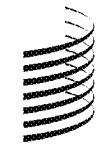


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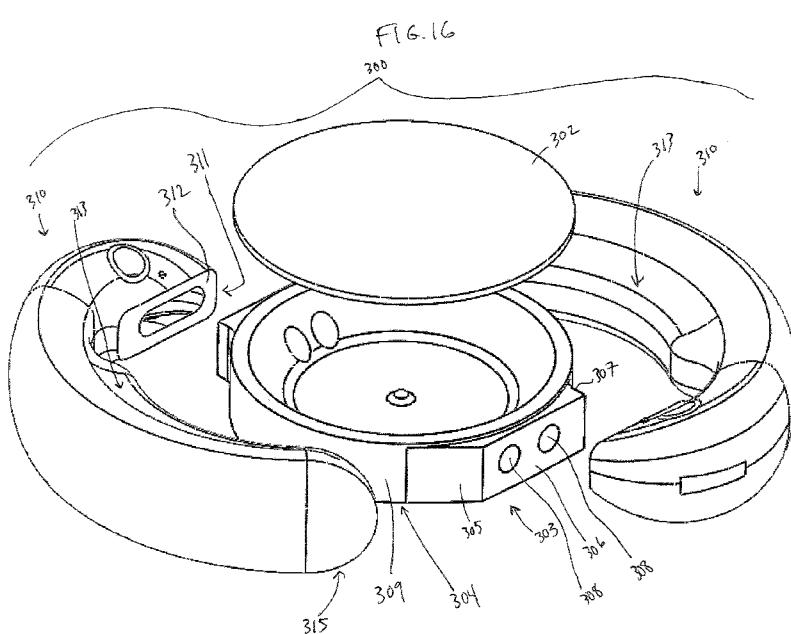
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*[Continued on next page]*

(54) Title: ACCOMMODATING INTRAOCCULAR LENSES AND METHODS OF MANUFACTURING



(57) Abstract: Methods of manufacturing an optic of an accommodating intraocular lens to have an aspheric lens surface, including providing an optic comprising an anterior element and a posterior element that at least partially define an optic fluid chamber, wherein at least one of the anterior element and the posterior element has an external surface that is spherical; and prior to inserting the accommodating intraocular lens into an eye, changing the shape of the at least one of the anterior element and the posterior element from the spherical configuration to an aspherical configuration.



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**ACCOMMODATING INTRAOCULAR LENSES AND METHODS OF MANUFACTURING****CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority to US Provisional Patent Application Nos. , 62/252,260 filed 06 November 2015; 62/321,678 filed 12 April 2016; 62/357,785 filed 01 July 2016; 62/321,704 filed 12 April 2016; 62/321,666 filed 12 April 2016; 62/321,665 filed 12 April 2016; 62/321,705 filed 12 April 2016; 62/321,684 filed 12 April 2016; 62/321,670 filed 12 April 2016 and 62/377,402 filed 19 August 2016; the disclosures of which are all incorporated by reference herein.

**10 INCORPORATION BY REFERENCE**

[0002] All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

**15 BACKGROUND**

[0003] Fluid-driven, accommodating intraocular lenses have been described. This disclosure describes a wide variety of aspects of exemplary intraocular lenses that may provide benefits to some fluid-driven, accommodating intraocular lenses. For example, it may be beneficial for a fluid-driven intraocular lens to have an aspherical configuration after it has been manufactured.

**20 SUMMARY OF THE DISCLOSURE**

[0004] One aspect of the disclosure is a method of manufacturing an optic of an accommodating intraocular lens to have an aspheric lens surface, comprising: providing an optic comprising an anterior element and a posterior element that at least partially define an optic fluid chamber, wherein at least one of the anterior element and the posterior element has an external surface that is spherical; and prior to inserting the accommodating intraocular lens into an eye, changing the shape of the at least one of the anterior element and the posterior element from the spherical configuration to an aspherical configuration.

[0005] In some embodiments changing the shape of the at least one of the anterior element and the posterior element from the spherical configuration to an aspherical configuration comprises adding fluid to the optic fluid chamber so as to increase the fluid pressure within the optic chamber and cause the at least one of the anterior element and the posterior element to deform from the spherical configuration to the aspherical configuration. Prior to adding fluid, the method can include securing at least one haptic to the optic.

[0006] In some embodiments providing the optic comprises bonding the anterior element to the posterior element.

[0007] In some embodiments the method also includes machining at least one of the anterior element and the posterior element.

[0008] In some embodiments, prior to changing the shape of the at least one of the anterior element and the posterior element from the spherical configuration to an aspherical configuration, the optic has a 10-15D base state.

[0009] One aspect of the disclosure is a fluid-filled intraocular lens, comprising: an optic portion 5 comprising an anterior element with an anterior optical surface and a posterior element with a posterior optical surface, the anterior element and the posterior element defining an optic fluid chamber, wherein at least one of the anterior optical surface and the posterior optical surface has an aspherical configuration in an as-manufactured state, prior to insertion in an eye.

[0010] One aspect of the disclosure is an intraocular lens, comprising: an optic portion; and a peripheral 10 portion including a peripheral fluid chamber, the peripheral portion having a cross section, in a plane passing through an optical axis of the optic portion, in which the fluid chamber is disposed in a radially outer portion of the peripheral portion, and wherein a radially inner portion of the peripheral chamber is non-fluid.

[0011] One aspect of the disclosure is an intraocular lens, comprising: an optic portion; and a peripheral 15 portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, and in a direction orthogonal to an optical axis of the optic portion through a midpoint of the peripheral portion, having a radially inner fluid chamber wall thickness that is between four and twenty times the thickness of a radially outer fluid chamber wall thickness.

[0012] One aspect of the disclosure is an intraocular lens, comprising: an optic portion; and a peripheral 20 portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, has an outer surface that is not symmetrical about every axis passing through the peripheral portion and parallel to an optical axis of the optic portion, and wherein the peripheral portion has, in a direction orthogonal to an optical axis of the optic portion through a midpoint of the peripheral portion, having a radially inner fluid chamber wall thickness greater than a radially outer 25 fluid chamber wall thickness.

[0013] One aspect of the disclosure is an intraocular lens, comprising: an optic portion; and a peripheral portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, having a height dimension measured in an anterior to posterior direction, wherein the greatest height of the peripheral portion in a radially outer half of the 30 peripheral portion is greater than the greatest height of the peripheral portion in a radially inner half of the peripheral portion.

[0014] One aspect of the disclosure is an intraocular lens, comprising: an optic portion coupled to a peripheral portion at a coupling, the coupling comprising a radially inner surface of the peripheral portion interfacing a radially outer peripheral edge of the optic portion.

35 [0015] In some embodiments the radially inner surface of the peripheral portion has a first end with a configuration that is different than a second end of the inner surface. The peripheral portion can include a haptic with a coupled end and a free end, the first end being closer to the haptic free end than the coupled

end. The haptic can have a configuration that follows a radially outer peripheral curvature of the optic from the haptic coupled end to the free end.

[0016] In some embodiments the first end has a greater surface area than the second end of the radially inner surface. The first end can have a tapered end configuration, wherein the taper is toward a free end 5 of the peripheral portion.

[0017] In some embodiments the radially inner surface of the peripheral portion defines a peripheral portion fluid port.

[0018] One aspect of the disclosure is an intraocular lens, comprising an optic body, a projection 10 extending radially outwards from a peripheral surface of the optic body, and a peripheral non-optic body having a first portion secured to the projection.

[0019] In some embodiments a radially inner surface of the first portion of the peripheral non-optic body follows a radially peripheral surface of the projection.

[0020] In some embodiments the projection and the first portion interface at a butt joint, with optionally flat or curved relative surfaces.

15 [0021] In some embodiments a radially peripheral surface of the projection comprises a flat surface, optionally entirely flat. A radially inner surface of the first portion of the peripheral non-optic body can comprise a flat surface, optionally entirely flat.

20 [0022] In some embodiments a radially peripheral surface of the projection comprises a curved surface, optionally entirely curved. A radially inner surface of the first portion of the peripheral non-optic body can comprise a curved surface, optionally entirely curved.

[0023] In some embodiments a radially peripheral surface of the projection is between 10 microns and 1 mm, optionally, 10 microns to 500 microns, farther away radially from a center of the optic body than the peripheral surface of the optic body.

25 [0024] In some embodiments the projection extends between 10 microns and 1mm, optionally between 10 microns and 500 microns, from the peripheral surface of the optic body.

[0025] In some embodiments the optic body and the projection are a single integral body.

[0026] In some embodiments the projection is attached to the optic body.

30 [0027] In some embodiments the optic body comprises a posterior element and an anterior element, optionally defining a fluid chamber therebetween. The posterior element can comprise the projection. The anterior element may comprise the projection.

[0028] In some embodiments the peripheral non-optic body further comprises a free second portion disposed away from the first portion.

[0029] In some embodiments the peripheral non-optic body comprises a peripheral fluid chamber.

35 [0030] In some embodiments the projection comprises at least one channel, and optionally at least two channels, in fluid communication with a peripheral fluid chamber in the peripheral non-optic body.

