(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
3 April 2014 (03.04.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/047680 A1

(51) International Patent Classification:
E21B 25/00 (2006.01)

(21) International Application Number:
PCT/AU2013/001093

(22) International Filing Date:
24 September 2013 (24.09.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2012904184 25 September 2012 (25.09.2012) AU

(71) Applicant: **CT TECH PTY LTD** [AU/AU]; 5 Sapphire Court, Mt Richon, Western Australia 6112 (AU).

(72) Inventor: **BEACH, Shayne**; 5 Sapphire Court, Mt Richon, Western Australia 6112 (AU).

(74) Agent: **GRIFFITH HACK**; Level 19, 109 St Georges Terrace, Perth, Western Australia 6000 (AU).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2014/047680 A1

(54) Title: A CORE LIFTER ASSEMBLY

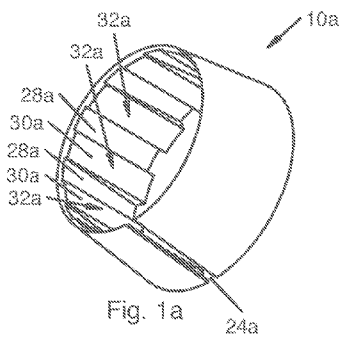


Fig. 1a

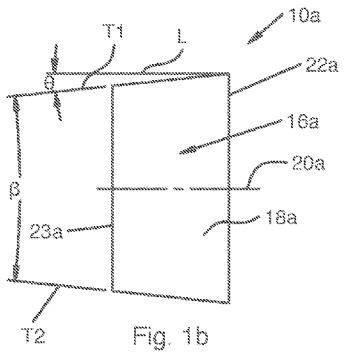


Fig. 1b

(57) Abstract: A core lifter assembly (12) comprises a combination of a core lifter ring (10) and a core lifter case (14). The ring (10) has an ax!a!!y extending portion (16) of an outer generally frusto-conical configuration having an included taper angle β. The included taper angle β is also the taper angle of the outer circumferential surface (18) of the ring (10). The included taper angle β may in alternate embodiments be ≥ 6°; > T°; ≥ 8°; or ≥ 10°. In one embodiment an upper limit of the included taper angle β may be about 30°. Thus in one embodiment the included taper angle β may be expressed by the relationship: 30° ≥ p ≥ 6°. Further, the angle β may comprise any sub range within the aforementioned range of 6 − 30°. However in other embodiments the taper angle may exceed 30°.

A CORE LIFTER ASSEMBLY

Technical Field

The present invention relates to a core lifter assembly of a type used in core drilling.

Background Art

A core lifter assembly is attached to a downhole end of a core barrel which in turn is carried by a core drill. When the core drill is in operation it cuts a core sample of the ground which passes through the core lifter assembly and into the core barrel. In order to retrieve the core sample once drilling has ceased the core drill is lifted from the toe of the hole. During this process the core lifter assembly grips the core so that the lifting force on the drill is transferred onto the core, breaking it from the ground. When the core barrel is retrieved either via use of a wireline, or by withdrawal of the entire core drill, the core sample is held in the core barrel by the core lifter assembly.

The core lifter assembly comprises two main components namely a core lifter case and a core lifter ring. An outer circumferential surface of the core lifter ring and an inner circumferential surface of the core lifter case are formed with complimentary tapered surfaces allowing the core lifter ring to slide axially relative to the core lifter case. The taper on the core lifter ring forms an included angle of about 4° – 5°.

The core lifter ring is not a full or complete ring but commonly a split ring having a longitudinal slot. Also the ring is made of a resilient material which biases the ring toward a maximum diameter and corresponding maximum width of the slot. The slot opens to a maximum width when the core lifter ring is in an uphole position relative to the case. This is the position of the core lifter ring when an associated core drill is drilling a core sample and the core sample is entering the core barrel. During a core breaking operation the core drill is lifted in an uphole direction. However the ring is retarded by friction against the core with the effect that the case slides uphole relative to the ring. Due to the tapered surfaces of the case and ring the ring is now compressed about an outer circumferential surface of the core sample, and the width of the slot is reduced.

The core lifter ring can clamp the core sample so tightly that it is very difficult to remove the core sample once it is retrieved to the surface. In order for a drill rig operator to

release the core sample from the core lifter they may strike the protruding core sample with a block of wood. If that does not succeed the operator may resort to use of a hammer or similar instrument to strike the end of the core sample.

Striking the end of the core sample usually results in damage to the end face of a sample. This is problematic as it makes it more difficult for a geologist to rotationally align the core sample with an adjacent sample. Further, the inability to easily release the core sample from the core barrel causes frustration to the drill rig operators and presents a significant safety risk.

Throughout this specification and claims the term “downhole end” is intended to denote a toe end of a bore hole while the expression “uphole end” is intended to denote a collar end. Accordingly the downhole end of a hole may be vertically above an uphole end where for example a hole is drilled upwardly or with at least a vertical upward inclination.

Summary of the Disclosure

In a first aspect there is disclosed a core lifter for a core drill comprising:

a core lifter ring having an axially extending portion having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$.

In a second aspect there is disclosed a core lifter for a core drill comprising:

a core lifter ring having N axially extending portions each having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$ wherein N is an integer ≥ 1.

In a third aspect there is disclosed a core lifter for a core drill comprising:

a plurality of core lifter rings each ring having N axially extending portions each having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$ wherein N is an integer ≥ 1.

In one embodiment the angle $\beta \geq 7°$.

In one embodiment the angle $\beta \geq 8°$.

In one embodiment the angle $\beta \geq 10°$.

In one embodiment the angle $30° \geq \beta \geq 6°$

In one embodiment one or more of the axially extending portions comprises a plurality of circumferentially alternating and generally axially extending grooves and splines formed on an inner circumferential surface or an outer circumferential surface of the one or more axially extending portions.

In one embodiment the grooves extend parallel to the central axis of the ring.

In one embodiment the grooves follow a spiral path between axially opposite ends of their corresponding axially extending portion.

In one embodiment the grooves extend to and reach a large outer diameter end of their corresponding axially extending portion.

In one embodiment the grooves extend to and reach a small outer diameter end of their corresponding axially extending portion.

In one embodiment the core lifter assembly comprises a core lifter case in which the or each core lifter ring is slidably retained.

In one embodiment of the third aspect the core lifter assembly comprises a core lifter case in which the plurality of core lifter rings are slidably retained in axially spaced relationship.

In one embodiment the core lifter case comprises a tapered section for each axially extending portion, each tapered section configured to engage a corresponding axially extending portion to cause a change in diameter of the core lifter ring associated with the axially extending portion in response to axial displacement of the associated core lifter ring relative to the tapered section.

In a fourth aspect there is disclosed a core lifter for a core drill comprising: a core lifter ring having opposite downhole and uphole ends spaced by an axial distance X, an interior circumferential surface having a substantially constant major diameter for the axial distance X, and an outer circumferential surface, the interior circumferential surface and outer circumferential surface configured to form a half angle $\theta \geq 3°$ for at

least a portion of the distance X in at least two circumferentially spaced locations wherein at the locations a wall of the ring decreases in thickness in a direction from the uphole end to the downhole end.

In a fifth aspect there is disclosed a core lifter for a core drill comprising: a core lifter ring having opposite downhole and uphole ends spaced by an axial distance X, an interior circumferential surface having a substantially constant major diameter for the axial distance X, and an outer circumferential surface, the interior circumferential surface and outer circumferential surface configured to provide the ring with a half angle $\theta \geq 3°$ for at least a portion of the distance X wherein a wall of the ring decreases in thickness in a direction from the uphole end to the downhole end for the corresponding portion of the distance X.

In one embodiment the angle $\theta \geq 4°$.

In one embodiment the angle $\theta \geq 5°$.

In one embodiment the angle $\theta \geq 6°$.

In one embodiment the angle $15° \geq \theta \geq 3°$.

In one embodiment the portion of the distance X is X/N where N is an integer ≥1 and wherein the ring comprises N number of integrally formed portions.

In one embodiment the outer circumferential surface of the ring for one or more of the N portions has a radius that is constant in a circumferential direction for any location along the central axis and continuously decreases in an axial direction from the uphole end to the downhole end.

In one embodiment one or more of the N portions comprises a plurality of circumferentially spaced recesses on the outer circumferential surface whereby an outer circumference of the ring in one or more of the N portions comprises alternating grooves and sloped splines wherein the angle θ is a measure of an angle of slope of the spline relative to a line co-axial with a central axis of the ring.

In an embodiment wherein $N \geq 2$ the axially extending portions are arranged to taper in a common direction. In this embodiment the core lifter may further comprise, between

mutually adjacent axially extending portions, one or more transition zones extending from a small diameter end of one of the axially extending portions to a larger diameter end of the other axially extending portions.

In one embodiment the one or more transition zone comprises a tapered transition zone having a substantially frusto-conical circumferential surface.

In one embodiment the one or more transition zones comprise a cylindrical transition zone having a substantially cylindrical circumferential surface.

In one embodiment the one or more transition zone comprises a tapered transition zone having a substantially frusto-conical circumferential surface and a contiguous cylindrical transition zone having a substantially cylindrical circumferential surface.

In one embodiment the frusto-conical outer circumferential surface of the transition zone slopes at a half angle of $90° > \alpha > 3°$.

In one embodiment $\alpha = -\beta/2$.

In one embodiment $\alpha = -\beta$.

In one embodiment an axial length of the one or more transition zone is substantially the same as an axial length of an axially extending portion.

In an alternate embodiment where $N \geq 2$ the axially extending portions are arranged to taper in a common direction and with a small diameter end of one axially extending portion located immediately adjacent a large diameter end of another axially extending portion. In such an embodiment there may be provided a stepwise transition between mutually successive axially extending portions.

In one embodiment a wall of the core lifter ring is formed of substantially uniform thickness for the axial length of each of the grooves.

In a sixth aspect there is disclosed a method of manufacturing a core lifter ring comprising:

injection moulding a metallic material into a mould provided with a moulding cavity having a shape and configuration such that when the metallic material is injected

into the cavity and subsequently set, the set material forms a core lifter ring having one or more axially extending portions each axially extending portion having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$.

In a seventh aspect there is disclosed a method of manufacturing a core lifter case comprising:

injection moulding a metallic material into a mould provided with a moulding cavity having a shape and configuration such that when the metallic material is injected into the cavity and subsequently set, the set material forms a core lifter case capable of receiving and working with a core lifter ring which has one or more axially extending portions each axially extending portion having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within the scope of the apparatus and method as set forth in the Summary, specific embodiments will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1a is an isometric view of a core lifter ring used in a first embodiment of a core lifter assembly in accordance with the present disclosure;
Figure 1b is a side elevation of the ring shown in Figure 1a;
Figure 1c is an end view of the ring shown in Figure 1a;
Figure 1d is an opposite end view of the ring shown in Figure 1a;
Figure 1e is a view of section A-A of the ring depicted in Figure 1d;
Figure 2a is a section view of a first embodiment of the core lifter assembly with an associated core lifter ring in a retracted position;
Figure 2b is a section view of the core lifter assembly shown in Figure 2a but with the core lifter ring in a clamping position;
Figure 3a is an isometric view of a core lifter ring used in a second embodiment of the core lifter assembly;
Figure 3b is a side elevation of the ring shown in Figure 3a;
Figure 3c is an end view of the ring shown in Figure 3a;
Figure 3d is an opposite end view of the ring shown in Figure3a;
Figure 3e is a view of section A-A of the ring depicted in Figure 3d;
Figure 4a is a section view of a second embodiment of the core lifter assembly with an associated core lifter ring in a retracted position;

Figure 4b is a section view of the core lifter assembly shown in Figure 4a but with the core lifter ring in a clamping position;

Figure 5a is an isometric view of a core lifter ring for a third embodiment of the core lifter assembly;

Figure 5b is a side view of the core lifter ring shown in Figure 5a;

Figure 5c is an end view of the core lifter ring shown in Figure 5a;

Figure 5d is a view of section A-A of the core lifter ring shown in Figure 5c;

Figure 5e is a view of section B-B of the core lifter ring shown in Figure 5c;

Figure 5f is a section view of the third embodiment of the core lifter assembly depicted with the core lifter ring in a clamping position;

Figure 6a is an isometric view of a core lifter ring for a fourth embodiment of the core lifter assembly;

Figure 6b is a side view of the core lifter ring shown in Figure 6a;

Figure 6c is an end view of the core lifter ring shown in Figure 6a;

Figure 6d is a view of section A-A of the core lifter ring shown in Figure 6c;

Figure 6e is a view of section B-B of the core lifter ring shown in Figure 6c;

Figure 6f is a section view of the fourth embodiment of the core lifter assembly depicted in the core lifter ring in a clamping position;

Figure 7a is an isometric view of a plurality of core lifter rings for a fifth embodiment of the core lifter assembly;

Figure 7b is a side view of the core lifter rings shown in Figure 7a;

Figure 7c is an end view of the core lifter rings shown in Figure 7a;

Figure 7d is a view of section A-A of the core lifter rings shown in Figure 7c;

Figure 7e is a view of section B-B of the core lifter rings shown in Figure 7c;

Figure 7f is a section view of the fifth embodiment of the core lifter assembly depicted with the plurality of core lifter rings in a clamping position;

Figure 8a is an isometric view of a core lifter ring for a sixth embodiment of the core lifter assembly;

Figure 8b is a side view of the core lifter ring shown in Figure 8a;

Figure 8c is an end view of the core lifter ring shown in Figure 8a;

Figure 8d is a view of section A-A of the core lifter ring shown in Figure 8c;

Figure 8e is a view of section B-B of the core lifter ring shown in Figure 8c;

Figure 8f is a section view of a core lifter case incorporated in the sixth embodiment of the core lifter assembly;

Figure 9a is a section view of the sixth embodiment of the core lifter assembly with the core lifter ring in a retracted position;

Figure 9b is a view of the core lifter assembly shown in Figure 9a but with the core lifter

ring in a clamping position;

Figure 10a is an isometric view of a core lifter ring for a seventh embodiment of the core lifter assembly;

Figure 10b is an end view of the core lifter ring shown in Figure 10a;

Figure 10c is a view of section A-A of the core lifter ring shown in Figure 10b;

Figure 10d is a view of section B-B of the core lifter ring shown in Figure 10b;

Figure 11a is an isometric view of a core lifter ring for an eighth embodiment of the core lifter assembly;

Figure 11b is a side view of the core lifter ring shown in Figure 11a;

Figure 11c is an end view of the core lifter ring shown in Figure 11a;

Figure 11d is a view of section A-A of the core lifter ring shown in Figure 11c;

Figure 11e is a view of section B-B of the core lifter ring shown in Figure 11c;

Figure 12a is a side view of a core lifter ring for a ninth embodiment of the core lifter assembly;

Figure 12b is an end view of the core lifter ring shown in Figure 12a;

Figure 12c is a view of section A-A of the core lifter ring shown in Figure 12b;

Figure 12d is a view of section B-B of the core lifter ring shown in Figure 12b;

Figure 12e is a section view of a core lifter case of the ninth embodiment of the core lifter assembly;

Figure 12f is a section view of the ninth embodiment of the core lifter assembly with its associated core lifter ring in the retracted position;

Figure 12g is a section view of the core lifter assembly shown in Figure 12f but the core lifter ring in the clamping position;

Figure 12h is an isometric view of the core lifter ring shown in Figure 12a;

Figure 12i illustrates the first variation of the core lifter ring shown in Figure 12a;

Figure 12j illustrates a variation to the core lifter ring shown in Figure 12i;

Figure 12k illustrates a further variation of the core lifter ring shown in Figure 12a;

Figure 13a is a side view of a core lifter ring for a tenth embodiment of the core lifter assembly;

Figure 13b is an end view of the core lifter ring shown in Figure 13a;

Figure 13c is a view of section A-A of the core lifter ring shown in Figure 13b;

Figure 13d is a section view of a core lifter case incorporated in the tenth embodiment of the core lifter assembly;

Figure 13e is a section view of a tenth embodiment of the core lifter assembly comprising the core lifter ring of Figure 13a and the core lifter case of Figure 13d, and showing the core lifter ring in a clamping position;

Figure 14a is an isometric view of a core lifter ring for an eleventh embodiment of the

core lifter assembly;

Figure 14b is a side view of the core lifter ring shown in Figure 14a;

Figure 14c is an end view of the core lifter ring shown in Figure 14a;

Figure 14d is a view of section A-A of the core lifter ring shown in Figure 14c;

Figure 14e is a view of section B-B of the core lifter ring shown in Figure 14c;

Figure 14f is a view of detail C shown in Figure 14e;

Figure 15a is an isometric representation of the core lifter ring for a twelfth embodiment of the core lifter assembly; and

Figure 15b is an isometric view of a core lifter ring of a thirteenth embodiment of the core lifter assembly.

Detailed Description of the Preferred Embodiments

Figures 1a – 1e illustrate a core lifter ring 10a (hereinafter referred to in general as "ring 10a") for a first embodiment of a core lifter assembly 12a depicted in Figures 2a and 2b. The core lifter assembly 12a comprises a combination of the ring 10a and a core lifter case 14a (hereinafter referred to in general as "case 14a"). The ring 10a has an axially extending portion 16a of an outer generally frusto-conical configuration having an included taper angle β. The taper angle β is also the taper angle of the outer circumferential surface 18a. The included taper angle β is a measure of the included angle between two diametrically opposed axial tangents T1 and T2 of the surface 18a. The taper of the portion 16a and surface 18a may also be designated by a half angle $\theta = \beta/2$ where θ is the angle between one of the tangents T1 or T2 and a line L drawn parallel to a central axis 20a and extending from a maximum diameter end 22a of the portion 16a. Reference number 23a designates an opposite minimum diameter end of the ring 10a and portion 16a.

