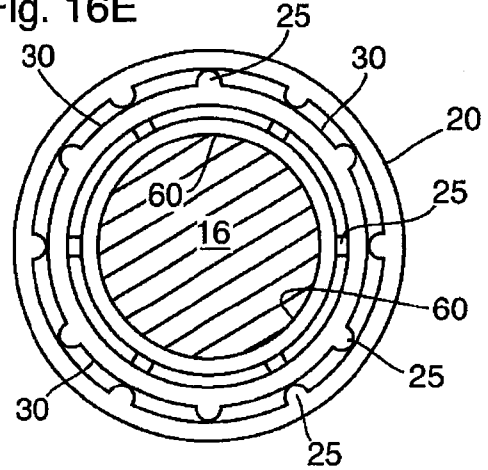


Fig. 16C

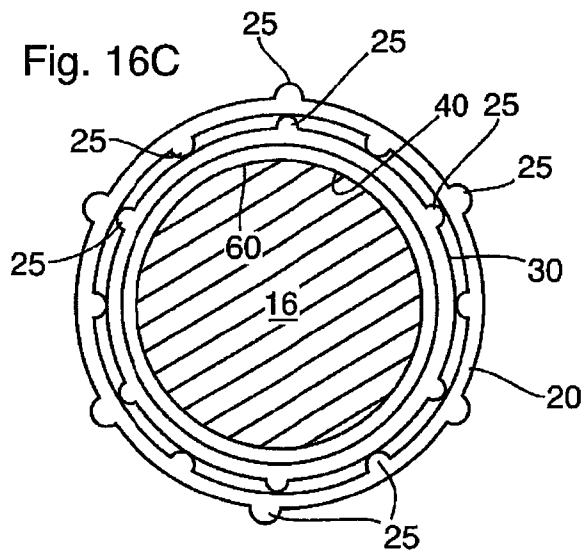


Fig. 16F