[0031] In some embodiments the peripheral non-optic body has a radially inner surface, optionally with a slight curve, coupled to the projection, wherein the projection is disposed on a radially outer peripheral edge of the optic body.

[0032] In some embodiments the peripheral non-optic body is adapted to deform in response to forces on the peripheral non-optic body due to ciliary muscle movement to thereby move a fluid between a peripheral fluid chamber in the peripheral non-optic body and an optic fluid chamber in the optic body to change an optical parameter of the intraocular lens.

5 [0033] In some embodiments the peripheral non-optic body comprises an opening configured to interface with the projection.

[0034] In some embodiments the projection is sized and configured to be disposed within and interface with an opening in the peripheral non-optic body.

10 [0035] One aspect of the disclosure is an intraocular lens comprising an optic body and a peripheral non-optic body, the optic body having, in a top view, an outer edge at least a portion of which is an arc, and wherein the peripheral non-optic body is coupled to the optic body projection at a location radially outward relative to the curve of the arc.

15 [0036] One aspect of the disclosure an intraocular lens wherein an adhesive between first and second components has a modulus of elasticity of between about 0.4 and 1000 MPa, such as between about 1 MPa and 600 MPa.

[0037] One aspect of the disclosure is an intraocular lens wherein an adhesive is 50-85% of a cross linkable polymer of a first polymeric material of the intraocular lens.

[0038] One aspect of the disclosure is an intraocular lens wherein an adhesive comprises between 7.5% and 30% of a reactive acrylic monomer diluent.

20 [0039] One aspect of the disclosure is an intraocular lens wherein the adhesive includes lauryl methacrylate or similar material in an amount between 2.5% and 30%.

[0040] One aspect of the disclosure is an intraocular lens, optionally, accommodating, comprising an optic portion; a peripheral portion; and at least one ridge extending along at least a portion of the length of the peripheral portion.

25 [0041] One aspect of the disclosure is an intraocular lens, wherein a tip of a first haptic overlays, optionally tapered, a second haptic, in a top view.

[0042] One aspect of the disclosure is an intraocular lens, optionally accommodating, including an optic portion; and a peripheral portion coupled to the optic portion, the peripheral portion comprising a first haptic and a second haptic, wherein the first haptic and the second haptic are configured to be closely fit together to reduce gaps therebetween, optionally overlapping in a top view.

[0043] One aspect of the disclosure is an intraocular lens, optionally, accommodating, comprising an optic portion comprising an opaque periphery around at least a portion of the optic portion; and a peripheral non-optic portion secured to the optic portion and disposed radially outward relative to the optic portion.

35 [0044] One aspect of the disclosure a method of air removal during loading of an intraocular lens, comprising: providing an intraocular lens; loading the intraocular lens into a cartridge; inserting a viscoelastic delivery device over the intraocular lens; injecting a fluid from the viscoelastic delivery device; and removing air from over a portion of the intraocular lens and away from the intraocular lens.

[0045] One aspect of the disclosure is a loading carrier for loading an intraocular lens and removing air over a portion of the intraocular lens in preparation for delivering the intraocular lens into an eye, comprising a base member comprising an intraocular lens receiving region; a loading member configured to advance the intraocular lens towards a delivery lumen; and an opening configured to allow insertion of

5 a viscoelastic delivery device over a portion of the intraocular lens to remove air away from the intraocular lens.

[0046] One aspect of the disclosure is a method of air venting in a delivery system of an intraocular lens, comprising: providing a loading carrier for a intraocular lens; loading the intraocular lens into a cartridge from the loading carrier, mounting a plunger assemble to the cartridge; injecting a viscoelastic fluid from 10 the plunger assemble; and removing air out of the plunger assembly.

[0047] One aspect of the disclosure is a method of removing air from an area adjacent an intraocular lens, comprising: providing an intraocular lens within a loading device in a loaded configuration; and delivering a viscoelastic material, optionally with a syringe, in the vicinity of the intraocular lens to remove air bubbles proximate the intraocular lens.

15 [0048] One aspect of the disclosure is an apparatus for delivering an intraocular lens into an eye, comprising: a distal tip adapted to deliver an intraocular lens into an eye; and a lumen extending from the proximal region to the distal tip, the lumen comprising a cross section having a first axis and a second axis of an internal ellipse; a first portion configured to fold the intraocular lens without stretching the intraocular lens out, a second portion configured to form a substantial seal between an inner wall and the 20 intraocular lens, and a third portion configured to compress the intraocular lens to extend the intraocular lens in length.

[0049] One aspect of the disclosure is a method for delivering an intraocular lens into an eye, comprising: engaging a delivery device to a loading carrier to accept the intraocular lens; folding the intraocular lens without stretching the intraocular lens out; forming a seal between an inner wall of the 25 delivery device and the intraocular lens; compressing the intraocular lens to extend the intraocular lens in length; and delivering the intraocular lens into the eye.

[0050] One aspect of the disclosure a delivery device for delivering an intraocular lens into an eye, comprising a delivery lumen configured to deform therein an intraocular lens during delivery out of a distal port; wherein in a first cross section the inner lumen has an elliptical shape, and in a second cross 30 section distal to the first cross section, the inner lumen has an elliptical shape, wherein in the first cross section the elliptical shape has a major axis and minor axis, and wherein in the second cross section the elliptical shape has a major axis and minor axis, wherein the major axis of the first cross section is perpendicular to the major axis of the second cross section.

35

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0051] Figures 1A and 1B illustrate an exemplary accommodating intraocular lens.

[0052] Figure 1C illustrates a sectional view of the accommodating intraocular lens from Figures 1A and 1B.

[0053] Figure 1D is a top view of an exemplary posterior element of an accommodating intraocular lens.

[0054] Figure 1E is a sectional assembly view of an exemplary optic portion of an accommodating lens.

5 [0055] Figures 1F and 1G illustrate an exemplary haptic.

[0056] Figure 1H illustrate an exemplary coupling between an optic portion and a haptic.

[0057] Figures 2A, 2B, and 2C illustrate an exemplary haptic.

[0058] Figures 2D, 2E, and 2F illustrate sectional views of the haptic from Figure 2A.

10 [0059] Figure 2G illustrates an opening in a first end of the haptic from Figures 2A-2C.

[0060] Figure 3 illustrates exemplary diameters of an accommodating intraocular lens.

[0061] Figure 4 illustrates an exemplary haptic.

[0062] Figures 5A and 5B illustrate the deformation of an exemplary haptic in response to exemplary forces.

15 [0063] Figure 6 illustrates an exemplary fluid opening in an exemplary haptic.

[0064] Figure 7 illustrates an exemplary fluid opening in an exemplary haptic.

[0065] Figure 8 illustrates a sectional view of an exemplary accommodating intraocular lens.

[0066] Figure 9 illustrates a sectional view of an exemplary accommodating intraocular lens with relatively short haptics.

20 [0067] Figure 10 illustrate a sectional view of an exemplary accommodating intraocular lens with an optic centered with a peripheral portion.

[0068] Figure 11 is an exemplary haptic.

[0069] Figure 12 shows an exemplary optic portion.

[0070] Figure 13 shows a portion of an exemplary haptic.

25 [0071] Figure 14 shows an exemplary IOL.

[0072] Figure 15 shows an exemplary IOL.

[0073] Figure 16 shows an exemplary IOL.

[0074] Figure 17 shows a top view of an exemplary IOL.

[0075] Figure 18 shows an exemplary optic portion.

30 [0076] Figure 19 shows a sectional view of an exemplary IOL.

[0077] Figure 20 shows a top view of an exemplary IOL.

[0078] Figure 21 shows a sectional view of an exemplary IOL.

[0079] Figure 22 shows a top view of an exemplary IOL.

[0080] Figure 23A shows a top view of an exemplary IOL.

35 [0081] Figure 23B shows a sectional view of an exemplary IOL.

[0082] Figure 24 is a section view of a cartridge with an IOL loaded inside.

[0083] Figures 25A, 25B, 25C illustrate a method of air venting during the delivery process.

[0084] Figures 26A, 26B, and 26C show viscoelastic fluid traveling from a syringe through a support tube.

[0085] Figure 27 is a top view of an exemplary cartridge, which can be used to deliver an intraocular lens into an eye.

5 [0086] Figures 28A, 28B, 28C, and 28D illustrate exemplary internal cross sections of the cartridge in Figure 27.

## DETAILED DESCRIPTION

10 [0087] The disclosure relates generally to accommodating intraocular lenses. In some embodiments the accommodating intraocular lenses described herein are adapted to be positioned within a native capsular bag in which a native lens has been removed. In these embodiments a peripheral non-optic portion (i.e., a portion not specifically adapted to focus light on the retina) is adapted to respond to capsular bag reshaping due to ciliary muscle relaxation and contraction. The response is a deformation of the 15 peripheral portion that causes a fluid to be moved between the peripheral portion and an optic portion to change an optical parameter (e.g., power) of the intraocular lens.

[0088] Figure 1A is a top view illustrating accommodating intraocular lens 10 that includes optic portion 12 and a peripheral portion that in this embodiment includes first and second haptics 14 coupled to and extending peripherally from optic portion 12. Optic portion 12 is adapted to refract light that enters the 20 eye onto the retina. Haptics 14 are configured to engage a capsular bag and are adapted to deform in response to ciliary muscle related capsular bag reshaping. Figure 1B is a perspective view of intraocular lens 10 showing optic portion 12 and haptics 14 coupled to optic portion 12.