The included taper angle β may in alternate embodiments be $\geq 6°$; $\geq 7°$; $\geq 8°$; or $\geq 10°$. In one embodiment an upper limit of the included taper angle β may be about 30°. Thus in one embodiment the included taper angle β may be expressed by the relationship: $30° \geq \beta \geq 6°$. Further, the angle β may comprise any sub range within the aforementioned range of 6 - 30°. However in other embodiments the taper angle may exceed 30°.

As shown most clearly in Figures 1a, 1c and 1d, the ring 10a is in the form of a split ring and provided with an axially extending slot 24a. Also the ring 10a is made from a resilient material such as but not limited to spring steel. As a consequence ring 10a

can be radially compressed and expanded. However the ring 10a is configured so that in the absence of radially applied (i.e. hoop) compression it assumes its relaxed working diameter configuration. This may be greater than the maximum inner diameter of the portion of the case 14a in which the ring 10a resides. In this event there will be some pressure applied by the ring 12a to the inside of the case 14a. Conversely it may be less than the maximum inner diameter of the portion of the case 14a.

In the present embodiment the outer circumferential surface 18a of ring 10a is a continuous smooth surface which progressively reduces in outer diameter in a direction from the large diameter end 22a to small diameter end 23a. However an interior circumferential surface 26a of the ring 10a is provided with alternating axially extending grooves 28a and splines 30a. The grooves 28a are formed to a depth and of a shape so that a wall thickness W (shown in Figure 1e) of the ring 10a along each groove 28a is constant. Conversely, the width of the ring 10a in an axial section through a spline 30a is tapered at the half angle θ as shown on the left hand side of Figure 1e.

The free faces 32a of the splines 30a are radiused and lie on a common cylinder of the same radius. The actual radius of the circle will change depending on the relative juxtaposition of the ring 10a in the case 14a. Also although not shown in this embodiment the free faces 32a may be provided with texturing such as circumferential ribs, grooves, dimples or grit to assist in gripping a core passing through the ring 10a.

Referring to Figures 2a and 2b the case 14a has an uphole end 34a provided with an internal screw thread 36a to enable coupling to an inner core barrel. Downhole of the thread 36a there is provided an internal shoulder 38a which acts as a stop to limit sliding motion of the ring 10a in an uphole direction relative to the case 14a. Downhole of the shoulder 38a there is provided a tapered surface portion 40a. The surface portion 40a has a taper substantially complimentary to the taper of the portion 16a. The tapered portions 40a and 16a cooperate with each other to effect a change in the internal diameter of the ring 10a as the ring 10a slides axially relative to the case 14a.

When the ring 10a is in the retracted position shown in Figure 2a it may abut or lie a relatively small distance from the shoulder 38a. In this juxtaposition the outer surface 18a is expanded to a maximum diameter possible as limited by the inner diameter of the contacting section of the tapered portion 40a. Consequently the internal diameter of the ring 10a is also at its maximum diameter under the constraint of the contacting tapered portion.

During a core breaking action when a core drill, housing the core lifter assembly 12a, is lifted from the toe of the hole, in relative terms the ring 10a slides axially in a downhole direction in relation to the case 14a to a clamping position shown in Figure 2b. Due to the cooperation of the outer surface 18a with the tapered portion 40a, this results in a reduction of the internal diameter of the ring 10a effectively clamping the ring 10a about an outer circumferential surface of a core (not shown).

Due to the increased internal taper angle β once the core barrel with the associated core lifter assembly 12a is retrieved less force is required to revert the ring 10a to the retracted position to release the captured core than for a comparable prior art core lifter assembly.

Figures 3a – 3e depict a lifter ring 10b incorporated in a second embodiment of a core lifter assembly. The features of the ring 10b which are identical in function to those of the ring 10a are denoted with the same reference numbers but with the suffix "a" replaced with the suffix "b". The substantive difference between the rings 10a and 10b is the provision of two contiguous axially extending portions 16b. Portions 16b are of the same configuration as each other and of the same general configuration of the portion 16a. In particular each portion 16b has an included taper angle β and half angle θ as described hereinabove in relation to the ring 10a, (i.e. $30° \geq \beta \geq 6°$ and $\theta=\beta/2$). The axially extending portions 16b are arranged to taper in a common direction and with a small diameter end of one axially extending portion located adjacent a large diameter end of the other axially extending portion. In this embodiment there is a stepwise transition between the mutually successive axially extending portions.

The ring 10b is also provided with a longitudinal slot 24b and each portion 16b has a smooth continuous outer surface 18b. Grooves 28b and splines 30b are formed on the inner surface 26b of the ring 10b. Each of the grooves 28b has a generally concave channel surface 33b of constant radius in any transverse plane along its axial length. As a consequence, the thickness of a wall of ring 10b in axial section along a groove 28b is of a form of two contiguous wedges W1 and W2 shown on the right hand side of Figure 3e. The splines 30b are arranged so that axial tangents to their respective free faces 32b lie parallel to a central axis of the ring 10b. Thus in combination the surfaces of the splines 30b lie substantially on a common cylinder.

A core lifter assembly 12b which utilises the ring 10b comprises a core lifter case 14b shown in Figures 4a and 4b. The case 14b has an uphole end 34b provided with an internal screw thread 36b to enable coupling to an inner core barrel. Downhole of the thread 36b there is provided an internal shoulder 38b which acts as a stop to limit sliding motion of the ring 10b in an uphole direction relative to the case 14b. Downhole of the shoulder 38b there is provided two tapered surface portions 40b and 40b. The surfaces 40b each have a taper substantially complimentary to the taper of the portions 16b. The tapered portions 40b cooperate with the portions 16b to effect a change in the internal diameter of the ring 10b as the ring 10b slides axially relative to the case 14b.

As in the first embodiment, when the ring 10b is in the retracted position shown in Fig. 4a it may abut or lie a relatively small distance from the shoulder 38b and the outer surfaces 18b have expanded to the maximum diameter possible in relation to the corresponding tapered portions 40b. In this position the internal diameter of the ring 10b is at a maximum within the constraints of the case 14b.

During a core breaking action when a core drill housing the core lifter assembly 12b is lifted from the toe of the borehole, in relative terms, the ring 10b slides axially in a downhole direction relative to the case 14b to a clamping position shown in Figure 4b. Due to the cooperation of the outer surfaces 18b with the tapered portions 40b, this motion results in a reduction of the internal diameter of the ring 10b effectively clamping the ring about an outer circumferential surface of a core.

It will be appreciated that as the angle β in the present embodiments is greater than that of the prior art, there is a quicker reduction in the wall thickness of the ring 10a along its axial length. Therefore in order to provide sufficient contact area between the interior surface 26a of the ring 10a and a core sample, and between the external tapered surface 18a of the ring 10a and the internal tapered surface 40a of the case 14a, to provide appropriate compressive force to grip the core sample, the ring 10a and case 14a must be formed of a greater wall thickness than a comparable prior art ring. This will lead to a reduced diameter core sample. This however can be avoided by virtue of the provision of two portions 16b in the ring 10b in accordance with the second embodiment. In this embodiment as each portion 16b is of a shorter axial length there is less reduction in the wall thickness for the portion 16b than the portion 16a. But to increase the area of the inner surface 26b to provide the appropriate clamping force on a core sample (i.e. on a par to that of a prior art ring), two portions

16b are provided. Thus substantially the same gripping force can be achieved as the prior art but the embodiments of the ring 10 are easier to release. As explained further below, a similar effect to the use of a ring 10 with multiple sections 16 is to provide multiple single portion rings 10 each having an included taper angle β as herein before described but of a reduced axial length to the comparable single portion ring 10a shown in Figures 1a – 1e.

Figures 5a – 5f depict a further embodiment of a core lifter assembly 12c which comprises a ring 10c and case 14c. The ring 10c has a single axially extending portion 16c with an outer generally frusto-conical configuration. The difference between the rings 10a and 10c resides in the location of the grooves 28c and splines 30c. In the ring 10c, the grooves 28c and splines 30c are formed on an outer circumferential surface 18a of the ring 10c. The surfaces 32c of the splines together create the outer generally frusto-conical configuration of the ring 10c. The portion 16c has an included taper angle β measured along the splines 30c on the outer surface 18c. Further, as shown in Figures 5d and 5e the interior surface 26c of the ring 10c is textured. The texture may be formed of ribs 44c such as a shallow helical thread like structure on the surface 26c.

The ring 10c operates in an identical manner to the ring 10a, and the core lifter case 14c can be identical to the core lifter case 14a. Operation of the core lifter assembly 12c is also in essence identical to that of the assembly 12a. In particular 12c, as the ring 10c moves from its retracted position to its clamping position the internal diameter of the surface 26c reduces to effectively clamp onto an outer circumferential surface of a cut core. Release of the ring 10c upon retrieval of an associated core tube is rendered easier in comparison with the prior art by the provision of the greater taper angle β.

Due to the provision of the grooves 28c and splines 30c on an outer circumferential surface 18c of the ring 10c naturally the outer circumferential surface is no longer smoothly continuous as in the ring 10a. Conversely however the interior surface 26c of ring 10c is substantially continuous (save for the texturing provided by ribs 44c). The tapering of the outer circumferential surface of ring 10c is provided by a reduction in a radial section width of the splines 30c in a direction from the maximum diameter end 22c to the minimum diameter end 23c of the ring 10c.

Also as a result of the alternating grooves 28c and splines 30c the description of the

outer surface 18c as being "substantially frusto-conical" is intended to refer to the general outer shape and configuration of an envelope encompassing the portion 16c.

Figures 6a – 6f depict a further embodiment of a core lifter assembly 12d having a ring 10d and case 14d. The ring 10d in this embodiment comprises two axially extending portions 16d each having an outer circumferential surface of substantially frusto-conical shape or configuration. The substantive difference between the ring 10d and the ring 10b is that the grooves 28d and splines 30d in the ring 10d are formed on an outer circumferential surface. In comparison in the ring 10b, corresponding grooves 28b and splines 30b are formed on the inner circumferential surface 26b. A further difference is that in the ring 10d the grooves 28d in the successive portions 16d are arranged in axial alignment and formed with respective depths so that in an axial cross section through respective channel surfaces 33d of the grooves 28d the ring 10d has a substantially constant wall thickness. This is shown most clearly with reference to Figures 6c and 6d which show the ring 10d having a substantially constant wall thickness W along the section AA. This differs from the corresponding cross section in the ring 10b shown in Figures 3d and 3e where the wall of the ring is in the form of two contiguous wedges W1 and W2. This difference arises because in the ring 10b the surfaces of the grooves 28b are not parallel to the opposing outer tapered portions of faces 18b whereas in the ring 10d the surfaces of the grooves 28d are parallel to the radially aligned portions on the inner surface 26d. A further difference is that in the ring 10b the grooves 28b are continuous for the whole axial length of the ring 10b. In contrast as clearly shown in Figures 6a and 6b, in the ring 10d the grooves 28d do not extend for the entire axial length of their corresponding portion 16d. This enables the portion 16d to be made of a relatively thin wall thickness similar to the wall thickness of conventional core lifter ring however due to the provision of multiple portions 16d, the total area of inner surface 26d which grips a core sample is on par with that of a conventional equivalent core lifter ring. Accordingly this embodiment enables easier release of the core lifter ring 10d due to the increased included taper angle β but provides the same or greater gripping force in comparison with a prior art ring of the same axial length.

The core lifter case 14d is identical to the case 14b. Thus the interaction between the ring 10d and case 14d and the consequential operation of the assembly 12d is in substance the same as that described herein above in relation to the assembly 12b.

Figures 7a – 7f depict a further embodiment of the core lifter assembly 12e. This

embodiment has two separate but identical rings 10eu and 10ed (referred to in general as "rings 10e") each having a single axial extending portion 16e. Moreover this embodiment may be seen as a variation of the embodiment 12d where the ring 10d is cut in a radial plane half way along its the axial length to form the two separate rings 10e. Thus while the ring 10d comprises a single ring with two contiguous axially extending portions 16d, the core lifter assembly 12e comprises two separate rings 10e each formed with a single axially extending portion 16e.

With specific reference to Figure 7f, it can be seen that in the core lifter assembly 12e, the two separate rings 10e are able to move independently of each other within the case 14e. The core lifter case 14e is formed with a circumferential shoulder 38e to limit the sliding of the uphole ring 10eu in an uphole direction relative to the case 14e. Upward motion of the down hole ring 10ed is limited by a shoulder or relatively steep outwardly tapered transition surface 48e which extends from an upper most of the tapered surfaces 40e to the adjacent lower tapered surface 40e. The combination of the two separate rings 10e provide the same gripping force on a core as the ring 10d because the combined area of the inner circumferential surfaces 26e is in substance the same as the area of inner circumferential surface 26d.

Figures 8a – 9b depict a further embodiment of a core lifter assembly 12f comprising a core lifter ring 10f and core lifter case 14f. The ring 10f comprises three axially extending portions 16f each of an outer generally frusto-conical configuration with corresponding substantially frusto-conical outer surfaces 18f all tapering in the same direction. Each of the portions 16f is substantially the same in shape and configuration to the portions 16d and 16e of the rings 10d and 10e respectively. Each of the portions 16f is formed with an included taper angle $6° \geq \beta \geq 30°$, and a half angle $\theta = \beta/2$. As with the rings 10d and 10e, the recesses 28f and splines 30f are formed alternately circumferentially about the corresponding outer circumferential surface 18f of the portion 16f. A longitudinal split 24f is formed in the ring enabling it to compress and expand in diameter as the ring 10f moves relative to the corresponding case 14f.

As shown in Figure 8d, the wall thickness of the ring 10f along an axial section taken through the grooves 28f is a substantially constant uniform thickness W. The axial section through the splines 30f is depicted in Figure 8e and shows that each of the splines 30f on the outer surface 18f tapers at the half angle θ. The inner diameter of the inner circumferential surface 26f is constant for the axial length of the ring 10f save for the provision of ribs 44f which provide texturing and assist in gripping a received

core.

As depicted in Figures 8f, 9a and 9b the corresponding core lifter case 14f has the same general shape and configuration as the case 14e but with the provision of a further inclined surface 40f. Thus the case 14f has three successive tapered portions 40f one for each of the three axially extending portions 16f of the ring 10f. The case 14f also comprises a shoulder 38f providing a stop for the motion of the ring 10f in an uphole direction relative to the case 14f. An internal thread 36f is formed on the case 14f for coupling to a core barrel. Figure 9a shows the relative position of the ring 10f and case 14f when the ring 10f is in a retracted position. This position corresponds to the position during drilling of a hole where a core sample is entering the case 14f and corresponding core barrel. Figure 9b depicts the relative juxtaposition of the ring 10f and the case 14f during core breaking and subsequent retrieval of the core barrel. Here the ring 10f is moved in a downhole direction relative to the case 14f thereby resulting in a compression of the ring 10f and thus firm clamping and gripping of a core sample.

It will be understood by those skilled in the art that the provision of the additional axially extending portion 40f provides additional surface area to the inner circumferential surface 26f in comparison for example to the ring 10e. This may assist in gripping a core in the event that the ground may be fractured or there are discontinuities in the surface of the core. However at the same time because of the increased taper angle β, retraction of the ring 10f to the position shown in 9a to release a captured core sample requires less force and effort in comparison with the prior art.

Figures 10a – 10d depict a core lifter ring 10g for a further embodiment of the core lifter assembly. The ring 10g comprises two contiguous axially extending portions 16g with alternating grooves 28g and splines 30g extending about outer circumferential surface 18g of the respective portions 16g. The ring 10g is generally similar to the ring 10d with the exception that the grooves 28g extend for the full length of their respective axially extending portions 16g. In contrast it can be seen in the ring 10d that each of the respective grooves 28d extends from a maximum diameter end 22d toward but stopping short of the minimum diameter end 23d of the respective axially extending portion 16d. To form the grooves 28g in a manner so that they extend for the full length of the respective portions 16g the grooves 28g may be cut deeper relative to the inner circumferential surface or the tapered splines may be thicker. A benefit of this is that the ring 10g can be adapted to different size core barrels to work with different

diameter core samples.

A further difference between the ring 10g and the ring 10d is that the splines 30g at the free small diameter end 23g extend axially beyond the adjacent grooves 28g. In a core lifter assembly comprising the ring 10g, the corresponding case will be substantially identical to case 14d.

In the embodiments described above which comprise grooves 28 and splines 30 on the outer circumferential surface the grooves and splines are shown as extending parallel to a central axis of the ring. However this is not an essential characteristic of the core lifter rings. As shown in Figures 11a – 11e, a core lifter ring 10h for a further embodiment of the core lifter assembly is formed with two axially extending portions 16h each having alternating grooves 28h and splines 30h formed about respective outer circumferential surfaces 18h. However the grooves 28h extend in a spiral or spiroidal type path between opposite axial ends of the ring 10h. Similarly, the splines 30h extend in a spiral path parallel to the grooves 28h. Apart from this difference in the configuration of the grooves and splines, the ring 10h is the same as the ring 10g.

In the embodiments shown in Figures 5a, 6a and 8a it will be recognised that if the axial length of a ring 10 is X, and the number of axially extending portions 16 is N (N being an integer ≥ 1), then each axially extending portion 16 has an axial length of X/N. Thus for any one of these embodiments each portion 16 is of the same axial length. However other embodiments are possible where the portions 16 are of different length. In such embodiments the different length may arise due to the inclusion of a taper, radius, transition taper or deliberate design.