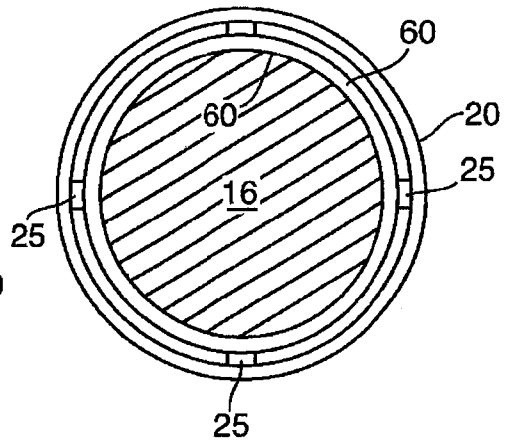


Fig. 17

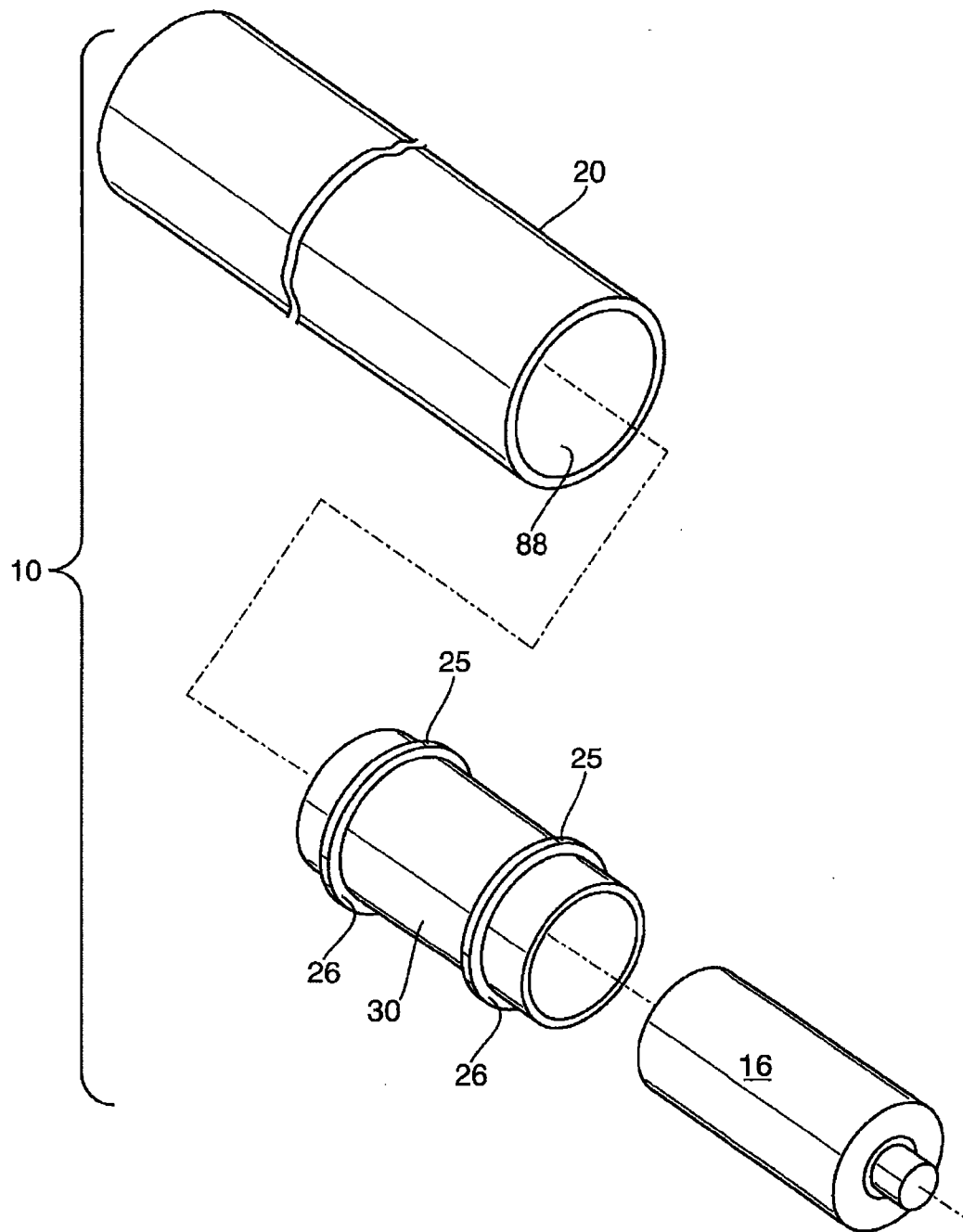


Fig. 18