[0089] The haptics are in fluid communication with the optic portion. Each haptic has a fluid chamber that is in fluid communication with an optic chamber in the optic portion. The haptics are formed of a 25 deformable material and are adapted to engage the capsular bag and deform in response to ciliary muscle related capsular bag reshaping. When the haptics deform the volume of the haptic fluid chamber changes, causing a fluid disposed in the haptic fluid chambers and the optic fluid chamber to either move into the optic fluid chamber from the haptic fluid chambers, or into the haptic fluid chambers from the optic fluid chamber. When the volume of the haptic fluid chambers decreases, the fluid is moved into the optic fluid 30 chamber. When the volume of the haptic fluid chamber increases, fluid is moved into the haptic fluid chambers from the optic fluid chamber. The fluid flow into and out of the optic fluid chamber changes the configuration of the optic portion and the power of the intraocular lens.

[0090] Figure 1C is a side sectional view through Section A-A indicated in Figure 1A. Optic portion 12 includes deformable anterior element 18 secured to deformable posterior element 20. Each haptic 14 35 includes a fluid chamber 22 that is in fluid communication with optic fluid chamber 24 in optic portion 12. Only the coupling between the haptic 14 to the left in the figure and option portion 12 is shown (although obscured) in the sectional view of Figure 1C. The haptic fluid chamber 22 to the left in the figure is shown in fluid communication with optic fluid chamber 24 via two apertures 26, which are

formed in posterior element 20. The haptic 14 to the right in Figure 1C is in fluid communication with optic chamber 24 via two additional apertures also formed in posterior element (not shown) substantially 180 degrees from the apertures shown.

[0091] Figure 1D is a top view of posterior element 20 (anterior element 18 and haptics 14 not shown).

5 Posterior element 20 includes buttress portions 29 in which channels 32 are formed. Channels 32 provide fluid communication between optic portion 12 and haptics 14. Apertures 26 are disposed at one end of channels 32. The optic fluid chamber 24 is therefore in fluid communication with a single haptic via two fluid channels. Buttress portions 29 are configured and sized to be disposed within an opening formed in haptics 14 that defines one end of the haptic fluid chamber, as described below. Each of buttress portions 10 29 includes two channels formed therein. A first channel in a first buttress is in alignment with a first channel in the second buttress. The second channel in the first buttress is in alignment with the second channel in the second buttress.

[0092] There are exemplary advantages to having two channels in each buttress as opposed to one channel. A design with two channels rather than one channel helps maintain dimensional stability during 15 assembly, which can be important when assembling flexible and thin components. Additionally, it was observed through experimentation that some one-channel designs may not provide adequate optical quality throughout the range of accommodation. In particular, lens astigmatism may occur in some one-channel designs, particularly as the intraocular lens accommodated. It was discovered that the two-channel buttress designs described herein can help reduce astigmatism or the likelihood of astigmatism, 20 particularly as the lens accommodated. Astigmatism is reduced in these embodiments because the stiffness of the buttress is increased by the rib portion between the two channels. The additional stiffness results in less deflection due to pressure changes in the channels. Less deflection due to the pressure changes in the channels results in less astigmatism. In some embodiments the channels are between about .4 mm and about .6 mm in diameter. In some embodiments the channels are about .5 mm in diameter. In 25 some embodiments the distance between the apertures is about .1 mm to about 1.0 mm.

[0093] Figure 1E is a side assembly view through section A-A of optic portion 12, which includes anterior element 18 and posterior element 20 (haptics not shown for clarity). By including fluid channels 32 in posterior element 20, posterior element 20 needs to have enough structure through which the channels 32 can be formed. Buttress portions 29 provide that structure in which channels 32 can be 30 formed. At its peripheral-most portion posterior element 20 is taller than anterior element 18 in the anterior-to-posterior direction. In alternative embodiments, the channels can be formed in anterior element 18 rather than posterior element 20. The anterior element would include buttress portions 29 or other similar structure to provide structure in which the channels can be formed. In these alternative embodiments the posterior element could be formed similarly to anterior element 18.

35 [0094] As shown in Figure 1E, posterior element 20 is secured to anterior element 18 at peripheral surface 28, which extends around the periphery of posterior element 20 and is a flat surface. Elements 18 and 20 can be secured together using known biocompatible adhesives. Anterior element 18 and posterior element 20 can also be formed from one material to eliminate the need to secure two elements together.

In some embodiments the diameter of the region at which anterior element 18 and posterior element 20 are secured to one another is about 5.4 mm to about 6 mm in diameter.

**[0095]** In some embodiments the thickness of anterior element 18 (measured in the anterior-to-posterior direction) is greater along the optical axis (“OA” in Figure 1C) than at the periphery. In some

5 embodiments the thickness increases continuously from the periphery towards the thickest portion along the optical axis.

**[0096]** In some embodiments the thickness of posterior element 20 decreases from the location along the optical axis towards the edge of central region “CR” identified in Figure 1C. The thickness increases again radially outward of central region CR towards the periphery, as can be seen in Figure 1C. In some

10 particular embodiments central region CR is about 3.75 mm in diameter. The apertures are formed in beveled surface 30.

**[0097]** In some embodiments the thickness of posterior element 20 along the optical axis is between about 0.45 mm and about 0.55 mm and the thickness at the periphery of posterior element 20 is between about 1.0 mm and about 1.3.

15 **[0098]** In some embodiments the thickness of posterior element 20 along the optical axis is about 0.5 mm and the thickness at the periphery of posterior element 20 is about 1.14 mm.

**[0099]** In some embodiments the thickness of anterior element 18 along the optical axis is between about 0.45 mm to about .55 mm, and in some embodiments is between about 0.50 mm to about 0.52 mm. In some embodiments the thickness at the periphery of anterior element 18 is between about 0.15 mm and

20 about 0.4 mm, and in some embodiments is between about 0.19 mm and about 0.38 mm.

**[0100]** In one particular embodiment the thickness of anterior element 18 along the optical axis is about 0.52 mm and the thickness of the periphery of anterior element 18 is about 0.38 mm, and the thickness of posterior element 20 along the optical axis is about 0.5 mm and the thickness at the periphery of posterior element 20 is about 1.14 mm.

25 **[0101]** In one particular embodiment the thickness of anterior element 18 along the optical axis is about 0.5 mm and the thickness of the periphery of anterior element 18 is about 0.3 mm, and the thickness of posterior element 20 along the optical axis is about 0.5 mm and the thickness at the periphery of posterior element 20 is about 1.14 mm.

**[0102]** In one particular embodiment the thickness of anterior element 18 along the optical axis is about 0.51 mm and the thickness of the periphery of anterior element 18 is about 0.24 mm, and the thickness of posterior element 20 along the optical axis is about 0.5 mm and the thickness at the periphery of posterior element 20 is about 1.14 mm.

30 **[0103]** In one particular embodiment the thickness of anterior element 18 along the optical axis is about 0.52 mm and the thickness of the periphery of anterior element 18 is about 0.19 mm, and the thickness of posterior element 20 along the optical axis is about 0.5 mm and the thickness at the periphery of posterior element 20 is about 1.14 mm.

**[0104]** The optic portion is adapted to maintain optical quality throughout accommodation. This ensures that as the accommodating intraocular lens transitions between the dis-accommodated and accommodated

configurations, the optic portion maintains optical quality. A number of factors contribute to this beneficial feature of the accommodating intraocular lenses herein. These factors include the peripheral region at which anterior element 18 is secured to posterior element 20, the shape profile of the anterior element 18 and posterior element 20 inside central region CR of the optic portion (see Figure 1C), and the thickness profiles of anterior element 18 and posterior element 20. These contributing factors ensure that both the anterior and posterior elements flex in such a way as to maintain the shape necessary to maintain optical quality across a range of optical powers.

5 **[0105]** Figure 1F illustrates one haptic 14 from intraocular lens 10 (optic portion 12 and the second haptic not shown for clarity). Haptic 14 includes radially outer portion 13 adapted to face the direction of the zonules, and radially inner portion 11, which faces the periphery of the optic (not shown). Haptic 14 includes a first end region 17 which is secured to optic portion 12, and second end region 19 that is closed. Haptic 14 also includes opening 15 in first end region 17 that provides the fluid communication with the haptic. In this embodiment opening 15 is sized and configured to receive buttress portion 29 of optic portion 12 therein.

10 **[0106]** Figure 1G is a close up view of opening 15 in haptic 14, which is adapted to receive buttress portion 29 therein. The opening 15 has curved surfaces 33 and 35 that are shaped to mate with curved surfaces on the optic buttress 29. Surface 31 surrounds opening 15 and provides a surface to which a corresponding surface of the optic can be secured.

15 **[0107]** Figure 1H is a top close up view of buttress portion 29 (in phantom) from posterior element 20 disposed within opening 15 in haptic 14 (anterior element of the optic not shown for clarity). Channels 32 are shown in phantom. Haptic 14 includes fluid chamber 22 defined by inner surface 21. Fluid moves between the optic fluid chamber and haptic fluid chamber 22 through channels 32 upon the deformation of haptic 14.