Figures 12a – 12h illustrate a ninth embodiment of a core lifter assembly 12i and its associated component parts namely a core lifter ring 10i and core lifter case 14i. In describing the core lifter assembly 12i the same reference numbers as used in the previous embodiments are intended to denote the same or similar features. The core lifter ring 10i comprises four axially extending portions 16i each having an outer generally frusto-conical configuration and a corresponding substantially frusto-conical outer surface 18i having an included taper angle $\beta°$. Each of the portions 16i taper in the same direction. However the ring 10i further comprises a plurality of transition zones 17i. A respective transition zone 17i is disposed between respective mutually adjacent portions 16i. Moreover, each of the transition zones 17i extends from a small diameter end 23i of one portion 16i to the large diameter end 22i of the adjacent

portion 16i. Each transition zone 17i in this embodiment is depicted as having an outer generally frusto-conical configuration and corresponding substantially frusto-conical outer circumferential surface 19i. Further, the surfaces 19i slope at a half angle $\theta < 90°$ in an outward direction relative to a central axis of the ring 10i. Thus, the zones 17i and surfaces 19i taper in an opposite or inverse direction relative to the taper of the surfaces 18i. More specifically in the present embodiment, the half angle $\alpha = -\beta/2$ where the – sign indicates the direction of the taper 19i is opposite to that of the half angle θ or the included taper angle β.

The transition zones 17i are also depicted as extending for an axial length the same as that of the portions 16i. However in alternate embodiments this need not necessarily be the case and indeed will not be the case where the angle $|\alpha| \neq |\beta/2|$.

The ring 10i is further provided with a single split or slot 24i which extends for the full axial length of the ring 10i.

A plurality of grooves 28i and splines 30i are formed in an axially extending direction in each of the portions 16i and 17i. The grooves 28i and splines 30i are arranged in an alternating manner circumferentially about each of the portions 16i and 17i. Further the grooves 28i and splines 30i in mutually adjacent portions 16i and 17i are axially aligned.

As depicted in Figure 12c, the thickness of the wall of ring 10i through a section taken through the grooves 28i is a substantially constant thickness W.

As shown in Figure 12d the thickness of the wall of ring 10i taken through a section through the splines 30i varies in thickness in accordance with the half angle of the respective portions 16i and 17i on which the spline 30i resides.

The core lifter case 14i incorporated in the assembly 12i is provided with a plurality of alternating inclined surface portions 40i and 41i. The surface portions 40i taper at substantially the same angle as the outer surface 18i of the splines 30i on portions 16i. The intervening surface portions 41i taper in an opposite direction and at substantially the same angle as the outer surface portion 19i of the splines 30i on portions 17i. As with the other core lifter cases, the case 14i comprises a shoulder 38i which limits relative motion of the ring 10i in an uphole direction relative to the case 14i; and a thread 36i to enable threaded connection to a core barrel.

Figures 12f and 12g depict the core lifter assembly 12i with the associated ring 10i in the retracted and clamping positions respectively. The assembly 12i operates in substantially the same manner as described herein above in relation to the earlier embodiments. The retracted position shown in Figure 12f is commensurate with the drilling phase in which: an inner diameter of the ring 10i is at a maximum with the ring 10i abutting, or spaced a relatively small distance from the shoulder 38i; and a core is entering the assembly 12i. Figure 12g illustrates the relative motion between the ring 10i and case 14i during a core breaking operation where the case 14i is lifted in the uphole direction relative to the ring 10i. This action causes the ring 10i to clamp around and thus grip the core sample.

Figure 12i illustrates a core lifter ring 10i' being a variation on the ring 10i. The ring 10i' differs from the ring 10i by forming the outer circumferential surface of each of the alternating portions 16i and 17i with a smooth continuous surface rather than with the alternating grooves 28i and splines 30i.

Figure 12j illustrates a core lifter ring 10i'' which differs from the ring 10i' by replacement of the single full length split or slot 24i with a plurality of circumferentially spaced apart blind splits or slots 24i''. It will be noted that alternating slots 24i'' commence from opposite axial ends of the ring 10i''. The replacement of a single slot 24 with multiple blind slots 24'' may be incorporated in each of the previously described embodiments.

Figure 12k illustrates a core lifter ring 10i''' which differs from 10i by including the alternating grooves 28i and splines 30i on the outside circumferential surface as well as grooves 29i on the inner circumferential surface. The grooves 29i may be adjacent to grooves 28i or offset from them. The grooves 29i provide localised flexibility to facilitate radial expansion and contraction of the diameter of the ring 10i'''. They also enable the surface area in contact with the core to be varied.

Figures 13a – 13c depict a core lifter ring 10j differing from 10i by the provision of two contiguous transition zones 17j and 21j of different configuration. Each zone 17j has an outer generally frusto-conical configuration with corresponding surface 19j tapering in an opposite direction to portion 16j and at a steeper angle. Each zone 21j has a substantially cylindrical outer surface with a diameter substantially the same as that of the small diameter end of adjacent portion 16i. In this embodiment the combined axial

length of a zone 17j and a contiguous zone 21j is substantial the same as that of a portion 16j although this may differ in other variations.

Figure 13d illustrates a core lifter case 14j for the assembly 12j. The case 14j has surface portions 40j that taper at substantially the same angle as the outer surface 18j of the portions 16j. Intervening surface portions 41j taper in an opposite direction and at substantially the same angle as the surface portions 19j. As with the other core lifter cases, the case 14j comprises a shoulder 38j which limits relative motion of the ring 10j in an uphole direction relative to the case 14j; and a thread 36j to enable threaded connection to a core barrel. The case 14j differs from 14i by the inclusion of a substantially cylindrical inner circumferential surface 42j disposed between each of the intervening surface portions 41j and the respective mutually adjacent portions 40j.

Figure 13e depicts the core lifter assembly 12j with the associated ring 10j in the retracted position relative to the case 14j. As in the previous embodiments, when the ring 10j is in the retracted position shown it abuts, or is spaced a relatively small distance from the shoulder 38j; and the ring 10j is expanded to the maximum diameter possible in relation to the corresponding tapered portions 40j. The cylindrical portions 21j on the ring 10j and the cylindrical portions 42j on the case 14j combine to provide gaps 44j that can accommodate particles of grit or foreign matter that may be present between the surfaces of the transition surfaces 19j on the ring 10j and the intervening surface portions 41j on the case 14j. This minimises the risk of jamming and facilitates a maximum retraction, and clamping action of the ring 10j. There is also a cylindrical portion 39j adjacent to the shoulder 38j on the case 14j. The cylindrical portion 39j also provides a gap 46j which allows the ring 10j to fully retract relative to the case 14j even if particles of grit or foreign matter are present between the large diameter end 22j of the ring 10j and the shoulder 38j on the case 14j.

Figures 14a – 14f depict a core lifter ring 10k that may be incorporated in yet a further embodiment of the core lifter assembly. The core lifter ring 10k is provided with two axially extending portions 16k each having an outer generally frusto-conical configuration tapering so as to reduce in outer diameter in a downhole direction. Each portion 16k is formed with a half angle θ in the same range as discussed and disclosed in relation to the earlier embodiments. The outer surface 18k of each portion 16k is substantially smooth and continuous. However on the interior surface 26k of the ring 10k each of the portions 16k is formed with circumferentially spaced grooves 28k. Splines 30k are formed between the grooves 28k. The splines 30k are in effect formed

by default by machining or otherwise forming the grooves 28k in the interior surface 26k.

In this embodiment edges 50 delineating the grooves 28k from the splines 30k are not straight and are not parallel with each other. This is to be contrast for example with the grooves 28a and splines 30a in the embodiment shown in Figure 1a. From Figure 14f it will also be seen that the width W of the wall of the core lifter ring 10k in an axial section taken through the grooves 28k is substantially constant.

Figures 15a and 15b depict core lifter rings 10l and 10m respectively for yet further alternate embodiments of the core lifter assembly. Core lifter ring 10l comprises three axial portions 16l formed contiguously with each other. Each portion 16l has an outer generally frusto-conical configuration and a continuous smooth outer surface 18l. Each portion 16l is formed with a taper having a half angle θ in the same range as disclosed herein before in relation to the earlier embodiments. An interior surface 26l may be provided with texturing to enhance friction and grip on a received core. The texture may be provided for example by way of circumferential grooves, helical grooves, grit, gnurling, dimples or the like. Also provided in the surface 26l is a plurality of longitudinally extending and circumferentially spaced apart grooves or recesses 28l. The recesses 28l are of a different configuration to those depicted in the earlier embodiments. Here, the recesses 28l extend only for an axial length bound by the corresponding portion 16l to which they relate. Further the recesses 28l have opposite axial ends that terminate in board of the axial ends of the their corresponding portions 16l and are axially spaced from grooves 28l of adjacent portions 16l. The grooves 28l provide a plurality of edges that may assist in the process of gripping a core and also provide enhanced flexibility for the radial expansion or contraction of the ring 10l. Further by forming the grooves 28l in a manner so that they increase in depth in the direction from the small diameter end 22l to the large diameter end 23l the ring 10l has a greater uniformity in wall thickness which may be beneficial when the ring 10l is made using a moulding process.

The ring 10l may be made from a moulding process such as metal injection moulding or other techniques using powder metallurgy or amorphous metal alloys. The use of for example metal injection moulding enables high speed mass production with dimensional stability; and the forming of shapes, features and textures that are difficult to produce with conventional machining.

The metal injection moulding process for the manufacture of the ring 10l initially requires the construction of a mould having an interior configuration complimentary to the exterior shape and configuration of the ring 10l. Fine metal powders (typically less than 20 microns) are combined with a binder into a feedstock that is granulated and fed to a conventional injection moulding machine. The machine then injection moulds the molten feedstock into the mould. The process is similar to that of conventional plastic injection moulding and high pressure die casting.

The ring 10l may also be made by a process of injection moulding low melting point alloys or amorphous metal alloys which may not need to be powdered or combined with a binder.

The ring 10m may also be produced by similar moulding processes used for production of the ring 10l. The ring 10m is formed with three axially extending portions 16m each having an outer generally frusto-conical configuration. Moreover each portion 16m tapers at a half angle θ in the same range as that described in relation to the earlier embodiments. The two major differences between the rings 10m and 10l lie in the configuration of their respective outer surfaces 18 and interior surfaces 26. In particular ring 10m has an interior surface 26m with substantially constant inner diameter and formed with no recesses 28. The surface 26m may however be provided with texturing such as by way of provision of circumferential or helical grooves, grit, gnurling, dimples or the like to enhance friction between the ring 10m and a core cut by a drill incorporating the ring 10m.

The outer surface 18m of each portion 16m is formed with a pattern of triangular and diamond shaped recesses 52 and 54 respectively delineated between adjacent diamond shaped borders or ridges 56.

The interior and outer surface configurations of each of the rings 10l and 10m can be reversed. For example for the ring 10l the recesses 28l may be applied to the outer surfaces 18l while the interior surface 26l may be provided with texturing such as by way of provision of circumferential or helical grooves, grit, gnurling, dimples or the like. Likewise for ring 10m the pattern of triangular and diamond shaped recesses 52 and 54 and diamond shaped borders 56 may be moved to the interior surface 26m leaving the outer surface 18m as smooth continuous surfaces.

While only the rings 10l and 10m are depicted as being manufactured by a moulding

process, each of the earlier embodiments of the rings 10a – 10k may be similarly made from a moulding process or other techniques using powder metallurgy or amorphous metal alloys. Alternately the rings 10a – 10m may be made by the metal working techniques including stamping, pressing, machining and 3D printing. In yet a further variation, embodiments of the rings 10a – 10m may be made from non-metallic materials including but not limited to composite materials and plastics such as polyether ether ketone (PEEK). Indeed embodiments of the core lifter case 14a-14j may be made via the same manufacturing techniques as described above in relation to the manufacture of the rings 10a-10m.

Whilst a number of specific embodiments are described, it should be appreciated that the core lifter assembly may be embodied in many other forms. For example in a variation to the embodiment of the core lifter assembly 12e the two separate rings 10e could be replaced with separate rings in which the alternating grooves 28e and splines 30e are formed on an inner circumferential surface of the ring with the outer circumferential surface being continuous as shown in rings 10a and 10b. Also each separate ring can be provided with two or more axially extending portions 16. For example two or more rings 10d (Figure 6a) or ring 10f (Figure 8a) may be used in place of the rings 10e each of which have only a single axially extending portion. Other variations could include grooves on either the inner or outer surface or both, no grooves at all or multiple partial length slots extending from either end or both. Further, embodiments of the core lifter assembly may be formed with three individual or separate rings each having a single axially extending portion. This will be akin to a core lifter assembly similar to assembly 12f but where the ring 10f having three contiguous portions 16f is split into three separate rings each having only a single portion 16f. Further rings may be formed with more than three contiguous axially extending portions 16.

All such modifications and variations together with others that would be obvious to persons of ordinary skill in the art are deemed to be within the scope of the present invention the nature of which is to be determined from the above description and the appended claims.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

CLAIMS:

1. A core lifter for a core drill comprising: a core lifter ring having an axially extending portion having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$.

2. A core lifter for a core drill comprising a core lifter ring having N axially extending portions each having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$ wherein N is an integer ≥ 1.

3. A core lifter for a core drill comprising: a plurality of core lifter rings each ring having N axially extending portions each having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$ wherein N is an integer ≥ 1.

4. The core lifter according to any one of claims 1 to 3 wherein the angle $\beta \geq 7°$.

5. The core lifter according to any one of claims 1 to 3 wherein the angle $\beta \geq 8°$.

6. The core lifter according to any one of claims 1 to 3 wherein the angle $\beta \geq 10°$.

7. The core lifter according to any one of claims 1 to 3 wherein the angle $30° \geq \beta \geq 6°$.

8. The core lifter according to any one of claims 1 to 7 wherein one or more of the axially extending portions comprises a plurality of circumferentially alternating and generally axially extending grooves and splines formed on an inner circumferential surface or an outer circumferential surface of the one or more axially extending portions.

9. The core lifter according to claim 8 wherein the grooves extend parallel to the central axis of the ring.

10. The core lifter according to claim 8 wherein the grooves follow a spiral path between axially opposite ends of their corresponding axially extending portion.

11. The core lifter according to any one of claims 8 to 10 wherein the grooves extend to and reach a large outer diameter end of their corresponding axially extending portion.

12. The core lifter according to any one of claims 8 to 11 wherein the grooves extend to and reach a small outer diameter end of their corresponding axially extending portion.

13. The core lifter according to any one of claims 1 to 12 comprising a core lifter case in which the or each core lifter ring is slidably retained.

14. The core lifter according to any one of claims 3 to 12 comprising a core lifter case in which the plurality of core lifter rings are slidably retained in axially spaced relationship.

15. The core lifter according to claim 13 or 14 wherein the core lifter case comprises a tapered section for each axially extending portion, each tapered section configured to engage a corresponding axially extending portion to cause a change in diameter of the core lifter ring associated with the axially extending portion in response to axial displacement of the associated core lifter ring relative to the tapered section.

16. A core lifter for a core drill comprising: a core lifter ring having opposite downhole and uphole ends spaced by an axial distance X, an interior circumferential surface having a substantially constant major diameter for the axial distance X, and an outer circumferential surface, the interior circumferential surface and outer circumferential surface configured to form a half angle $\theta \geq 3°$ for at least a portion of the distance X in at least two circumferentially spaced locations wherein at the locations a wall of the ring decreases in thickness in a direction from the uphole end to the downhole end.

17. A core lifter for a core drill comprising: a core lifter ring having opposite downhole and uphole ends spaced by an axial distance X, an interior circumferential surface having a substantially constant major diameter for the axial distance X, and an outer circumferential surface, the interior circumferential surface and outer circumferential surface configured to provide the ring with a half angle $\theta \geq 3°$ for at least a portion of the distance X wherein a wall of the ring decreases in thickness in a

direction from the uphole end to the downhole end for the corresponding portion of the distance X.

18. The core lifter according to claim 16 or 17 wherein the angle $\theta \geq 4°$.

19. The core lifter according to claim 16 or 17 wherein the angle $\theta \geq 5°$.

20. The core lifter according to claim 16 or 17 wherein the angle $\theta \geq 6°$.

21. The core lifter according to claim 16 or 17 wherein the angle $15° \geq \theta \geq 3°$.

22. The core lifter according to any one of claims 16 or 21 wherein the portion of the distance X is X/N where N is an integer ≥1 and wherein the ring comprises N number of integrally formed portions.

23. The core lifter according to claim 22 wherein the outer circumferential surface of the ring for one or more of the N portions has a radius that is constant in a circumferential direction for any location along the central axis and continuously decreases in an axial direction from the uphole end to the downhole end.

24. The core lifter according to claim 22 or 23 wherein one or more of the N portions comprises a plurality of circumferentially spaced recesses on the outer circumferential surface whereby an outer circumference of the ring in one or more of the N portions comprises alternating grooves and sloped splines wherein the angle θ is a measure of an angle of slope of the spline relative to a line co-axial with a central axis of the ring.

25. The core lifter according to any one of claims 2 to 15 wherein when $N \geq 2$ the axially extending portions are arranged to taper in a common direction.

26. The core lifter according to claim 25 further comprising between mutually adjacent axially extending portions one or more transition zone extending from a small diameter end of one of the axially extending portions to a larger diameter end of the other axially extending portions.

27. The core lifter according to claim 26 wherein the one or more transition zone comprises a tapered transition zone having a substantially frusto-conical circumferential surface.

28. The core lifter according to claim 26 wherein the one or more transition zones comprise a cylindrical transition zone having a substantially cylindrical circumferential surface.

29. The core lifter according to claim 26 wherein the one or more transition zone comprises a tapered transition zone having a substantially frusto-conical circumferential surface and a contiguous cylindrical transition zone having a substantially cylindrical circumferential surface.

30. The core lifter according to claim 27 or 29 wherein the frusto-conical outer circumferential surface of the transition zone slopes at a half angle of $90° > \alpha > 3°$.

31. The core lifter according to claim 27 or 29 wherein $\alpha = -\beta/2$.

32. The core lifter according to claim 27 or 29 wherein $\alpha = -\beta$.

33. The core lifter according to claim 29 wherein an axial length of the one or more transition zone is substantially the same as an axial length of an axially extending portion.