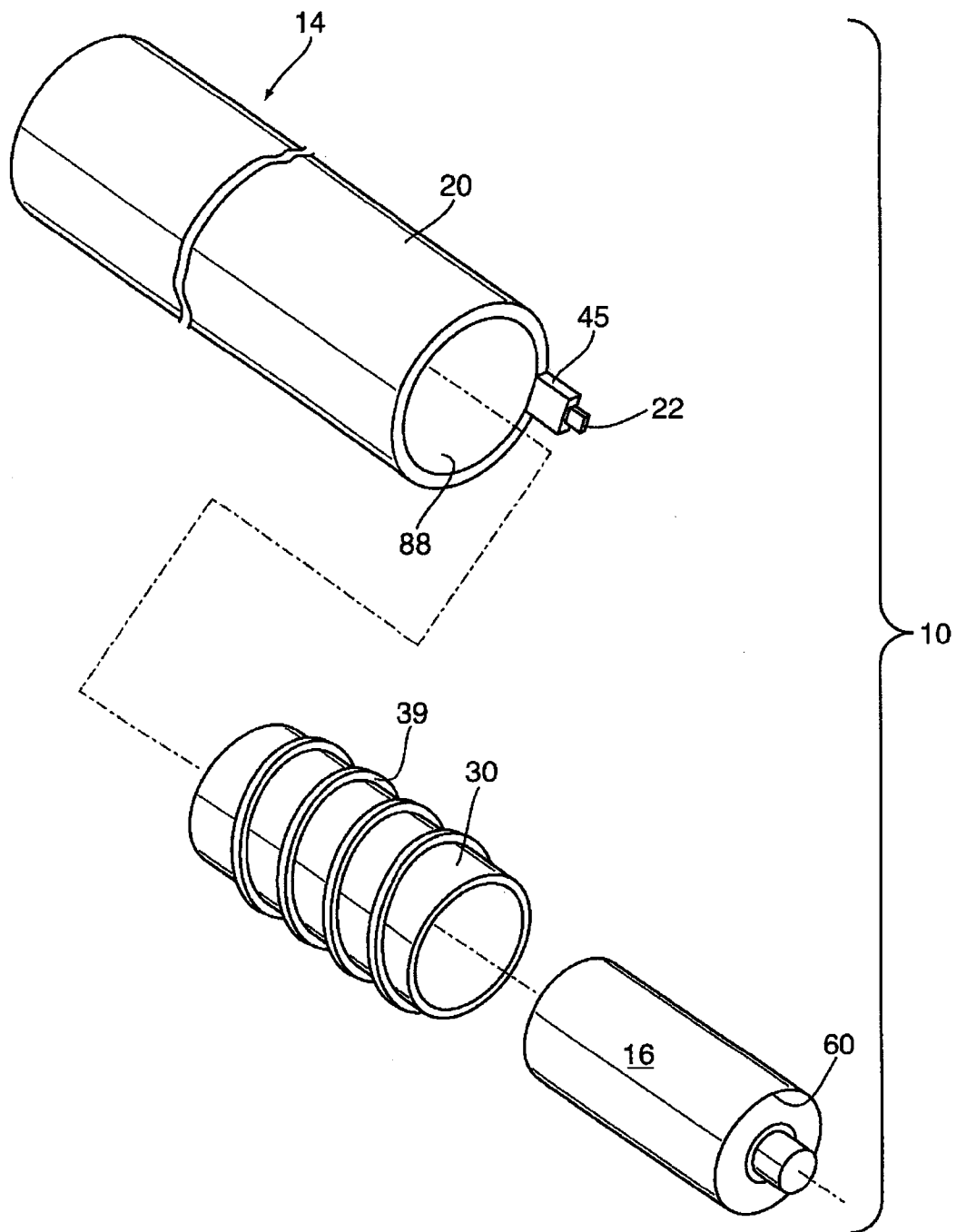


Fig. 19

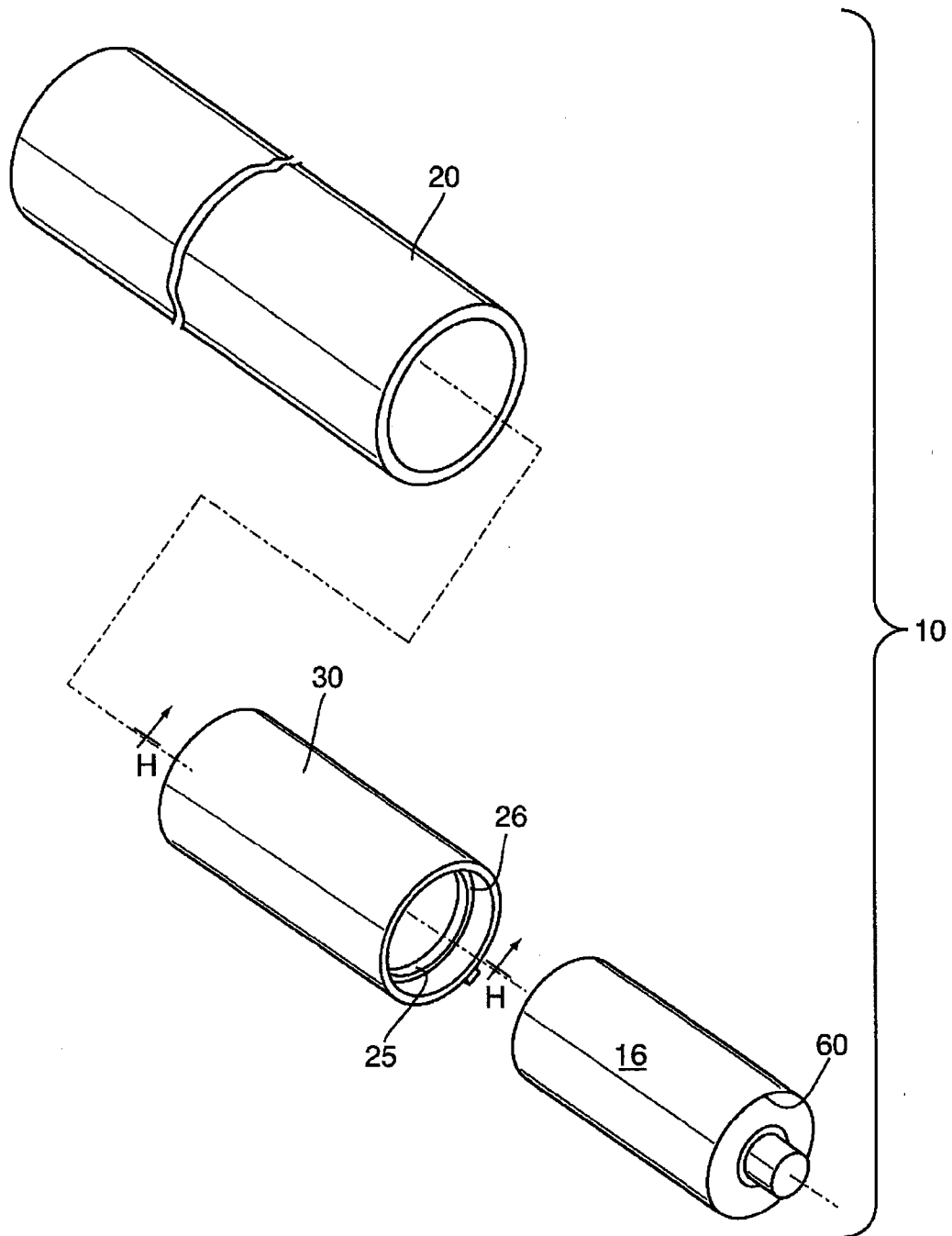


Fig. 20