20 **[0108]** Figure 2A is a top view showing one haptic 14 shown in Figures 1A-1H. The optic portion and the second haptic are not shown. Four sections A-D are identified through the haptic. Figure 2B illustrates a side view of haptic 14, showing opening 15 and closed end 19. Figure 2C is a side view of haptic 14 showing radially outer portion 13 and closed end 19.

25 **[0109]** Figure 2D is the cross sectional view through section A-A shown in Figure 2A. Of the four sections shown in Figure 2A, section A-A is the section closest to closed end 19. Radially inner portion 11 and radially outer portion 13 are identified. Fluid channel 22 defined by surface 21 is also shown. In this section the radially inner portion 40 is radially thicker (in the direction "T") than radially outer portion 42. Inner portion 40 provides the haptic's stiffness in the anterior-to-posterior direction that more predictably reshapes the capsule in the anterior-to-posterior direction. Radially inner portion 40 has a greatest thickness dimension 41, which is along an axis of symmetry in this cross section. The outer surface of haptic 14 has a generally elliptical configuration in which the greatest height dimension, in the anterior-to-posterior direction ("A-P"), is greater than the greatest thickness dimension (measured in the "T" dimension). The fluid chamber 22 has a general D-shaped configuration, in which the radially inner wall 43 is less curved (but not perfectly linear) than radial outer wall 45. Radially outer portion 42

engages the capsular bag where the zonules attach thereto, whereas the thicker radially portion 40 is disposed adjacent the optic.

**[0110]** Figure 2E illustrates section B-B shown in Figure 2A. Section B-B is substantially the same as section A-A, and Figure 2E provides exemplary dimensions for both sections. Radially inner portion 40 has a greatest thickness along the midline of about .75 mm (in the radial direction "T"). Radially outer portion 42 has a thickness along the midline of about .24 mm. Fluid chamber 22 has a thickness of about .88 mm. Haptic 14 has a thickness along the midline of about 1.87 mm. The height of the haptic in the anterior to posterior dimension is about 2.97 mm. The height of the fluid chamber is about 2.60 mm. In this embodiment the thickness of the radially inner portion 40 is about 3 times the thickness of the radially outer portion 42. In some embodiments the thickness of the radially inner portion 40 is about 2 times the thickness of the radially outer portion 42. In some embodiments the thickness of the radially inner portion 40 is about 2 to about 3 times the thickness of the radially outer portion 42. In some embodiments the thickness of the radially inner portion 40 is about 1 to about 2 times the thickness of the radially outer portion 42.

**[0111]** Fluid chamber 22 is disposed in the radially outer portion of haptic 14. Substantially the entire radially inner region of haptic 14 in this section is bulk material. Since the fluid chamber 22 is defined by surfaces 43 and 45 (see Figure 2D), the positioning and size of fluid chamber 22 depends on the thickness of the radially inner portion 40 and the radially outer portion 42.

**[0112]** Figure 2F illustrates Section C-C shown in Figure 1A. In Section C-C radially inner portion 40 is not as thick as radially inner portion 40 in sections A-A and B-B, although in Section C-C radially inner portion 40 is slightly thicker than radially outer portion 42. In this particular embodiment radially inner portion 40 is about .32 mm in Section C-C. Radially outer portion 42 has a thickness about the same as the radially outer thickness in Sections A-A and B-B, about .24 mm. The outer surface of haptic 14 does not have the same configuration as the outer surface in Sections A-A and Section B-B. In Section C-C the radially inner outer surface of haptic 14 is more linear than in Sections A-A and Section B-B, giving the outer surface of haptic in Section C-C a general D-shape. In Section C-C fluid chamber 22 has a general D-shape, as in Sections A-A and Section B-B. The haptic, in Section C-C has a fluid chamber configuration that is substantially the same as the fluid chamber configurations in Sections A-A and B-B, but has an outer surface with a configuration different than the configuration of the outer surface of haptic 14 in Sections A-A and B-B.

**[0113]** The thinner radially inner portion 40 in Section C-C also creates access pathways 23 that are shown in Figure 1A. This space between optic portion 12 and haptics 14 allows a physician to insert one or more irrigation and/or aspiration devices into space 23 during the procedure and apply suction to remove viscoelastic fluid that may be used in the delivery of the intraocular lens into the eye. The pathways 23 could also be anywhere along the length of the haptic, and there could be more than one pathway 23. This application incorporates by reference the disclosure in Figures 23 and 24, and the textual description thereof, from U.S. Pub. No. 2008/0306588, which include a plurality of pathways in the haptics.

[0114] Figure 2G shows a view through Section D-D from Figure 2A. Haptic 14 includes opening 15 therein, which is adapted to receive the buttress from the optic portion as described herein. The height of opening 15 in this embodiment is about .92 mm. The width, or thickness, of the opening is about 2.12 mm.

5 [0115] Figure 3 illustrates relative diameters of optic portion 12 (not shown) and of the peripheral portion, which includes two haptics 14 (only one haptic is shown). In this embodiment the optic has a diameter of about 6.1 cm, while the entire accommodating intraocular lens, including the peripheral portion, has a diameter of about 9.95 cm. The dimensions provided are not intended to be strictly limiting.

10 [0116] Figure 4 is a top view of haptic 14, showing that haptic 14 subtends an angle of about 175 degrees around optic (i.e., substantially 180 degrees). The optic portion is not shown for clarity. The two haptics therefore each subtend an angle of about 180 degrees around the optic. A first region 61 of haptic 14 is shown to subtend exemplary angle of about 118 degrees. This is the radially outermost portion of haptic 14, is adapted to engage the capsular bag, and is adapted to be most responsive to capsular shape 15 changes. Region 61 can be thought of as the most responsive part of haptic 14.

[0117] The angle between Sections A-A and B-B, which are considered the boundaries of the stiffer radially inner portion of the haptic, is about 40 degrees. The stiff radially inner portion of haptic 14 is positioned directly adjacent the periphery of the optic. The dimensions and angles provided are not intended to be strictly limiting.

20 [0118] Figures 5A and 5B illustrate a portion of accommodating intraocular lens 10 positioned in a capsular bag (“CB”) after a native lens has been removed from the CB. The anterior direction is on top and the posterior direction is on bottom in each figure. Figure 5A shows the accommodating intraocular lens in a lower power, or dis-accommodated, configuration relative to the high power, or accommodated, configuration shown in Figure 5B.

25 [0119] The elastic capsular bag “CB” is connected to zonules “Z,” which are connected to ciliary muscles “CM.” When the ciliary muscles relax, as shown in Figure 5A, the zonules are stretched. This stretching pulls the capsular bag in the generally radially outward direction due to radially outward forces “R” due to the general equatorial connection location between the capsular bag and the zonules. The zonular stretching causes a general elongation and thinning of the capsular bag. When the native lens is 30 still present in the capsular bag, the native lens becomes flatter (in the anterior-to-posterior direction) and taller in the radial direction, which gives the lens less power. Relaxation of the ciliary muscle, as shown in Figure 5A, provides for distance vision. When the ciliary muscles contract, however, as occurs when the eye is attempting to focus on near objects, the radially inner portion of the muscles move radially inward, causing the zonules to slacken. This is illustrated in Figure 5B. The slack in the zonules allows 35 the capsular bag to move towards a generally more curved configuration in which the anterior surface has greater curvature than in the disaccommodated configuration, providing higher power and allowing the eye to focus on near objects. This is generally referred to as “accommodation,” and the lens is said to be in an “accommodated” configuration.

[0120] In section A-A (which is the same as section B-B ) of haptic 14, illustrated in Figures 5A and 5B, radially inner portion 40 includes thicker bulk material that provides haptic 14 with stiffness in the anterior-to-posterior direction. When capsular bag forces are applied to the haptic in the anterior-to-posterior direction, the inner portion 40, due to its stiffness, deforms in a more repeatable and predictable manner making the base state of the lens more predictable. Additionally, the haptic, due to its stiffer inner portion, deforms the capsule in a repeatable way in the anterior-to-posterior direction. Additionally, because the haptic is less flexible along the length of the haptic, the accommodating intraocular lens's base state is more predictable because bending along the length of the haptic is one way in which fluid can be moved into the optic (and thereby changing the power of the lens). Additional advantages realized with the stiffer inner portion are that the haptics are stiffer to other forces such as torqueing and splaying because of the extra bulk in the inner portion.

[0121] The radially outer portion 42 is the portion of the haptic that directly engages the portion of the capsular bag that is connected to the zonules. Outer portion 42 of the haptics is adapted to respond to capsular reshaping forces "R" that are applied generally radially when the zonules relax and stretch. This allows the haptic to deform in response to ciliary muscle related forces (i.e., capsular contraction and relaxation) so that fluid will flow between the haptic and the optic in response to ciliary muscle relaxation and contraction. This is illustrated in Figure 5B. When the ciliary muscles contract (Figure 5B), the peripheral region of the elastic capsular bag reshapes and applies radially inward forces "R" on radially outer portion 42 of haptic 14. The radially outer portion 42 is adapted to deform in response to this capsular reshaping. The deformation decreases the volume of fluid channel 22, which forces fluid from haptic chamber 22 into optic chamber 24. This increases the fluid pressure in optic chamber 42. The increase in fluid pressure causes flexible anterior element 18 and flexible posterior element 20 to deform, increasing in curvature, and thus increasing the power of the intraocular lens.