34. The core lifter according to claim 25 wherein mutually adjacent axially extending portions are arranged in a manner such that a small diameter end of one axially extending portion is located immediately adjacent a large diameter end of an adjacent axially extending portion.

35. The core lifter according to claim 34 wherein a stepwise transition is formed between the one axially extending portion and the adjacent axially extending portion.

36. The core lifter according to any one of claims 26-33 wherein the lifter case is provided with an intervening surface portion for each transition zone of an associated core lifter ring, each intervening surface portion being configured to match a corresponding transition zone of a core lifter ring associated with the transition zone to facilitate axial displacement of the associated core lifter ring.

37. The core lifter according to any one of claims 8 – 12 wherein a wall of the core lifter ring is formed of substantially uniform thickness for the axial length of each of the grooves.

38. A method of manufacturing a core lifter ring comprising:

injection moulding a metallic material into a mould provided with a moulding cavity having a shape and configuration such that when the metallic material is injected into the cavity and subsequently set, the set material forms a core lifter ring having one or more axially extending portions each axially extending portion having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$.

39. A method of manufacturing a core lifter case comprising:

injection moulding a metallic material into a mould provided with a moulding cavity having a shape and configuration such that when the metallic material is injected into the cavity and subsequently set, the set material forms a core lifter case capable of receiving and working with a core lifter ring which has one or more axially extending portions each axially extending portion having an outer generally frusto-conical configuration formed with an included taper angle $\beta \geq 6°$.