[0122] The haptic is adapted to be stiffer in the anterior-to-posterior direction than in the radial direction. In this embodiment the radially outer portion 42 of haptic 14 is more flexible (i.e., less stiff) in the radial direction than the stiffer inner portion 40 is in the anterior-to-posterior direction. This is due to the relative thicknesses of outer portion 42 and inner portion 40. The haptic is thus adapted to deform less in response to forces in the anterior-to-posterior direction than to forces in the radial direction. This also causes less fluid to be moved from the haptic into the optic in response to forces in the anterior-to-posterior direction than is moved into the optic in response to forces in the radial direction. The haptic will also deform in a more predictable and repeatable manner due to its stiffer radially inner portion.

[0123] The peripheral portion is thus more sensitive to capsular bag reshaping in the radial direction than to capsular bag reshaping in the anterior-to-posterior direction. The haptics are adapted to deform to a greater extent radially than they are in the anterior-to-posterior direction. The disclosure herein therefore includes a peripheral portion that is less sensitive to capsular forces along a first axis, but is more sensitive to forces along a second axis. In the example above, the peripheral portion is less sensitive along the posterior-to-anterior axis, and is more sensitive in the radial axis.

**[0124]** An exemplary benefit of the peripheral portions described above is that they deform the capsular bag in a repeatable way and yet maintain a high degree of sensitivity to radial forces during accommodation. The peripheral portions described above are stiffer in the anterior-to-posterior direction than in the radial direction.

5    **[0125]** An additional example of capsular forces in the anterior-to-posterior direction is capsular forces on the peripheral portion after the accommodating intraocular lens is positioned in the capsular bag, and after the capsular bag generally undergoes a healing response. The healing response generally causes contraction forces on the haptic in the anterior-to-posterior direction, identified in Figure 5A by forces “A.” These and other post-implant, such as non-accommodating-related, capsular bag reshaping forces  
10 are described in U.S. Application No. 12/685,531, filed January 11, 2010, which is incorporated herein by reference. For example, there is some patient to patient variation in capsular bag size, as is also described in detail in U.S. Application No. 12/685,531, filed January 11, 2010. When an intraocular lens is positioned within a capsular bag, size differences between the capsule and intraocular lens may cause forces to be exerted on one or more portions of the intraocular lens in the anterior-to-posterior direction.

15    **[0126]** In the example of capsular healing forces in the anterior-to-posterior direction, the forces may be able to deform a deformable haptic before any accommodation occurs. This deformation changes the volume of the haptic fluid chamber, causing fluid to flow between the optic fluid chamber and the haptic fluid chambers. This can, in some instances undesirably, shift the base power of the lens. For example, fluid can be forced into the optic upon capsular healing, increasing the power of the accommodating  
20 intraocular lens, and creating a permanent myopic shift for the accommodating intraocular lens. Fluid could also be forced out of the optic and into the haptics, decreasing the power of the accommodating intraocular lens.

**[0127]** As used herein, “radial” need not be limited to exactly orthogonal to the anterior-to-posterior plane, but includes planes that are 45 degrees from the anterior-to-posterior plane.

25    **[0128]** Exemplary fluids are described in U.S. Application No. 12/685,531, filed January 11, 2010, and in U.S. Application No. 13/033,474, filed 2/23/2011, both of which are incorporated herein by reference. For example, the fluid can be a silicone oil that is or is not index-matched with the polymeric materials of the anterior and posterior elements. When using a fluid that is index matched with the bulk material of the optic portion, the entire optic portion acts a single lens whose outer curvature changes with increases  
30 and decreases in fluid pressure in the optic portion.

**[0129]** In the embodiment in Figures 2A-2G above the haptic is a deformable polymeric material that has a substantially uniform composition in Sections A-A, B-B, and C-C. The stiffer radially inner body portion 40 is attributed to its thickness. In alternative embodiments the radially inner body portion has a different composition than the outer body portion, wherein the radially inner body portion material is  
35 stiffer than the material of the radially outer body portion. In these alternative embodiments the thicknesses of the radially inner and outer portions can be the same.

**[0130]** Figure 6 illustrates haptic 50, which is the same haptic configuration as in shown in Figure 2B. The radially outer portion 54 is identified. The haptic has axis “A” halfway through the height of the

haptic, or alternatively stated, axis A passes through the midpoint of the height of the haptic in the anterior-to-posterior direction. Opening 52, in which the optic buttress is disposed, is on the posterior side of axis A. In this embodiment the optic sits slightly closer to the posterior-most portion of the haptics than the anterior-most portion of the haptics. That is, in this embodiment the optic is not centered 5 with the haptics in the anterior-to-posterior direction.

[0131] Figure 7 illustrates an alternative haptic 60 (optic not shown), wherein the radially outer portion 64 is identified. Haptic 60 includes axis “A” halfway through the thickness of the haptic, or alternatively stated, axis A passes through the midpoint of the height of the haptic in the anterior-to-posterior direction. Opening 62 is symmetrical about the axis A, and an axis passing through the midpoint of opening 62 is 10 aligned with axis A. Additionally, axis A is an axis of symmetry for haptic 60. The symmetry of the haptic along axis A can improve the ability to mold low relatively low stress components. Figure 8 shows an embodiment of intraocular lens 70 in which the optic 72 is coupled to two haptics 60, which are the haptics shown in Figure 7. The optic sits further in the anterior direction than in the embodiment in which the opening is not along the midline of the haptic. In this embodiment, optic 72 is centered, in the 15 anterior-to-posterior direction, with the haptics. The cross sections A-A, B-B, and C-C of haptic 60 are the same as those shown in other embodiments shown above, but the haptics can have any alternative configuration as well.

[0132] Figure 9 illustrates intraocular lens 80 including optic 82 and two haptics 84. The optic is the same as the optic portions described herein. Haptics 84 are not as tall, measured in the anterior-to-posterior direction, as haptic 60, haptic 50, or haptic 14. In exemplary embodiments haptics 84 are 20 between about 2.0 mm and about 3.5 mm tall, and in some embodiments they are about 2.8 mm tall. Intraocular lens 80 can be considered a size “small” accommodating intraocular lens for patients with a capsular bag that is below a certain threshold size. The posterior surface of posterior element 86 is disposed slightly further in the posterior direction than the posterior-most portions 90 of haptics 84.

[0133] Figure 10 illustrates an accommodating intraocular lens 98 that includes an optic body 100 and a peripheral non-optic body, which in this embodiment includes haptics 160 and 180. Optic body 100 can be in fluid communication with one or both haptics 160 and 180, and fluid movement between the optic and haptics in response to ciliary muscle movement can change the power of the intraocular lens. This general process of fluid-driven accommodation in response to deformation of the haptics can be 25 found herein. Optic 100 includes anterior element 120 secured to posterior element 140, together defining an optic fluid chamber in communication with haptic fluid chambers 170 and 190 in the haptics. The “height” of the components in this disclosure is measured in the anterior-to-posterior direction. Optic 100 has a greatest height “H1” dimension measured in the anterior to posterior direction along the optic axis. Haptics 160 and 180 have greatest height “H2” dimensions measured in the anterior to posterior 30 direction parallel to the optical axis. The optic body has a centerline B, measured perpendicular to the optical axis and passing through the midpoint of H1. The haptics also have centerlines, B, measured perpendicular to the optical axis and passing through the midpoint of H2. In this embodiment the centerlines coincide and are the same centerline B. Stated alternatively, the anterior-most surface or point

of anterior element 120 is spaced from the anterior-most point or surface of the haptics the same distance as is the posterior-most surface or point of posterior element 140 from the posterior-most point or surface of the haptics. They can be considered substantially the same lines in some embodiments even if they do not coincide, but are near in space to one another (e.g., a few millimeters away). An optic centered with 5 the haptics is also shown in figure 8.

[0134] In this embodiment the position of the optic 100 relative to the haptics can provide some benefits. For example, during folding and/or insertion, the centered (or substantially centered) optic, measured in the anterior-to-posterior direction, can prevent or reduce the likelihood of one or more haptics from folding over the anterior element 120 or posterior element 140, which may happen when the 10 optic body is not substantially centered relative to the haptics. For example, an optic that is much closer to the posterior side of the lens may increase the likelihood that a haptic (e.g., a haptic free end) can fold over the anterior surface of the optic during deformation, loading, or implantation.

[0135] An additional benefit to having the optic body 100 centered or substantially centered relative to the peripheral body is that it is easier for the optic to pass through the capsulorhexis when placed in the 15 eye. When the optic is closer to the posterior side of the lens, it may be more difficult for it to rotate into the capsular bag.

[0136] An additional benefit is that, compared to optics that are further in the posterior direction, glare from the intraocular lens is reduced. By moving the optic in the anterior direction (it will be closer to the iris once implanted), less light can reflect off of the radially outer peripheral edge of the optic (i.e., 20 the edge surface adjacent the haptics), thus reducing glare from edge effect.

[0137] In some embodiments of the intraocular lens in Figure 10, anterior element 120 can have a height between 0.2mm and 0.35mm, such as between .25mm and .30mm, such as about 0.28mm, and the posterior element 140 can have a height between 0.36mm and 0.50mm, such as between .40mm and .45mm, such as about 0.43mm.

[0138] Prior to insertion, such as during manufacturing, the intraocular lens shown in Figure 10 can 25 be filled with fluid. In some embodiments the intraocular lens has a base state (at zero fluid pressure in the optic; or no fluid inside it) less than 15D, such as about 13D. About 13D, as used herein, refers to base states about 10D to about 15D. By having a base state of about 13D, it may be possible to generally only have to change the fluid pressure in one direction – higher. When the base state of an intraocular 30 lens is higher, such as about 20D, it may be necessary to change the fluid pressure either higher or lower, depending on the desired vision correction and the intended use of the intraocular lens. By having a lower base state, the changes to the state of the lens become more predictable by only having to change the base state in one direction.

[0139] One aspect of this disclosure is an accommodating intraocular lens, optionally fluid-filled and 35 fluid-driven, that has an aspheric optical surface after manufacture and prior to implantation. That is, the intraocular lens is manufactured with an aspheric optical surface. An aspheric optical surface can avoid spherical aberration when the pupil is fully dilated. There can be challenges in manufacturing an

intraocular lens, particularly an accommodating, fluid-driven intraocular lens, with aspheric optical surfaces.

**[0140]** In some embodiments the accommodating intraocular lens is manufactured with an aspheric anterior surface and/or an aspheric posterior surface. One exemplary manner in which a fluid-filled

5 accommodating intraocular lens can have an anterior or posterior optical surface with built-in asphericity is to, during manufacturing, create the optical surface with a spherical configuration prior to fluid filling, then create the asphericity in the optical surface during the fill process. For example, during manufacture, one or both of the anterior surface and the posterior surface can be manufactured to have spherical outer optical surfaces. The anterior surface can then be secured to the posterior surface. One or more haptics  
10 can then be secured to the optic. In some embodiments the optic is manufactured, but prior to filling, to have a base state (at zero fluid pressure in the optic; or no fluid inside it) less than 15D, such as about 13D. About 13D, as used herein, refers to base states about 10D to about 15D. When a fluid is injected into the accommodating intraocular lens (e.g., via a septum), the fluid filling step can increase the fluid pressure in the optic and cause the anterior surface and/or the posterior surface of the optic to have an  
15 aspherical configuration. One aspect of this disclosure is thus a method of manufacturing an accommodating intraocular lens that includes creating an optic with a fluid-filled state prior to insertion, which has asphericity built into one or more optical surfaces, such as an anterior optic surface. The method of manufacturing can include manufacturing the optic wherein the optical surface is spherical prior to fluid filling.

20 **[0141]** It may be desirable to maintain good optical quality in at least one surface of the central portion of the optic as it is deformed, either throughout disaccommodation or throughout accommodation. One of the aspects of the disclosure is an optic that has a very controlled and somewhat stable amount of asphericity in a central region of the optic, across the whole range of powers. This may be referred to herein as “beneficial asphericity” in a central region of the optic. The beneficial asphericity includes lens  
25 surfaces with surface aberrations that are configured to compensate for the spherical aberrations in the optical system of the eye, and contribute to maintaining optical quality. The beneficial asphericity is maintained across all or substantially all of the range of powers during accommodation and disaccommodation. In some instances the asphericity can be controlled such that the spherical aberration of the whole lens systems can remain low (or zero) across all range of power. The optic region outside  
30 of the central region may have larger, more uncontrolled amount of asphericity.

**[0142]** In some embodiments the central region of the optic, or the region of beneficial asphericity, has a diameter of less than 6.5mm, less than 6.0mm, less than 5.5mm, less than 5.0mm, less than 4.5mm, less than 4.0mm, less than 3.5mm, or even less than 3.0mm. In some embodiments the central region has a diameter between 3.5mm and 5.5mm. In some embodiments the central region of the optic with  
35 beneficial asphericity has a diameter less than 90% of the diameter of the optic body, less than 85%, less than 80%, or less than 75%. The diameter of the optic can be between 4mm and 8mm, such as between 5mm and 7mm. In some embodiments the central region is between 4mm and 5mm, and the optic

diameter is between 5mm and 7mm. In some embodiments the central region is between 4.25mm and 4.75mm, and the optic diameter is between 5.75mm and 6.25mm.

**[0143]** The configuration of the anterior element and the posterior element can influence the configurations that they assume throughout deformation, either throughout accommodation or 5 throughout disaccommodation. In some embodiments, one or both of the anterior element and the posterior element is contoured, or configured, such that the central region of the optic has the beneficial asphericity that is controlled and beneficial to the overall system of the eye. In this embodiment anterior element 120, and to a lesser extent posterior element 140, are configured so that an anterior surface of anterior element 120 and a posterior surface of posterior element 140 maintain the controlled, beneficial asphericity in a central 10 region of the optic during accommodation. In this embodiment one aspect of the configuration that contributes to the central portion maintaining beneficial asphericity is that anterior element 120, and optionally the posterior element 140, has a thickness (also referred to as “height” herein) that is greater in the center (such as at the apex of the anterior element 120) than at the periphery of the anterior element 120. An additional aspect of the configuration that contributes to beneficial asphericity is that the 15 anterior element is flatter on the inner surface (posterior surface) than on the outer surface (anterior surface). During accommodation, the central region of the anterior element 120 steepens in the center (which increases power of the AIOL), but the optic body maintains its beneficial asphericity, due at least in part to the relatively larger thickness of the anterior element central region. It may also be aspherical prior to accommodating in the exemplary embodiments in which asphericity is built into the anterior 20 element, described below.

**[0144]** The thickness contours of the anterior and posterior elements can contribute to the optic maintaining the beneficial asphericity across all powers, an example of which is the thickness of the anterior and posterior elements.

**[0145]** Figure 11 illustrates an exemplary haptic that can be part of any of the accommodating 25 intraocular lenses herein or other suitable IOLs not described herein. One or both haptics can be configured as shown in Figure 11. The haptic in Figure 11 is labeled as “160,” but it is understood that the haptic in Figure 11 can be a part of intraocular lenses other than that shown in Figure 10. The haptic includes a surface 220 that is secured to an outer edge of the optic body. Surface 220 is a radially inner 30 surface of the haptic, and is configured with a slight curve to it (along the length of the haptic) that is substantially the same curve as the outer edge of the optic so that the entire surface 220 interfaces the optic body outer edge surface(s). Surface 220 has a configuration relative to the optic such that an extension of the surface does not pass through an optic axis of the optic. An adhesive can be used to 35 secure surface 220 to the optic outer edge surface(s). In this embodiment the coupling between the haptic and the optic body does not include one of the haptic and optic being disposed within a channel, bore, or aperture in the other, as can be used for some haptic/optic coupling designs, such as in the embodiment shown in figures 1A-9. Some exemplary advantages of this type of design are described below.

**[0146]** Figure 12 shows a perspective view of optic 100, with the haptics excluded for clarity. Surface 220 of the haptic (not shown) is secured to both anterior element 120 and posterior element 140

of the optic body 100. Most of surface 220 interfaces posterior portion 140, but a portion of surface 220 interfaces anterior element 120. This is because the outer edge of the optic body is largely comprised of the posterior element 140. With different optic configurations, surface 220 could be secured to more of the anterior element than the posterior element. It is also noted that the height H3 of surface 220 (see

5 Figure 11) is substantially the same as the height of the outer edge of the optic body.

[0147] Haptic 160 surface 220 has a first end region 230 (see Figure 11) that has a configuration with a larger surface than second end region 250. End region 230 of surface 220 has a larger surface area than end region 250 of surface 220, and includes at least partially beveled surfaces B, as shown in figure 13. The width W1 of end region 230 is greater than width W2 of end region 250. The configuration of 10 end region 230 can provide exemplary benefits. For example, as part of a process of loading the intraocular lens into a delivery device and/or into an eye of a patient, one or both of haptics 160 and 180 may be “splayed” relative to optic. That is, one or both haptics can be reconfigured from the natural at rest configuration shown in Figures 10-14 by moving free end 170 of haptic away from the optic body. The extent to which the free end (and a large portion of the haptic) is moved away from the optic during 15 splaying can vary. In some methods of loading, one of both haptics can be splayed substantially, such that the haptic is oriented behind or in front of the optic. In some instances the haptic free end (i.e., the end of the haptic not coupled directly to the optic) is “pointing” substantially 180 degrees from where it is pointing in the at-rest configuration. In general, splaying the haptic(s) causes stresses at the coupling interface between the haptic and optic. The coupling interface between the optic and haptic must be able 20 to withstand these forces so that the haptic does not disengage from the optic. When splaying haptics, there can be a high stress location at the optic/haptic coupling at the end of the interface 230, which is closer to the free end. End region 230 is thus the location where the haptic / optic interface is most likely to fail. End region 230, with its larger surface area and tapering and beveled configuration, acts to 25 distribute the applying stresses (or stresses anytime haptic is reoriented relative to the optic) and prevent the haptic from disengaging from the optic.