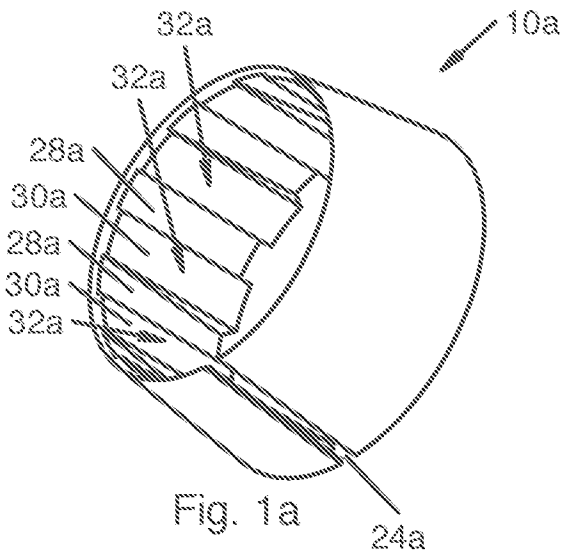


Fig. 1a

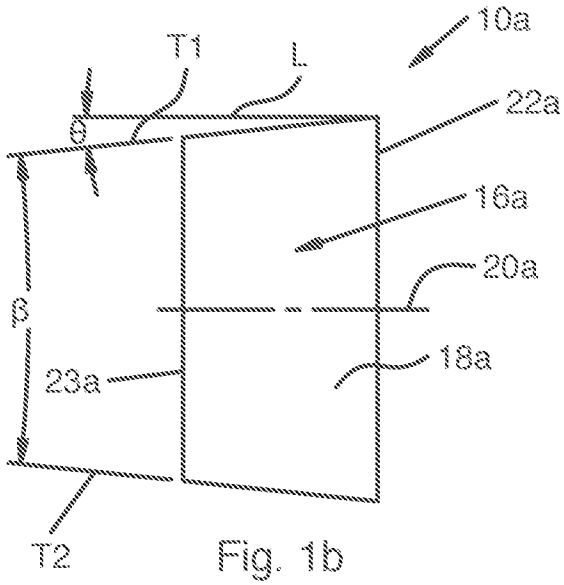


Fig. 1b

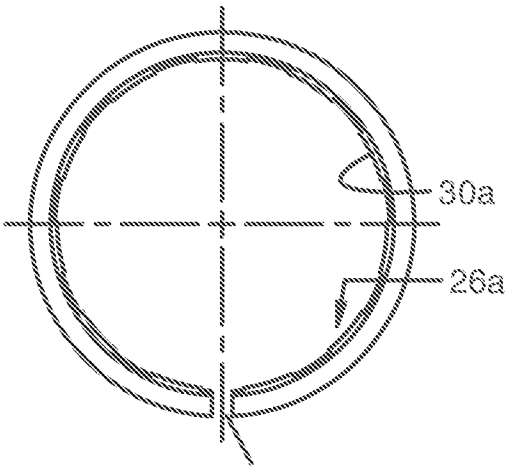


Fig. 1c

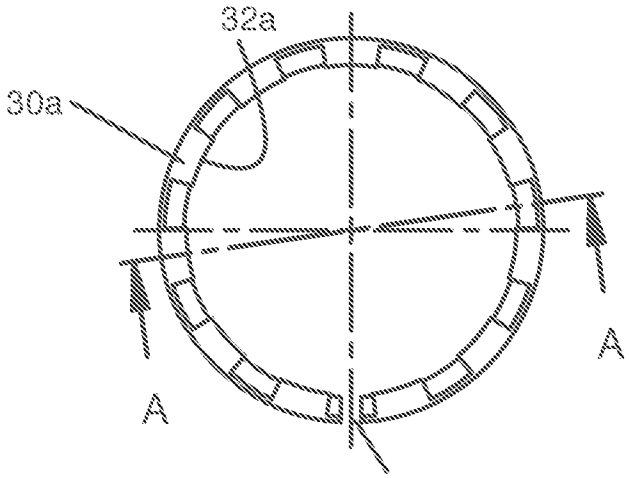


Fig. 1d

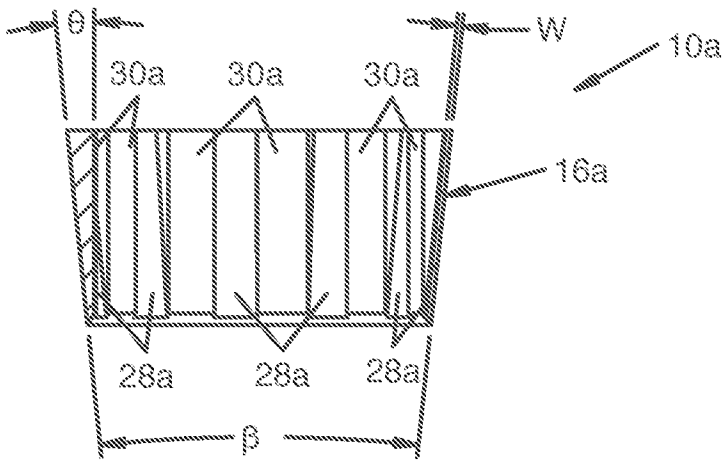


Fig. 1e
SECTION A-A

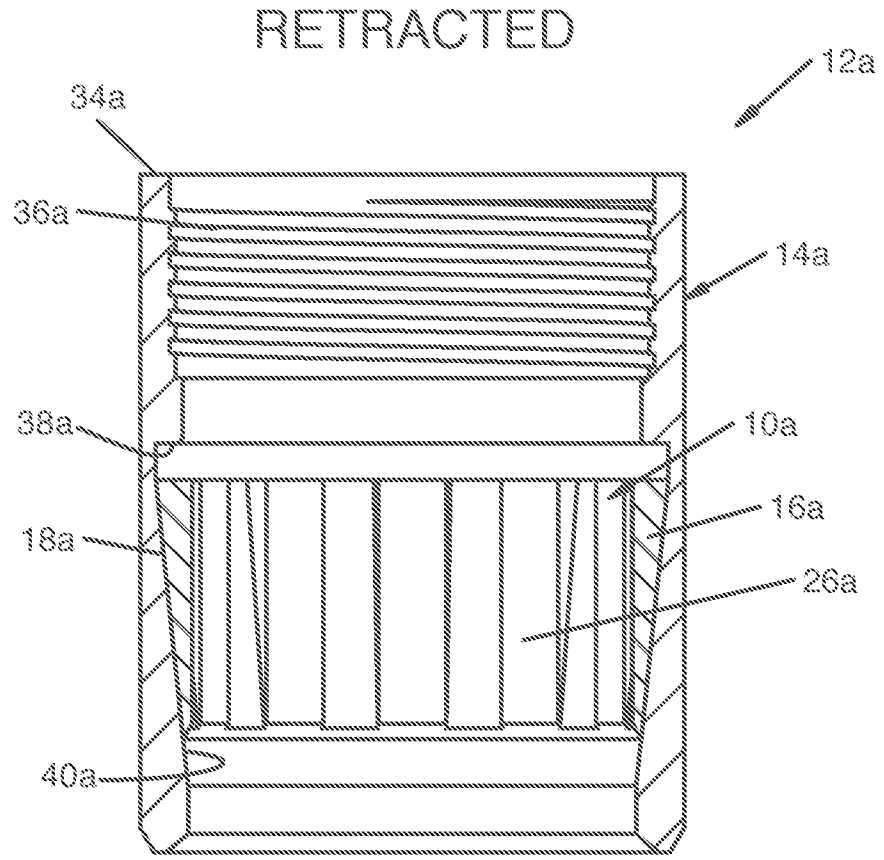

RETRACTED
12a
34a
36a
14a
38a
10a
16a
18a
26a
40a

Fig. 2a

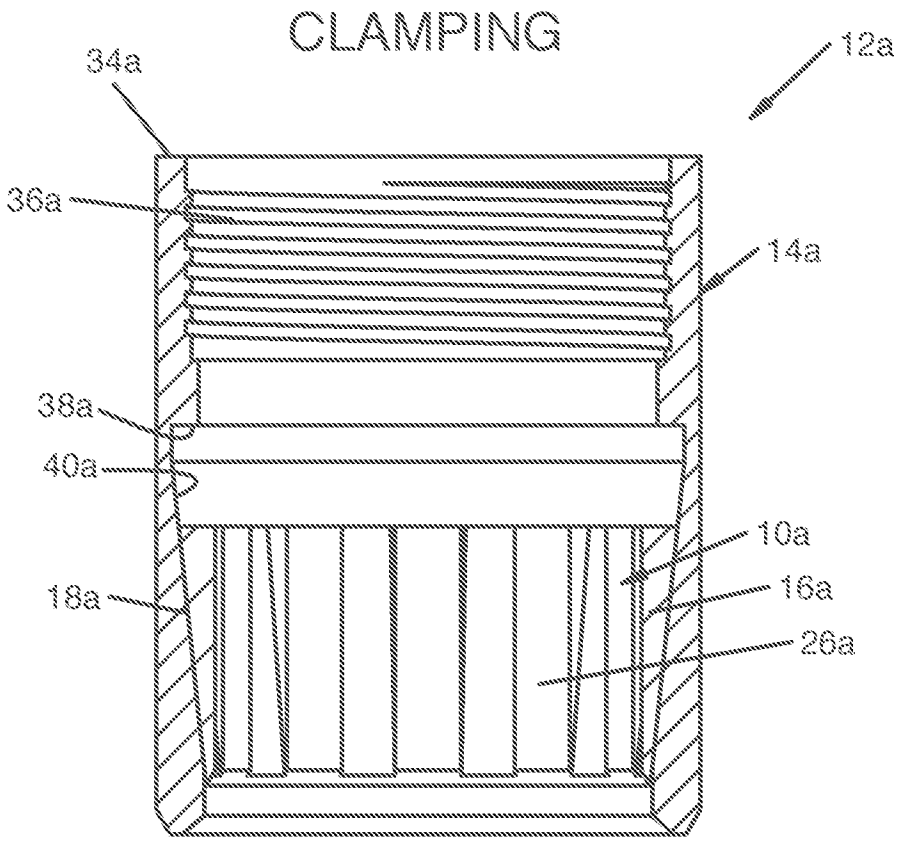

CLAMPING
12a
34a
36a
14a
38a
40a
10a
16a
18a
26a

Fig. 2b

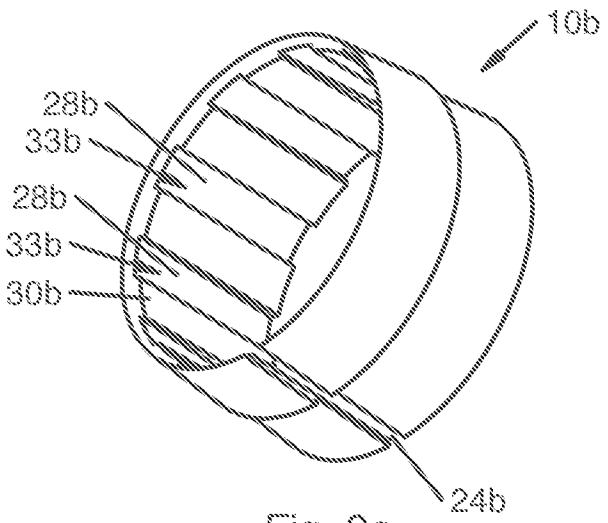


Fig. 3a

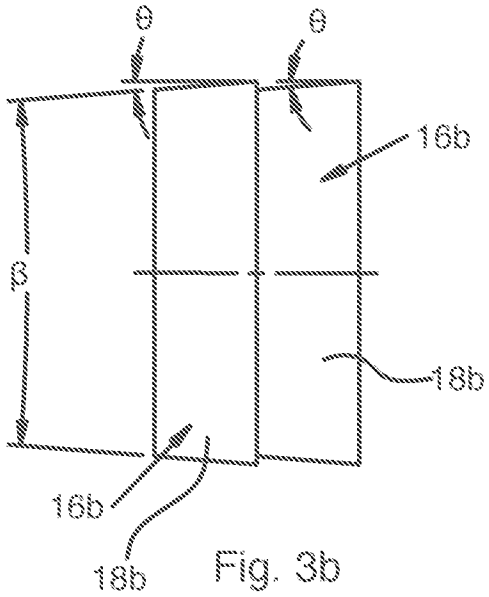


Fig. 3b

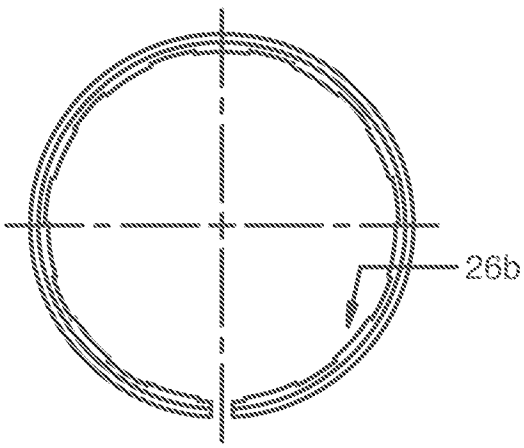


Fig. 3c

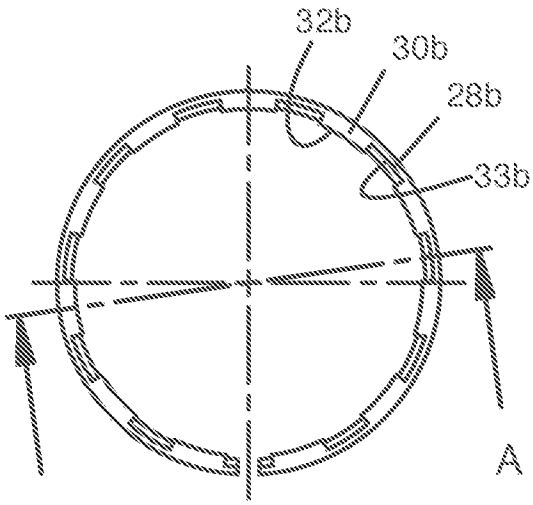


Fig. 3d

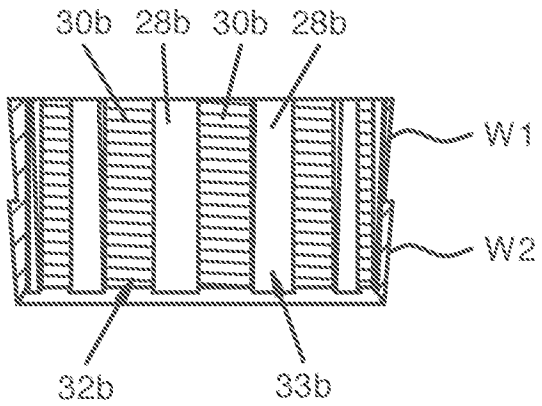


Fig. 3e
SECTION A-A

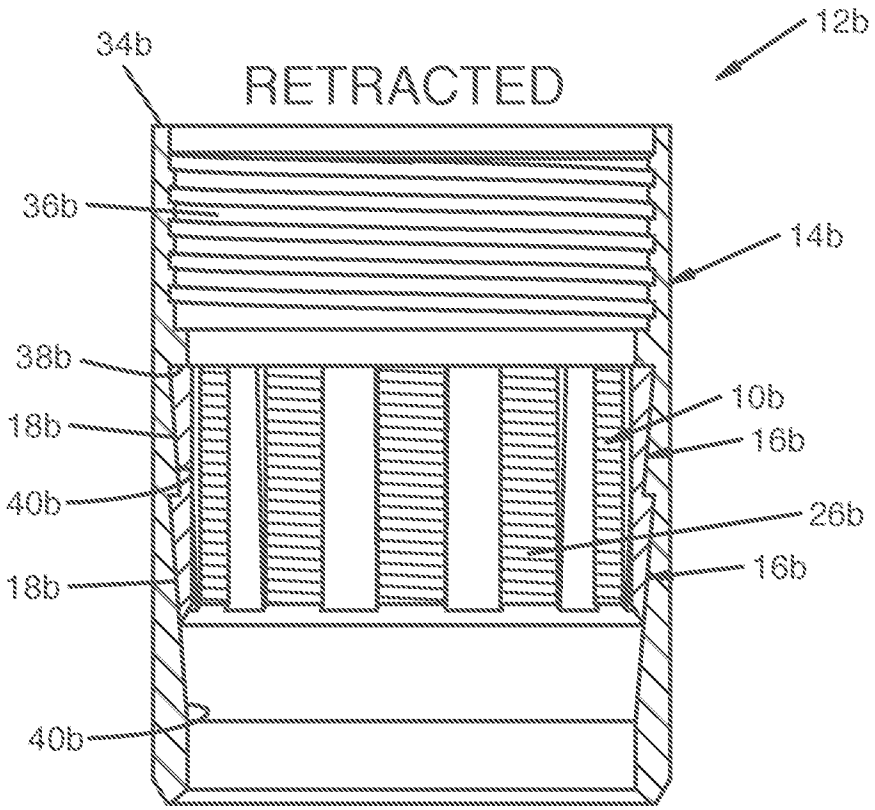

RETRACTED
34b
12b
36b
14b
38b
10b
18b
16b
40b
26b
18b
16b
40b

Fig. 4a

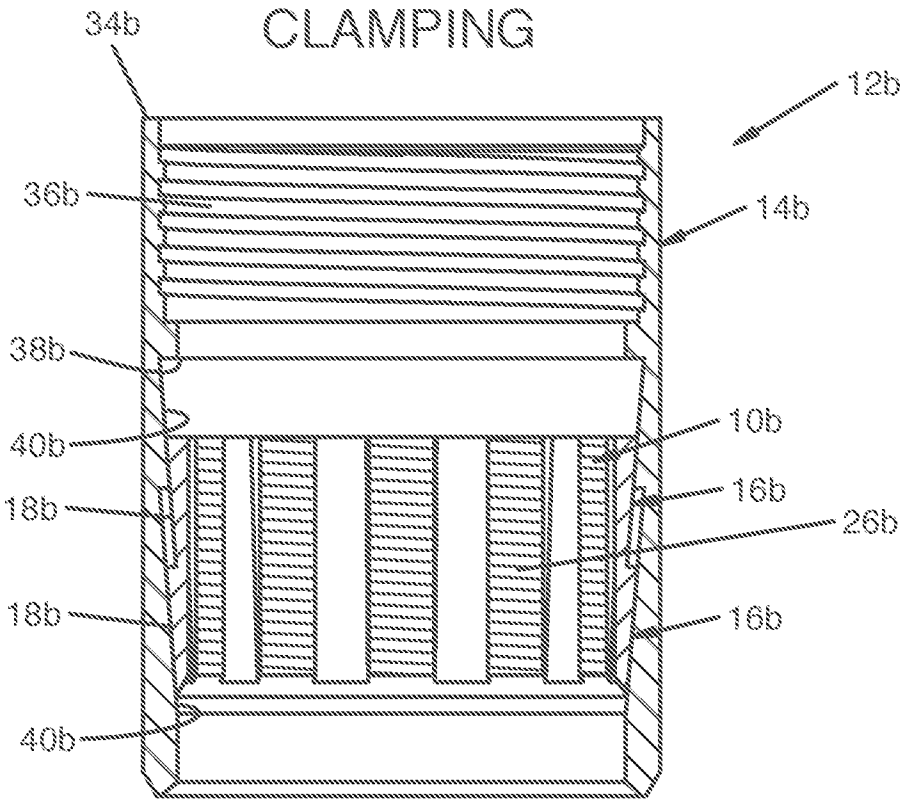

CLAMPING
34b
12b
36b
14b
38b
10b
40b
16b
18b
26b
18b
16b
40b

Fig. 4b

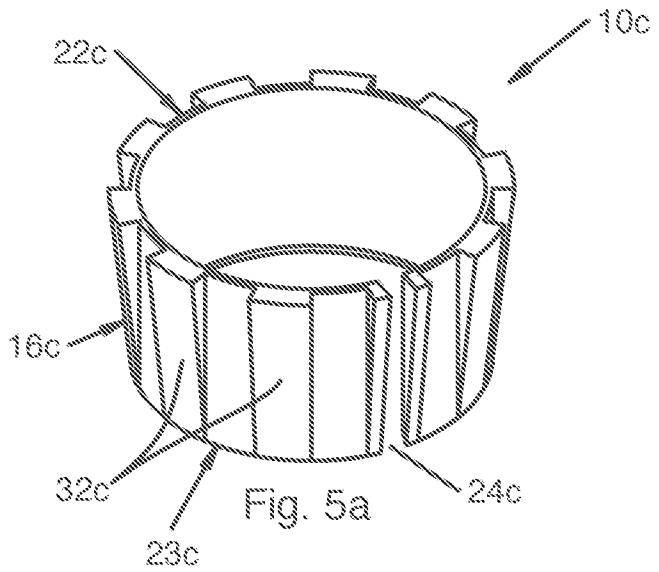


Fig. 5a

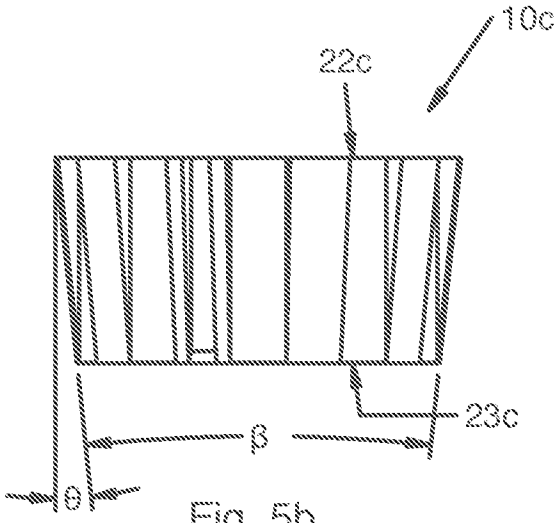


Fig. 5b

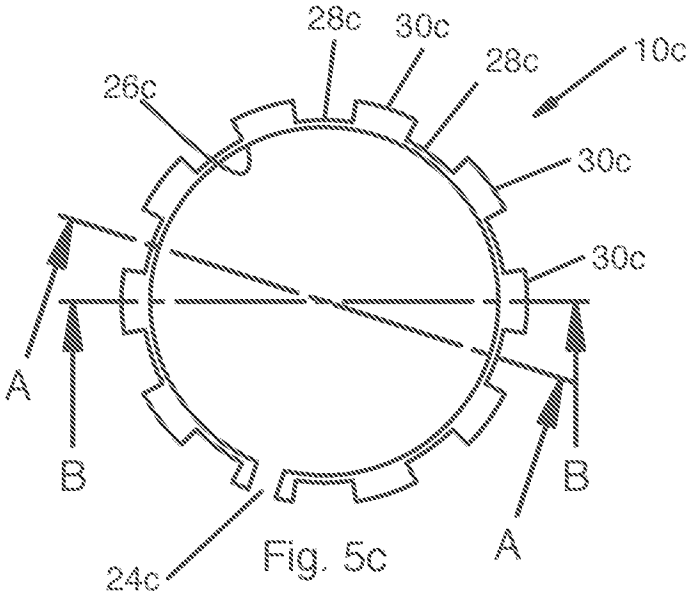


Fig. 5c

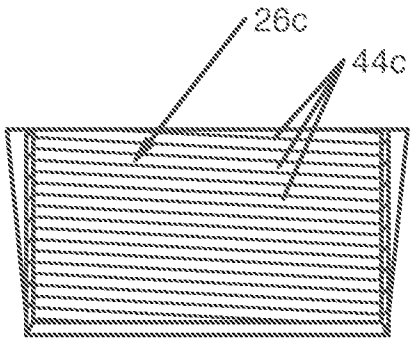


Fig. 5d
SECTION A-A

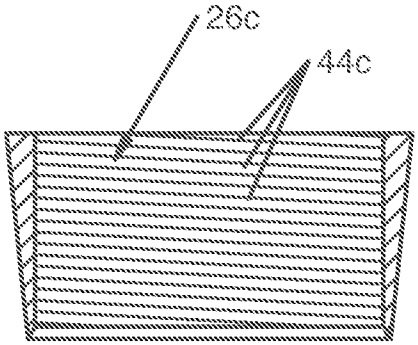


Fig. 5e
SECTION B-B

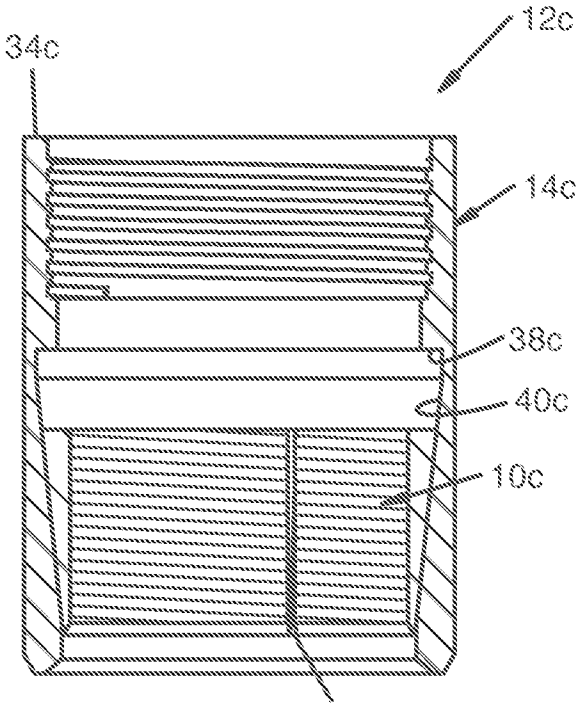


Fig. 5f

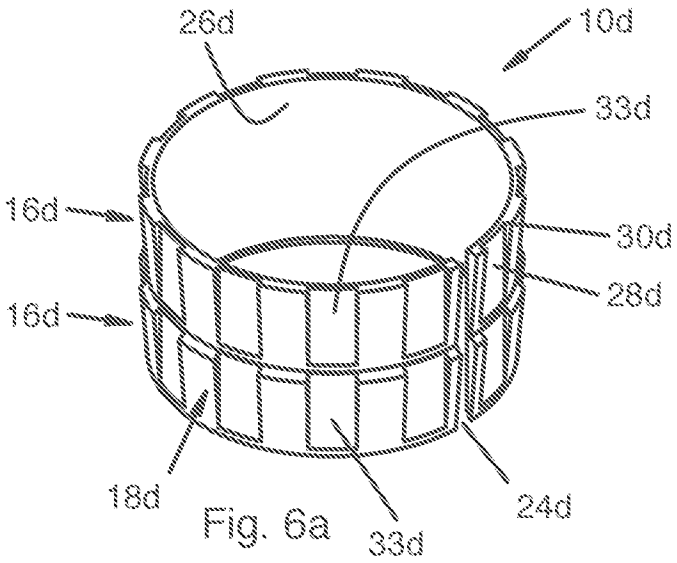


Fig. 6a

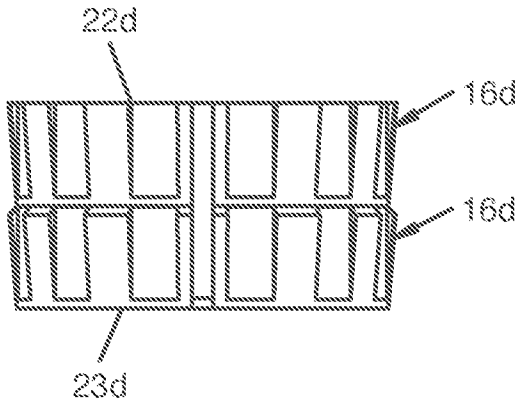


Fig. 6b

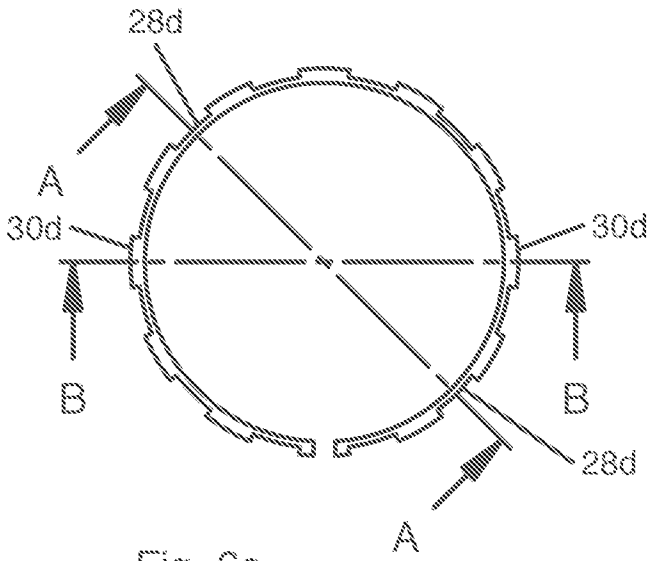


Fig. 6c

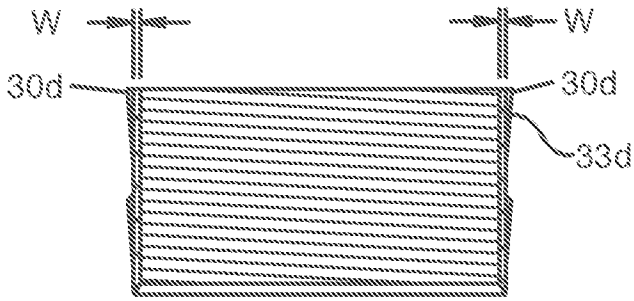


Fig. 6d
SECTION A-A

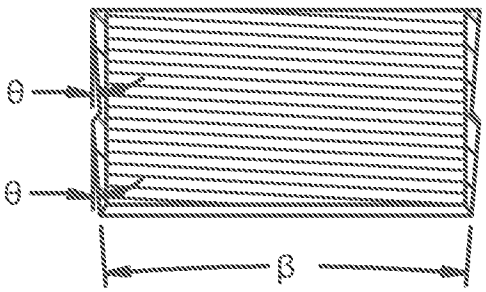


Fig. 6e
SECTION B-B

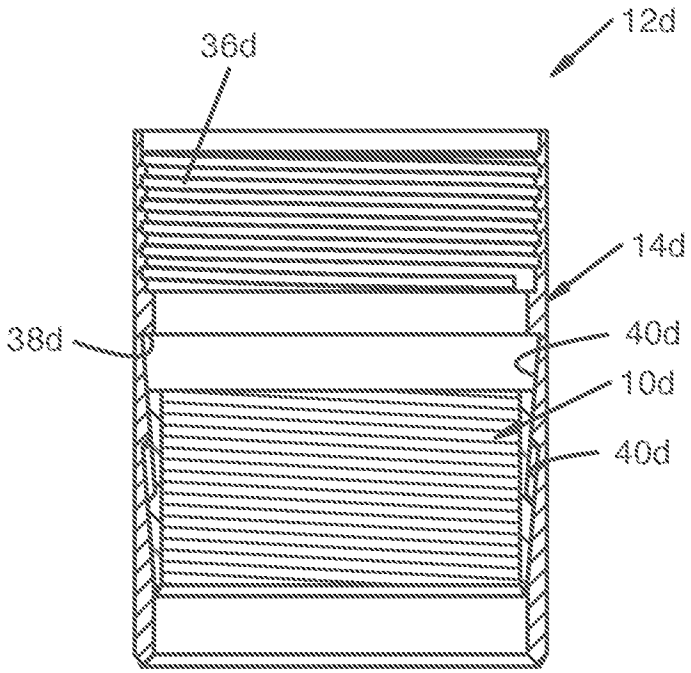


Fig. 6f

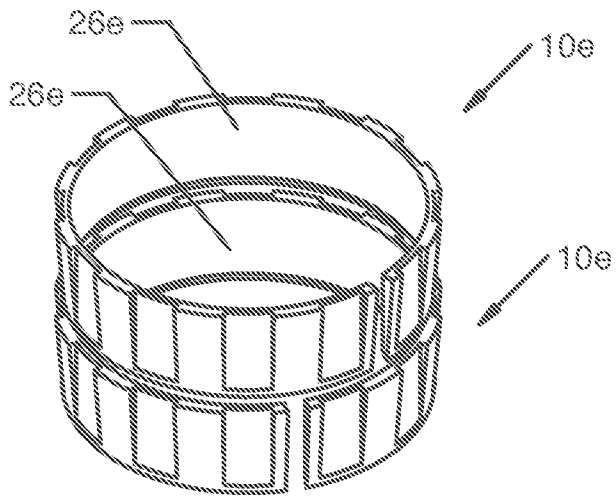


Fig. 7a