[0148] The configuration of surface 220 can be modified in many ways to provide the desired joinery between the haptic and the optic. Joining the haptic and the optic in this manner (as opposed to having one component fit within the other) thus allows for many more interface configurations, which provides more flexibility in design.

30 [0149] In the embodiment of the haptic in Figure 11, fluid aperture 240 is centered along the midline of the haptic. The centerline is defined in the same manner as described in Figure 10. The centerline passes through the midpoint of the haptic height (measured in an anterior-to-posterior direction) in a side view of the haptic.

[0150] Other aspects of the haptic can be the same as described herein, such as a thicker radially 35 inner wall thickness along a portion of the haptic, and one or both haptics that follows the curvature of the periphery of the optic from the coupled end to the free end, and the anterior most aspect of the haptic extending further anteriorly than the anterior-most aspect of the optic.

[0151] The posterior element 140 has two fluid channels 210 therein that are in fluid communication with the haptic fluid chambers 170 and 190. The outer edge of the posterior element 140 includes two apertures therein that define ends of the fluid channels 210. The haptic/optic interface (which can be a glue joint) surrounds the two fluid apertures in the posterior element 140. In some alternatives the optic 5 only has one fluid channel instead of two.

[0152] Figure 13 is another view of haptic 160, showing the slight curvature of optic interface surface 220 and fluid aperture 240 therein.

[0153] Figure 14 is a perspective view of the intraocular lens from Figure 10, viewed from the posterior side. Fluid channels 210 can be seen in the posterior element 140, two of which are associated 10 with each haptic. The interface between the haptics and optic can also be seen. Figure 14 shows section A-A that is shown in Figure 10.

[0154] Figure 15 shows an additional view of the intraocular lens from Figure 10, in which spacings 292 between the outer edge of optic and haptics can be seen, as well as the coupling between the optic and haptics.

[0155] In some embodiments in which one or more haptics are adhered to the optic body at discrete 15 locations, rather than 180 degrees around the optic, a curing step that cures an adhesive that secures the haptic to the optic body may cause shrinkage of the material at the location where the two components are adhered. This shrinkage at the discrete locations can cause distortions in the lens, such as astigmatism. It can be beneficial, or necessary, to prevent or reduce the extent of the distortions. Figure 16 illustrates an 20 exploded perspective view of alternative accommodating intraocular lens 300. Figure 17 illustrates a top view of AIOL 300. Figure 18 illustrates a perspective view of option 301 of AIOL 300. Figure 19 is a view of section A-A shown in figures 17.

[0156] Figures 16-18 illustrate an exemplary interface between an exemplary optic body 301 (see 25 figure 18) and haptics 310 that may help alleviate distortions due to shrinkage at the location where the optic body and haptics are secured. The interface between the optic body 301 and the haptics 310 is relocated radially away from the optic body 301, and specifically the optical surfaces, compared to other embodiments such as in figures 10-15. By moving the interface, and thus the location of potential shrinkage, away from the optical surfaces, the amount of distortion caused to the optical surfaces by the curing step can be reduced. A coupling region 311 of haptics 310 each interface with an optic projection 303, such that the interface between the haptics and the projection 303 is radially away from the optical 30 303, such that the interface between the haptics and the projection 303 is radially away from the optical surface of the optic. This type of interface can be used with non-accommodating or accommodating intraocular lenses, but in this embodiment the lens is an accommodating intraocular lens.

[0157] For example, the accommodating intraocular lens 300 can comprise the optic body 301 (see 35 figure 18), and haptics 310. In this embodiment, haptics 310 are manufactured separately from the optic 310, and then secured to the optic 310. The haptics 310 each include a radially inner flat surface 312 (only one labeled in figure 16) that is secured to a radially peripheral surface 306 of the optic 310. In this embodiment surface 312 is a radially inner surface of the coupling region 311 of haptic 310. For example, an adhesive can be used to secure surface 312 to the radially peripheral surface 306 of the optic

310. The process of securing the haptic to the optic may affect the optical performance of the optic 70, as discussed above. For example, the curing process of the adhesive may cause shrinkage of the optic 301 at two discrete locations, thus possibly resulting in distortion and aberration such as astigmatism of the intraocular lens.

5 [0158] In this embodiment, the intraocular lens comprises two projections 303 extending radially outwards away from a peripheral surface 309 of the posterior element 304 of optic 301. The projections 303 can be thought of as projections from the general curved periphery of the optic, as defined by outer edge surface 309. The haptics 310 can each have a first portion 311 secured to the projection 303 and a free second portion 315 disposed away from the first portion 311, wherein a radially inner surface of each 10 of the haptics follows a radially outer peripheral surface of the optic. Projection 303 may also be referred to herein as a “landing” or “land” in this disclosure.

[0159] Projections 303 can be raised areas extending between 10 microns and 1 mm, optionally between 10 microns and 500 microns, radially outward from the periphery surface 309 of the optic. The radially peripheral surface 306 of the projections 303 can be between 10 microns and 1 mm, optionally 15 between 10 microns and 500 microns, farther away radially from a center of the optic than the peripheral surface 309 of the optic. For example, projections 303 can be a raised area extending between 100 microns and 200 microns radially outward from the periphery surface 309 of the optic. The radially outer peripheral surface 305 of projection 303 may be between 100 microns and 200 microns farther away 20 radially from a center of the optic than the peripheral surface 309 of the optic. Values outside the above range are also possible. Projections 303 can move the securing surfaces or coupling surfaces away from the optic to prevent optic disruption due to shrinkage when curing the adhesive between the optic and the haptic.

[0160] In some embodiments the optic has a circular shape, in a top view, and the radially outer peripheral edge 309 of the optic is generally circular. When the projections are described herein as 25 extending radially away from the optic body, the projections may be extending away from the general curve of the radially outer peripheral edge of the optic.

[0161] In some embodiments, the optic and the projections 303 of the intraocular lens can be a single integral body. For example, projections 303 can be molded as part of the optic. In some other 30 embodiments, projections 303 can be attached to the optic, such as by gluing.

[0162] In some embodiments the optic 301 comprises a posterior element and an anterior element, 35 optionally defining a fluid chamber therebetween, such as in embodiments above. For example, projections 303 can be part of the posterior element because the posterior has a thicker periphery. The projections may also be part of the anterior element. For yet another example, the projections can be part of the posterior element and anterior element of the optic.

[0163] Outer surfaces 306 of projections 303 and inner surfaces 312 of haptics 310 can all be flat, such that they interface at a butt joint. For example, the radially outer peripheral surface 306 of 40 projections 303 can comprise a flat surface, optionally entirely flat. The radially inner surface 312 of haptics 310 can comprise a flat surface as well, optionally entirely flat. For another example, the radially

outer peripheral surface 306 of projections 303 can comprise a curved surface, optionally entirely curved. The radially inner surface 312 of haptics 310 can comprise a curved surface as well, optionally entirely curved. A curvature of radially outer peripheral surface 306 can be the same as the curvature of the periphery surface 309 of the optic body, and in some embodiments can be larger or smaller than the curvature of the periphery surface 309 of the optic body.

5 [0164] Haptics 310 can comprise a peripheral fluid chamber as described herein. The projections 303 can comprise at least one fluid channel 308, and optionally at least two channels, in fluid communication with the peripheral fluid chamber in the haptics. The raised projections 303 may provide more stability to the fluid channel because there is more optic material at the locations of the projections.

10 [0165] In general, the projection can be disposed on a non-accommodating (fixed power) intraocular lens that is manufactured by coupling haptics and optic as well. For example, a fixed power intraocular lens, where the intraocular lens is a non-fluid filled optic body with a single power (e.g., PMMA material) and two haptics, can comprise a projection extending radially outwards from a peripheral surface of the optic body as well.

15 [0166] The embodiment in figures 16-19 also illustrate an alternative haptic cross sectional configuration (see figure 19 for the cross section) that can be incorporated into any of the suitable optics herein, such as optic 100 shown in figure 10. The height H (measured in anterior to posterior direction) of haptics 310 can be from 2mm -2.5mm, and may be 2.1mm to 2.4mm. This may be smaller than other haptic heights for other intraocular lenses, such as heights above 3mm. It may be advantageous, but not 20 necessarily necessary, to have heights between 2 and 2.5mm for the haptics. There is some patient to patient variability in the size of the anatomy in the eye. There is variability in capsular size, for example, or distance between capsule and the posterior side of the iris. With some haptics, there may be some rubbing between the haptic and the posterior side of the iris. And even if there is, it may not raise any concerns. It may thus be advantageous, merely in an abundance of caution, to have haptics heights that 25 minimize the chance of such rubbing.

30 [0167] Haptics 310 also include a radially inner wall portion 313 on the radially inner side of fluid chamber 316, which has a thickness “ $t_i$ ” that is greater than a thickness “ $t_o$ ” of the haptic wall on the radially outer side of chamber 316. In some embodiments “ $t_i$ ” is between four and nine times greater than “ $t_o$ .” Radially inner wall portion 313 may be referred to herein as a “spacer.” As shown in figure 16, the spacer extends along almost the entire length of haptic, but does not exist where the spacing exists between the optic and haptic. The fluid chamber 316 radially inner wall is, as shown, flatter than fluid chamber 316 radially outer wall. Haptics 310 are examples of haptics that have a cross section, in a plane passing through an optical axis of the optic portion, in which the haptic fluid chamber is disposed in a radially outer portion of the haptic, and wherein a radially inner portion of the haptic is non-fluid.