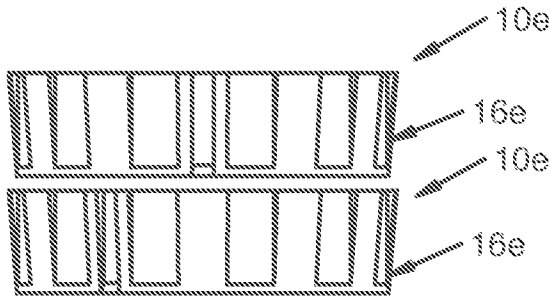


Fig. 7b

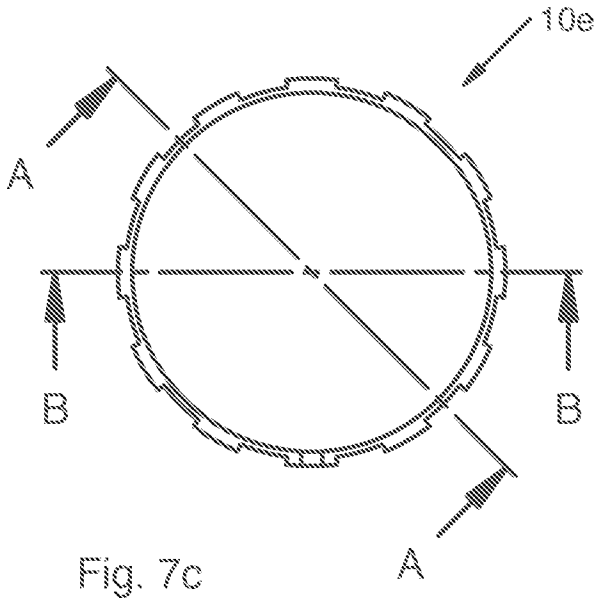


Fig. 7c



Fig. 7d
SECTION A-A

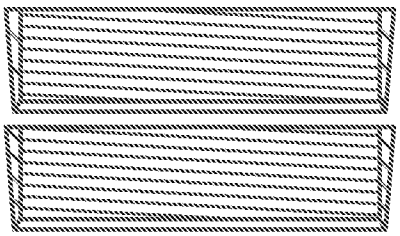


Fig. 7e
SECTION B-B

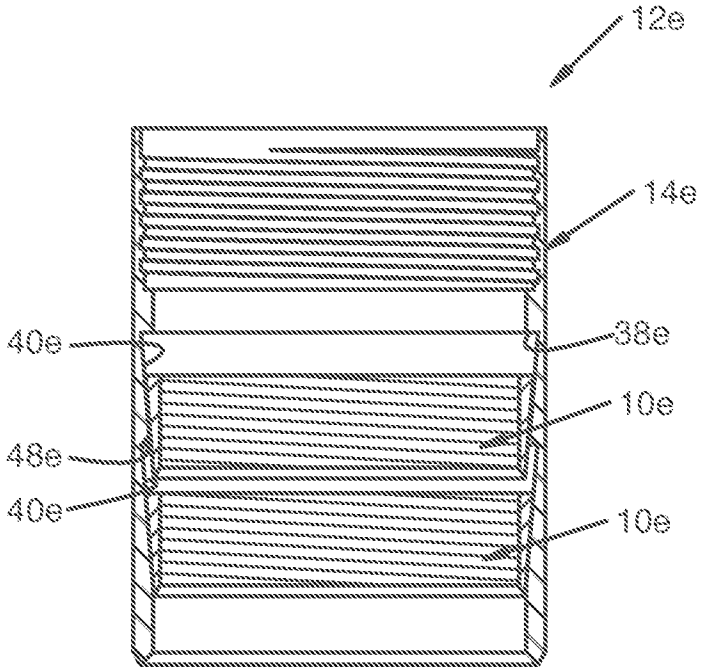


Fig. 7f

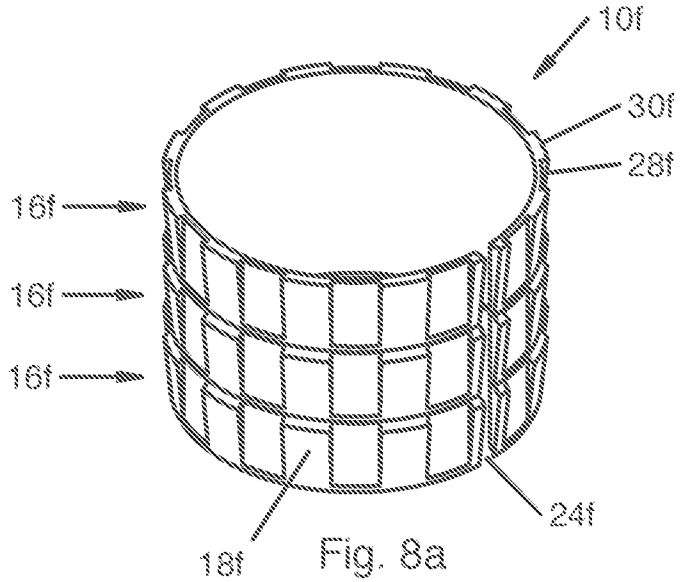


Fig. 8a

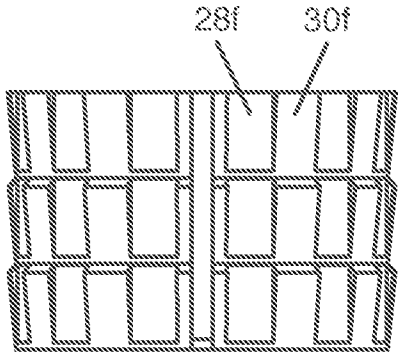


Fig. 8b

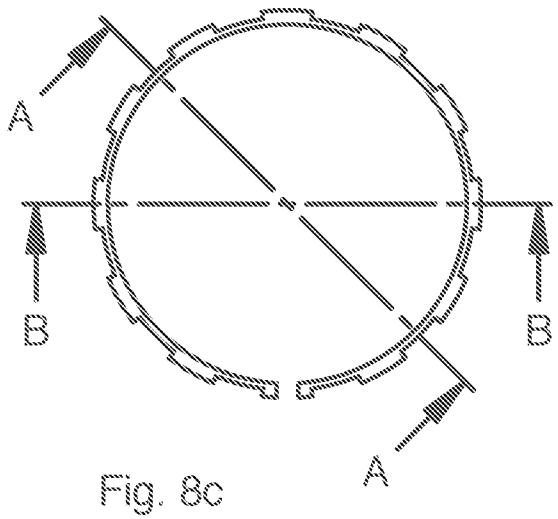


Fig. 8c

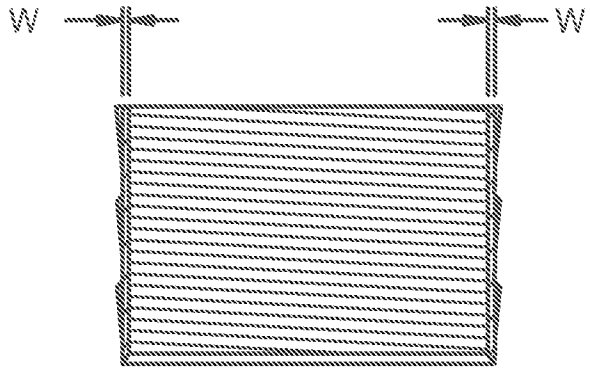


Fig. 8d
SECTION A-A

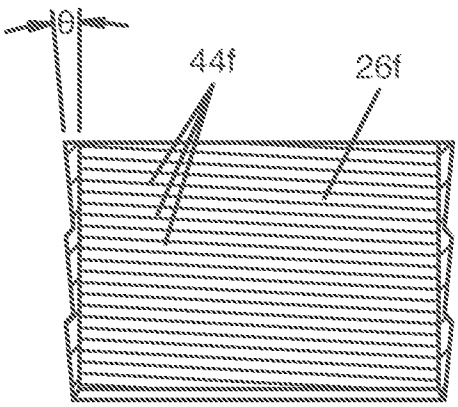


Fig. 8e
SECTION B-B

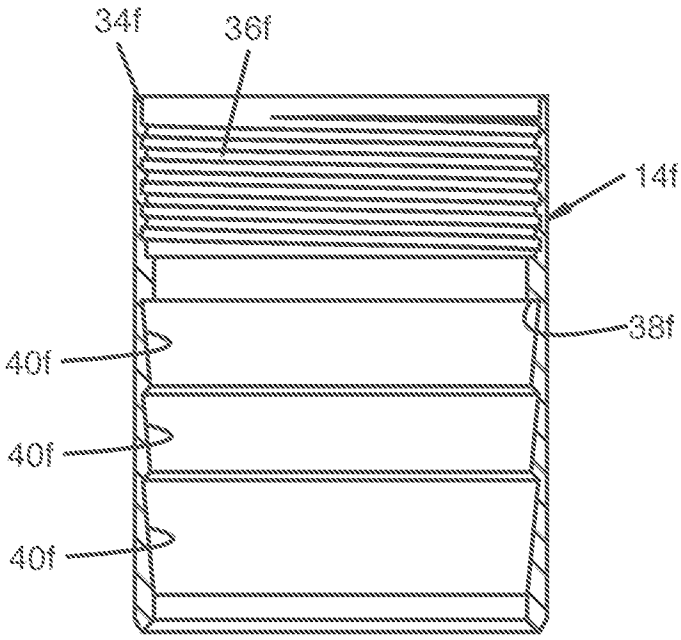


Fig. 8f

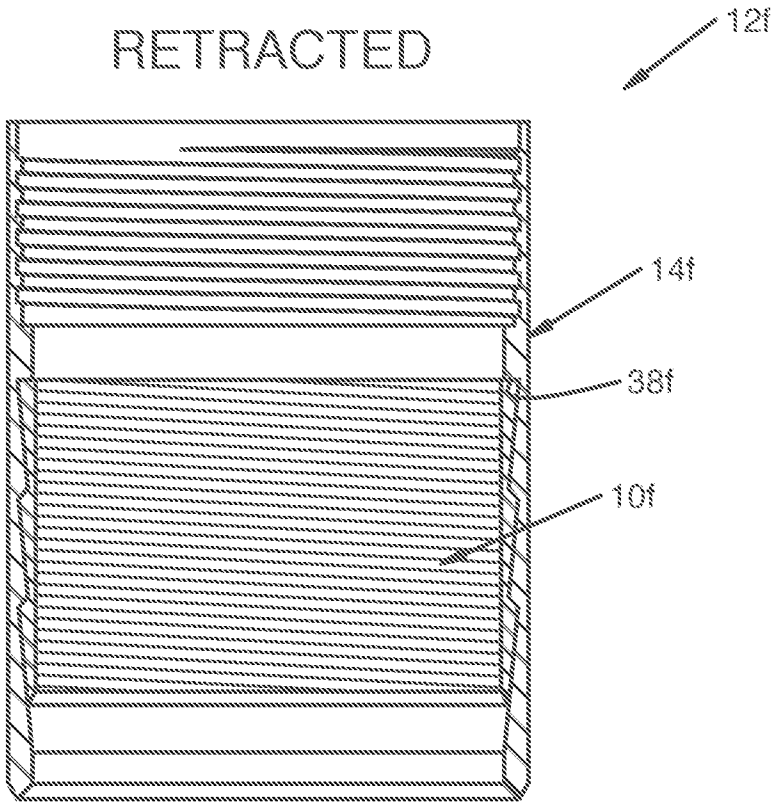


Fig. 9a

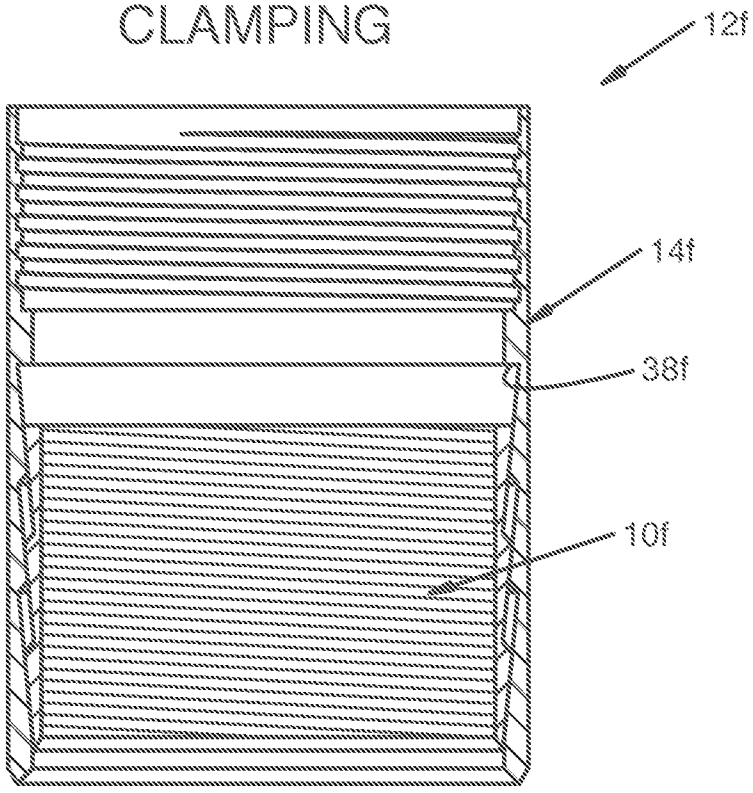


Fig. 9b

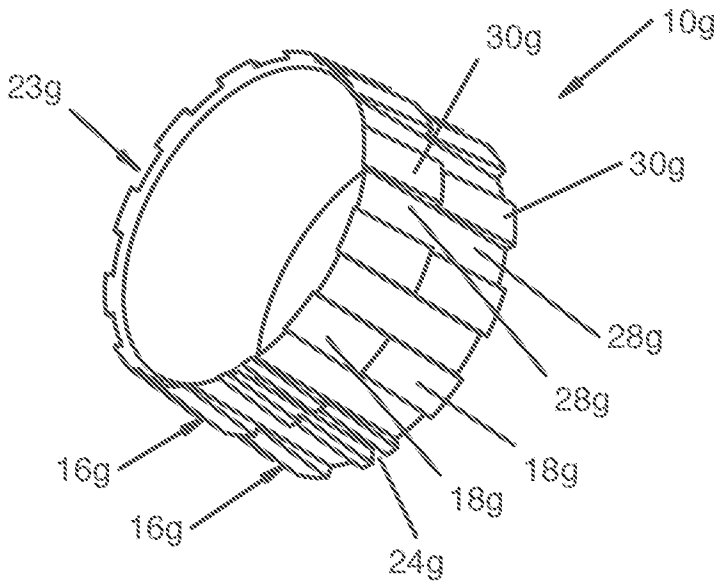


Fig. 10a

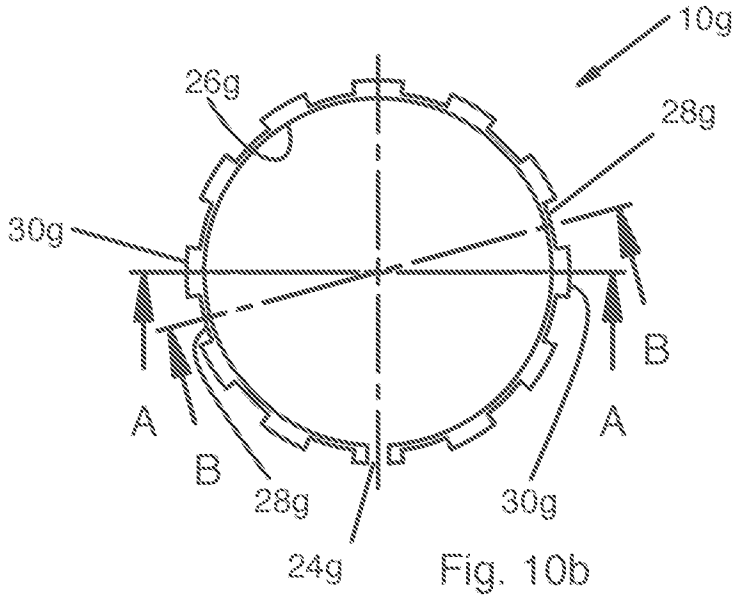


Fig. 10b

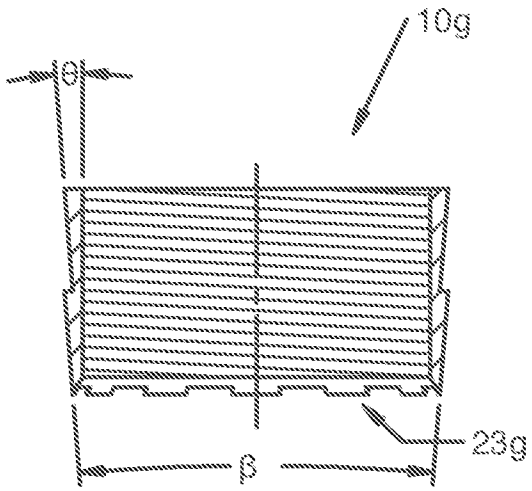


Fig. 10c
SECTION A-A

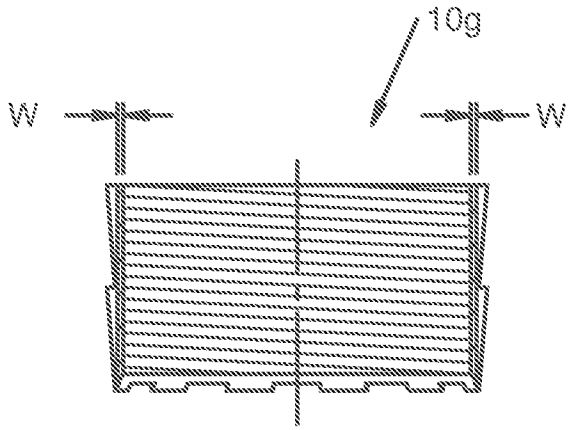


Fig. 10d
SECTION B-B

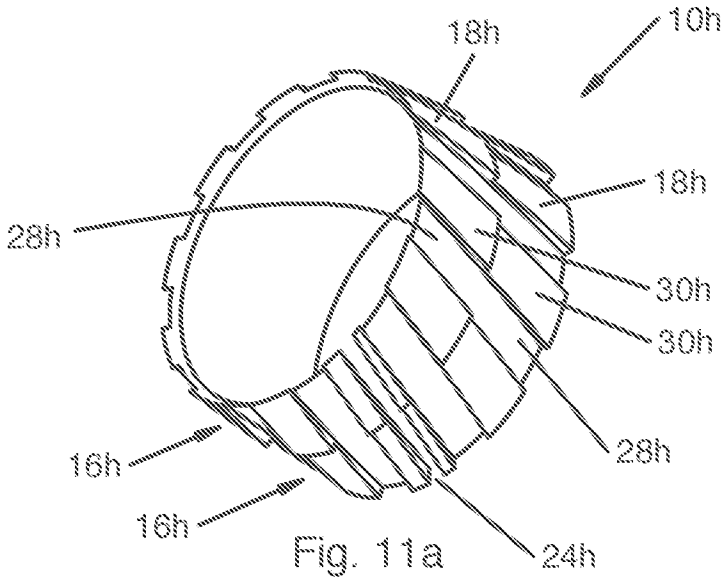


Fig. 11a

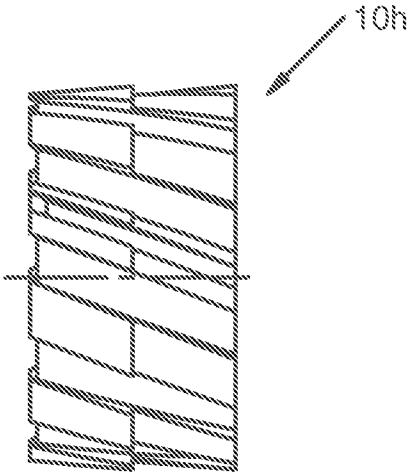


Fig. 11b

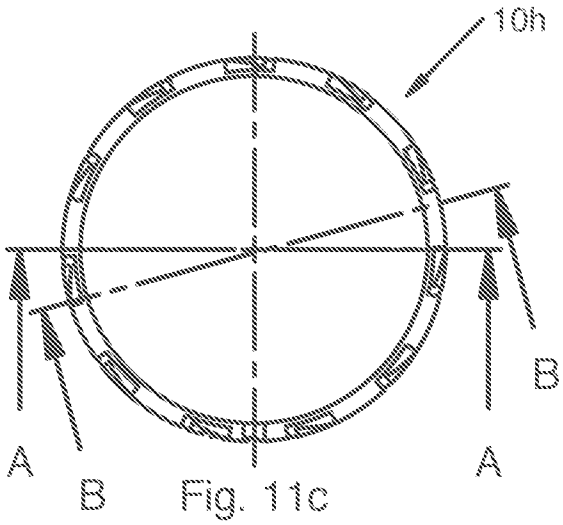


Fig. 11c

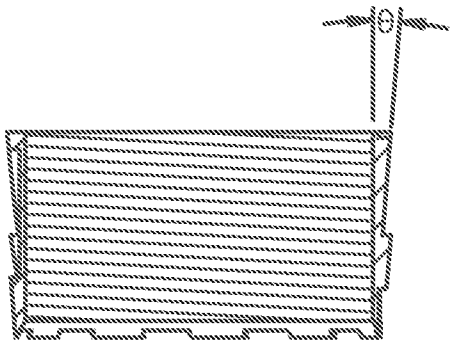


Fig. 11d
SECTION A-A

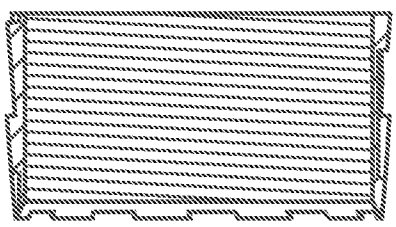


Fig. 11e
SECTION B-B

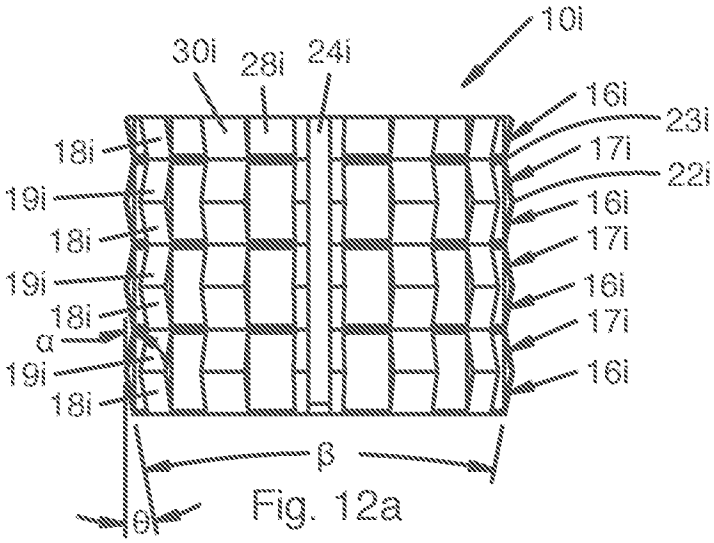


Fig. 12a

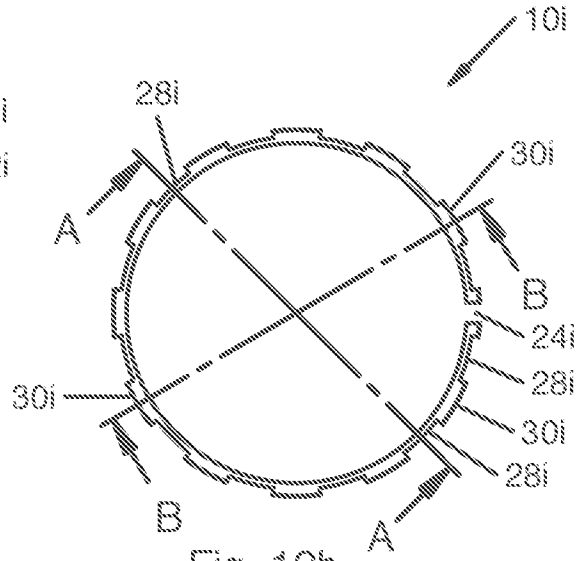


Fig. 12b

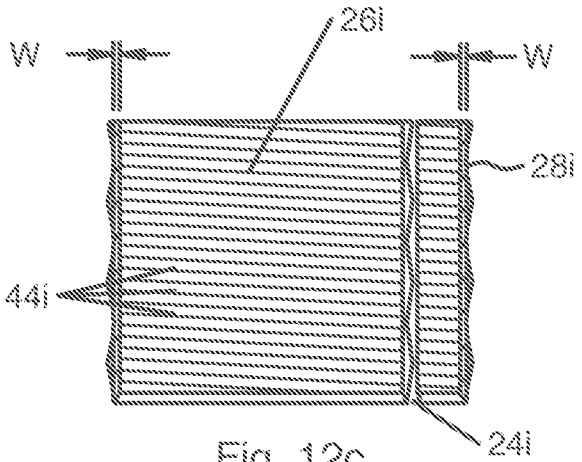


Fig. 12c
SECTION A-A

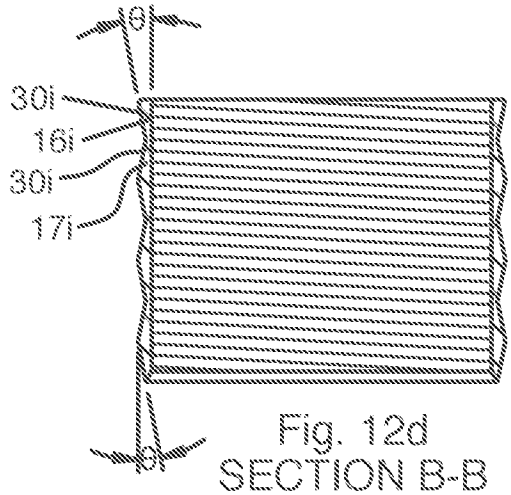


Fig. 12d
SECTION B-B

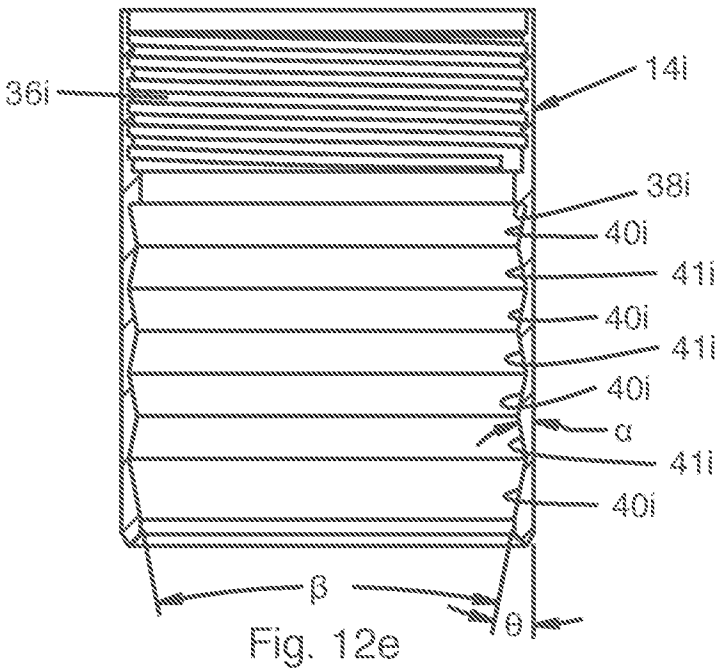


Fig. 12e

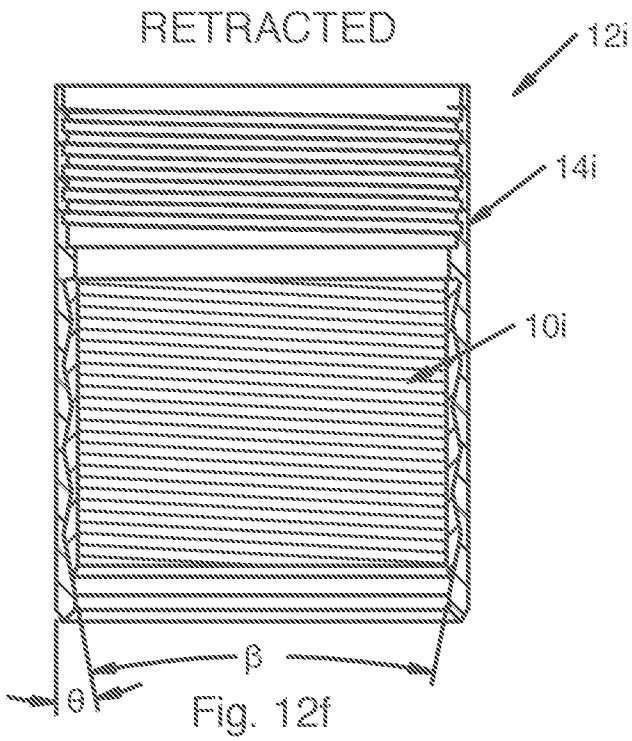


Fig. 12f

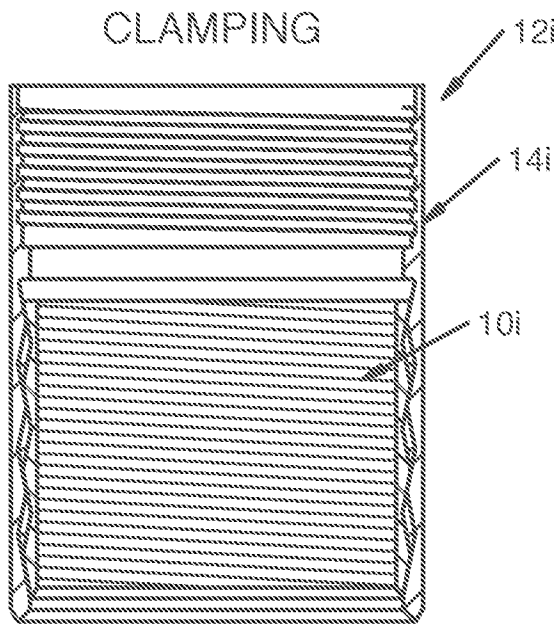


Fig. 12g

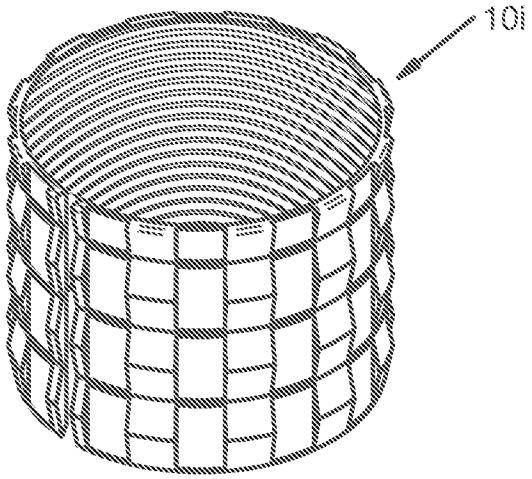


Fig. 12h

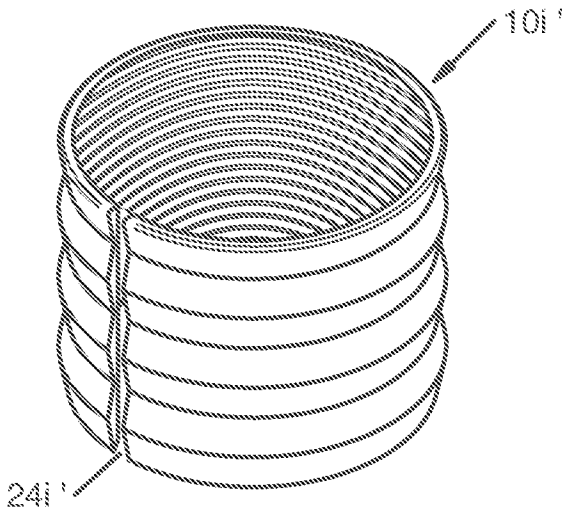


Fig. 12i

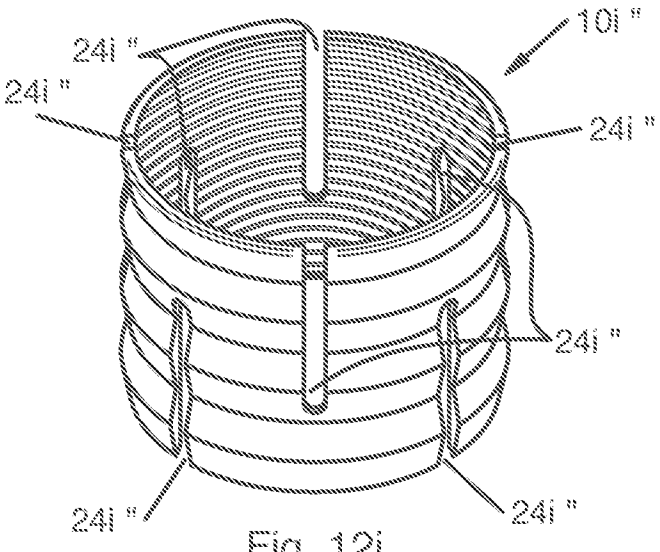


Fig. 12j

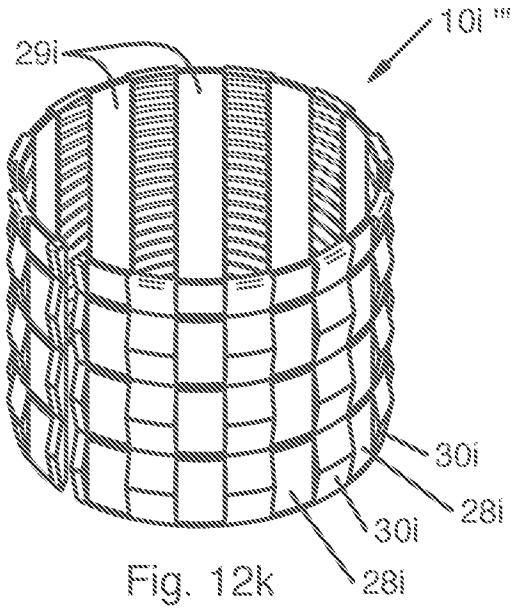


Fig. 12k

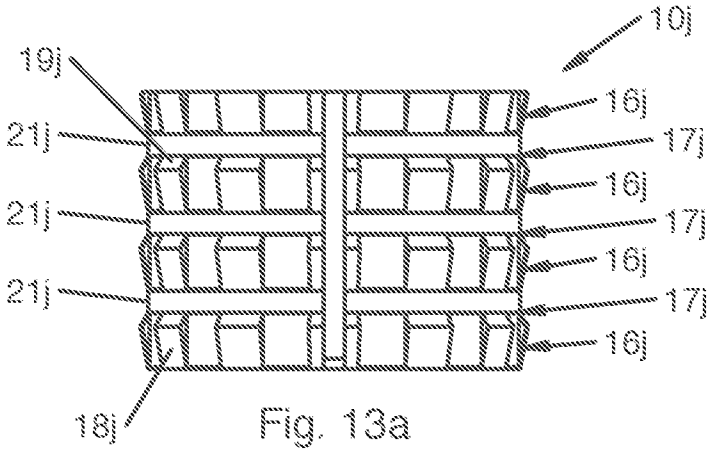


Fig. 13a

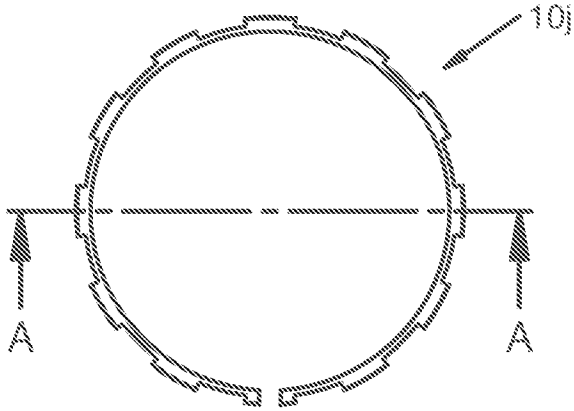


Fig. 13b

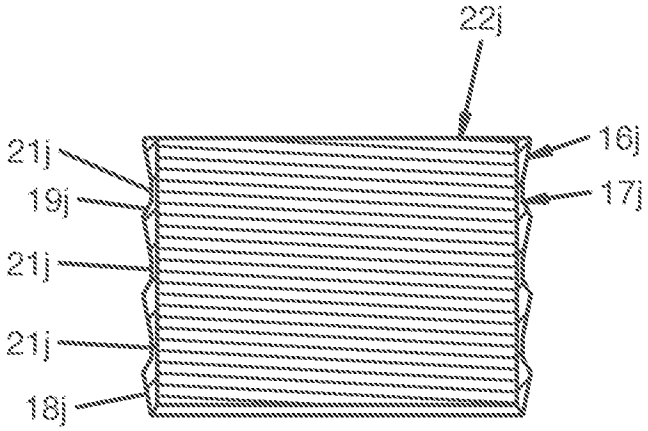


Fig. 13c
SECTION A-A

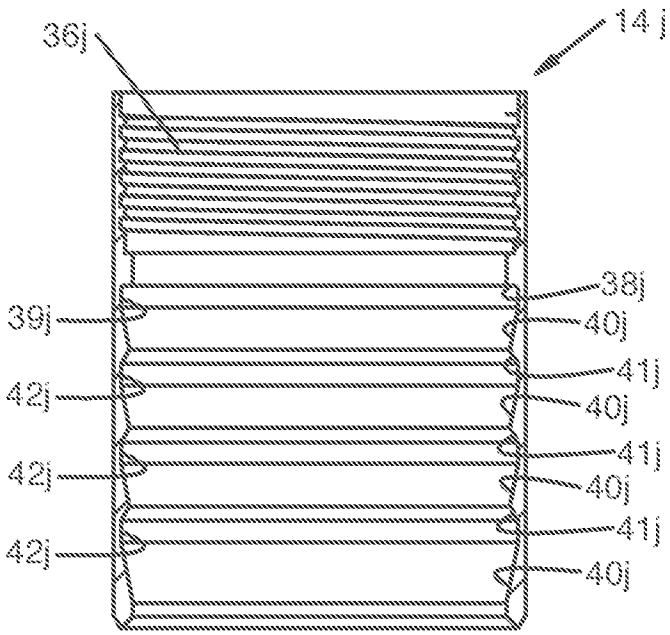


Fig. 13d

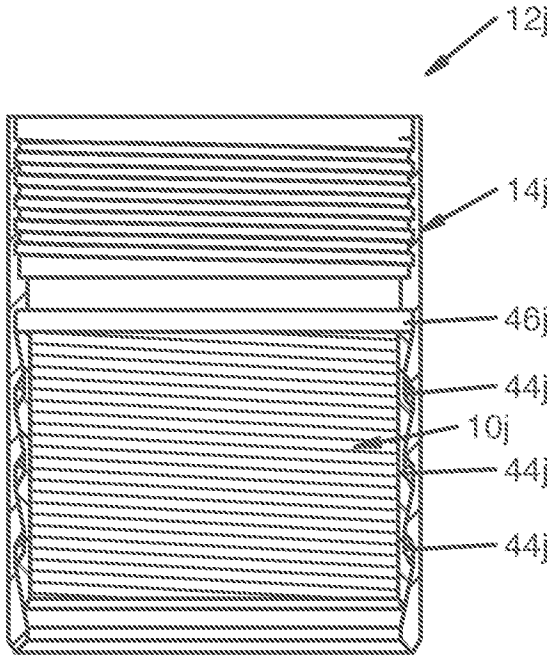


Fig. 13e

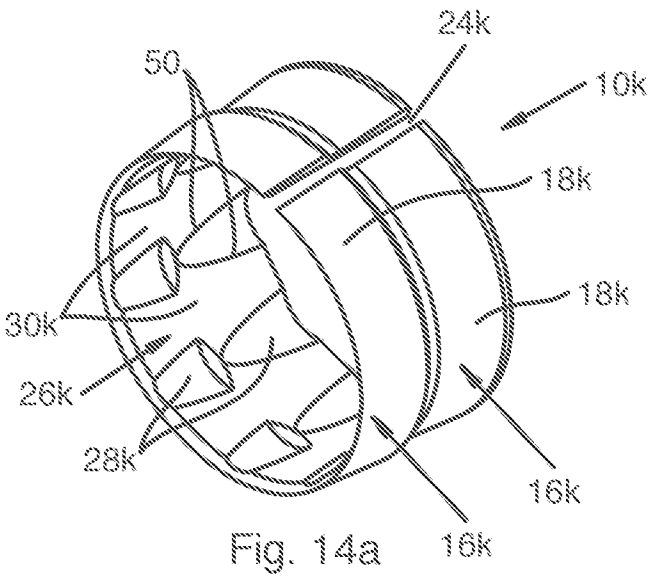


Fig. 14a

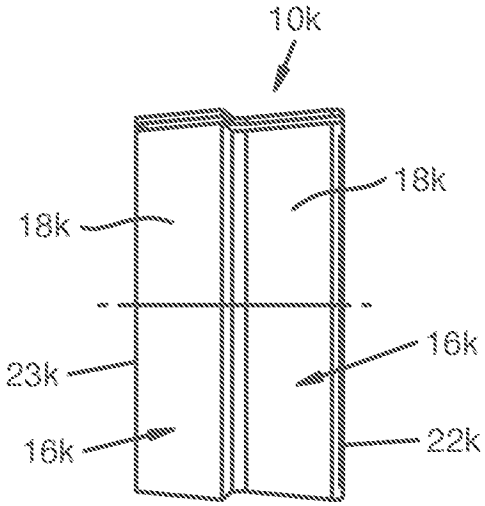


Fig. 14b

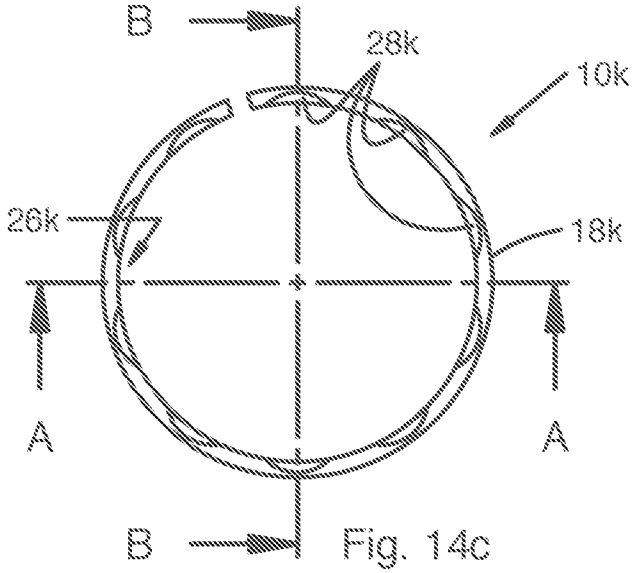


Fig. 14c

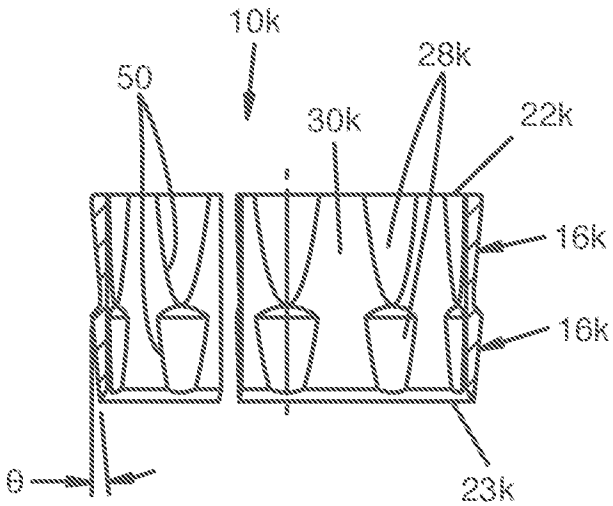


Fig. 14d
SECTION A-A

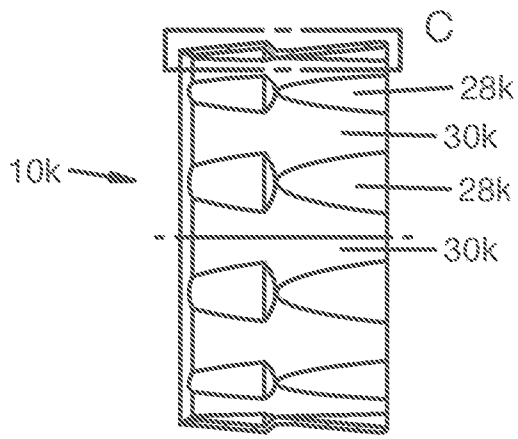


Fig. 14e
SECTION B-B

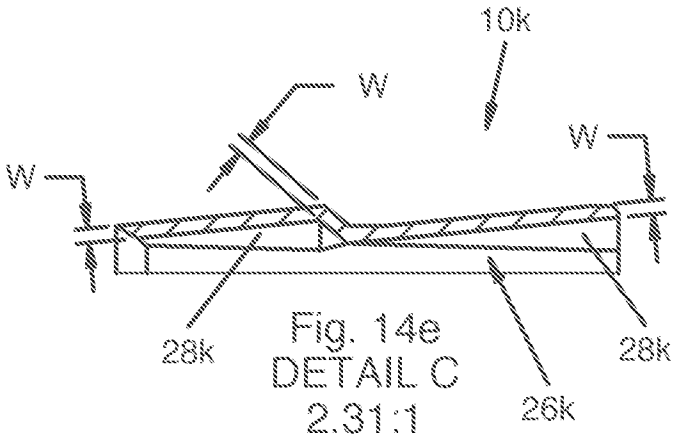


Fig. 14e
DETAIL C
2.31:1

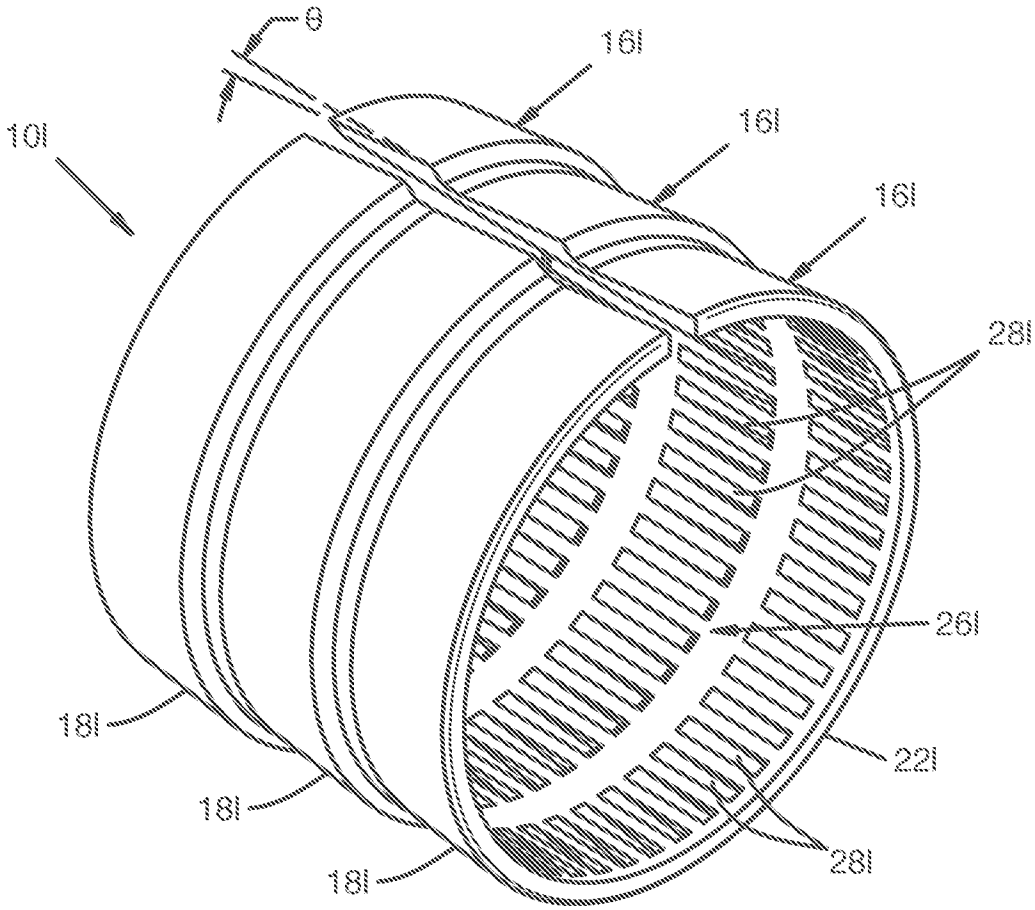


Fig. 15a

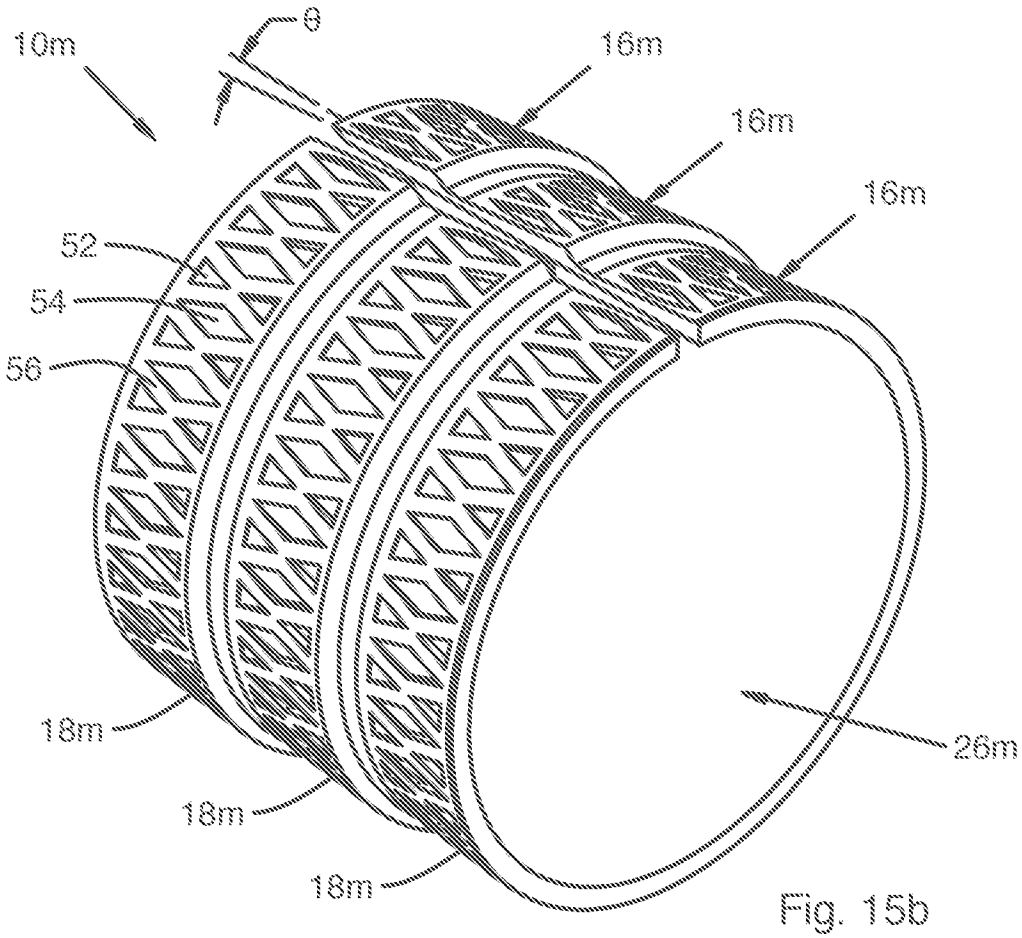


Fig. 15b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2013/001093

A. CLASSIFICATION OF SUBJECT MATTER

E21B 25/00 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

EPODOC & Derwent WPI: IPC & CPC E21B25 with keywords core/coring, cone/conical, wedge, angle/angular, gradient, taper, slope, slant, chamfer, larger, greater, more, smaller, less, than, equal, degree/s, alpha, beta, projection, protrusion, channel, ridge, valley, rib, spline, extension, protuberence, ring, cup, bowl, sleeve, barrel, bush, cylinder, catcher, fetcher, receive, lift/er, assembly, multi, plurality, many several, portion, part, segment, section, injection, mould, mold, etc.; Google Patent database with keywords core, sample, ring, frusto-conical, angle, degree, multi, portion, inject, mould/mold, and like.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

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

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 January 2014	08 January 2014

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
Email address: pct@ipaustralia.gov.au
Facsimile No.: +61 2 6283 7999

Authorised officer

Jude Fernando
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. 0262832419

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2013/001093**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 6116358 A (FANUEL) 12 September 2000 Abstract, col 3 ln 19-65, col 6 ln 11-35; Figs. 1-3 Abstract, col 3 ln 19-65, col 6 ln 11-35; Figs. 1-3	1-9, 11-24, 37-39 10, 25-36
A	US 2011/0079436 A1 (DRENTH et al.) 07 April 2011 Abstract; Figures 1-9	1-39

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2013/001093**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 6116358 A	12 Sep 2000	WO 9726440 A1	24 Jul 1997
US 2011/0079436 A1	07 Apr 2011	AU 2010339878 A1	05 Jul 2012
		AU 2010339959 A1	05 Jul 2012
		CA 2776923 A1	14 Apr 2011
		CA 2784531 A1	14 Jul 2011
		CA 2784532 A1	14 Jul 2011
		CN 102770618 A	07 Nov 2012
		CN 102782248 A	14 Nov 2012
		CN 102791954 A	21 Nov 2012
		EP 2486223 A2	15 Aug 2012
		EP 2513412 A2	24 Oct 2012
		EP 2513413 A2	24 Oct 2012
		NZ 599635 A	27 Sep 2013
		PE 00542013 A1	04 Feb 2013
		PE 00552013 A1	04 Feb 2013
		PE 16762012 A1	05 Dec 2012
		US 2011079436 A1	07 Apr 2011
		US 8485280 B2	16 Jul 2013
		US 2011079435 A1	07 Apr 2011
		US 2011083901 A1	14 Apr 2011
		US 2013192901 A1	01 Aug 2013
		US 2013313024 A1	28 Nov 2013
		WO 2011044314 A2	14 Apr 2011
		WO 2011084587 A2	14 Jul 2011
		WO 2011084589 A2	14 Jul 2011

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.