35 Haptics 310 are examples of haptics that, in a cross section of a plane passing through an optical axis of the optic portion, and in a direction orthogonal to an optical axis of the optic portion through a midpoint of the haptic, have a radially inner fluid chamber wall thickness that is between four and 10 times the thickness of a radially outer fluid chamber wall thickness. Haptics 310 are examples of haptics that, in a

cross section of a plane passing through an optical axis of the optic portion, has an outer surface that is not symmetrical about any axis passing through the peripheral portion and parallel to an optical axis of the optic portion, and wherein the haptic has, in a direction orthogonal to an optical axis of the optic portion through a midpoint of the haptic has a radially inner fluid chamber wall thickness greater than a radially outer fluid chamber wall thickness. Haptics 310 are examples of haptics that, in a cross section of a plane passing through an optical axis of the optic portion, having a height dimension measured in an anterior to posterior direction, wherein the greatest height of the peripheral portion in a radially outer half of the peripheral portion is greater than the greatest height of the peripheral portion in a radially inner half of the peripheral portion.

5 [0168] In some embodiments one or more aspects of the optic body have a refractive index that is between about 1.48 and 1.55, such as between 1.50 and 1.53. In some embodiments the refractive index of one or components is about 1.48, about 1.49, about 1.50, about 1.51, about 1.52, about 1.53, about 10 1.54, or about 1.55. There may be a designed mismatch in refractive index between any of the anterior element, fluid, and posterior element, but in some embodiments there is a designed index matching

15 between at least two of the components, and optionally all three. When all components of the optic are designed to have the same or substantially the same index of refraction, they are said to be index-matched. Any of the properties of the intraocular lenses (e.g., refractive index, fluid, monomer compositions) described in U.S. Prov. App. No. 62/173,877, filed June 10, 2015 can be implemented in any of the intraocular lens designs herein.

20 [0169] Exemplary materials that can be used to make any of the IOLs, including fluid, herein, can be found in PCT/US2016/037055, fully incorporated by reference herein.

[0170] As described in some embodiments above, the accommodating intraocular lens can include first and second haptics that are adhered to the optic, and optionally about 180 degrees from one another around the optic. During lens formation, the haptics are adhered, or glued, to the optic, with an adhesive.

25 The haptic/optic adhesion is important for a variety of reasons. The haptics are deformed away from the optic, or splayed, during loading and delivery. It may be beneficial to have a relatively softer adhesion joint between the optic and haptic to help with the deformation of the haptic. If the haptic/optic joint is too rigid, it may be difficult to deform the haptic or the haptic/optic joint during loading and/or delivery.

Secondly, the haptics are joined to the optic at two discrete locations around the optic. That is, the joint

30 between the haptic and optic does not extend all the way around the optic. This creates an opportunity for the haptic/optic coupling to interfere with the desired optical quality of the optic. For example, during curing of an adhesive used to adhere the optic to the haptic, the adhesive can shrink and disrupt optical quality of the optic, such as by creating an astigmatism in the optic. To the contrary, it may not be as important to use a low modulus adhesive for adhering the anterior element and the posterior element in

35 the optic, since that joint is annular, and shrinkage will not occur at discrete locations, like with the haptic/optic coupling. In fact, it has been shown that optical quality of the optic can be improved as a consequence of having a relatively rigid adhesion ring joining the anterior and posterior elements of the

optic. For at least these two reasons, in some embodiments the adhesive for the haptic/optic joint may be a relatively low modulus adhesive.

[0171] As set forth above, the adhesives used can include a CLP as a first primary component and a reactive acrylic monomer diluent (e.g., ADMA) as a second primary component, and can also include a 5 third component. In general, as the CLP percentage goes up, the amount of shrinkage during curing goes down. It can thus be beneficial to increase the amount of the CLP in an adhesive when used for securing at least components together in which it is desirable to reduce the amount of shrinkage that occurs, such as with a haptic/optic joint. In some of the embodiments above the second primary component (e.g., ADMA) is present in amount of about 18% to about 43%. While the adhesives in those examples could 10 be used for the haptic/optic adhesive, some adhesive on the higher end of that range may be better suited for the optic joint between the anterior and posterior elements, which there is less concern for the shrinkage occurring all the way around the optic rather than at discrete locations.

[0172] In some embodiments, the adhesive for a haptic/optic coupling has a greater percentage of a CLP than the optic adhesive (between the anterior and posterior elements). Similarly, in some 15 embodiments the adhesive for the haptic/optic coupling has less of a reactive acrylic monomer diluent (e.g., ADMA) than the optic adhesive. In some embodiments the adhesive for the haptic/optic coupling has about 5-35%, such as 10-30%, or 15-25%, of the reactive acrylic monomer diluent (e.g., ADMA). The CLP can be about 50-85% of the adhesive. A third component, such as laurel methacrylate, can also be included to increase strength, flexibility, and provide low shrinkage. Laurel methacrylate is an 20 example of a material with a low modulus, low shrinkage, and has similarly low diffusion characteristics as the reactive acrylic monomer diluent (e.g., ADMA). This helps make the bonds between the haptic and optic softer. In some embodiments securing the haptics to the optic creates no more than a +/- .3D change in the optic during manufacturing.

[0173] Table 1 lists some exemplary adhesives that can be used, for example, as adhesives for the 25 haptic/optic coupling. Each example also includes 2.3% of a photoinitiator, such as Darocur 4265. SR 313 is lauryl methacrylate, and provides water resistance, weatherability, impact strength, flexibility, and low shrinkage, and other advantage described herein. Exemplary shrinkages are provided for some examples.

**Table 1**

				DMA @ 35°C		DMA @ 20°C		Viscosity 40°C	E' at 20C (MPa)	E' at 35C (MPa)	Shrinkage %
Adhesive	CLP-1.5%F	ADMA	SR 313	0.1 Hz	1.0 Hz	0.1 Hz	1.0 Hz				
Gen 0-(65:35) (1:0)	63.50	34.20	0.00	229	400	347	750	28000	495.7	245.2	1.84
SH11743-B-(70:30) (1:0)	68.39	29.31	0.00	n/a	140	n/a	380				
X8-(63.5:36.5) (2:1)	63.51	22.80	11.40	37	75	61	200				
X5-(68.4:31.6) (3:1)	68.39	22.00	7.31	52	90	85	220				
X4-(67.5:32.5) (2:1)	67.50	20.13	10.07	29	55	53	180	21233	120.8	45.7	1.52
X7-(73.3:26.7) (2:1)	73.28	16.28	8.14	14	30	26	100				
X2-(67.5:32.5) (1:1)	67.50	15.10	15.10	4	9	7	55	16471	16.6	3.1	
X6-(78.2:21.8) (2:1)	78.16	13.03	6.51	5	15	10	55				
X3-(67.5:32.5) (1:2)	67.50	10.07	20.13	1	3	n/a	11	13011	4.0	45.7	

5 [0174] In some alternative to the some embodiments above, the optic adhesive includes, in addition the CLP, HEA rather than HEMA.

[0175] The disclosure now includes a description of exemplary intraocular lenses that may help reduce posterior capsule opacification (“PCO”). Posterior capsule opacification (PCO) may be a major long-term complication of successful cataract surgery with some intraocular lens (IOL) implantation. The 10 residual lens epithelial cells (LECs) can proliferate and migrate from the peripheral posterior capsular bag into the space between the capsule and the optic of the intraocular ocular lens (IOL). This phenomenon can lead to PCO and decreased visual acuity.

[0176] Some accommodating intraocular lenses, for example, the accommodating intraocular lenses described above, have been demonstrated to have the ability to reduce or delay PCO. For example, haptics described above can fill the peripheral capsular bag and likely reduce LECs proliferation by tight contact with the capsule bag. However, this contact may not occur for the entire 360° around the capsule, and there may be gaps between the distal end tip of one haptic and the other haptic, or there may be gaps between the optic and the interior of the haptic adjacent the optic/haptic coupling location.

5 [0177] There may be, in some situations, advantages for peripheral portions of intraocular lenses to be configured and adapted to further reduce the PCO effect to increase visual acuity.

10 [0178] Figure 17 shows a top view of an exemplary intraocular lens, in which the spacing between the optic and haptics can be seen, as well as the coupling between the optic and haptics.

15 [0179] As shown in Figure 17, though the haptics 310 can substantially fill the peripheral capsular bag and likely reduce or prevent cellular proliferation by tight contact with the capsular bag, this contact is not entire 360° around the capsule. There are small gaps between the distal end tips 315 of the haptics and the proximal ends of the optic haptic. The residual LECs can proliferate and migrate from the peripheral capsular bag, such as from the equatorial region, into the space between the capsule and the optic of IOL. LECs growth through the gap can be observed, which can lead to PCO and decreased visual acuity. In addition, LECs have been observed in the space between the optic and the interior haptic adjacent to the location wherein the haptic couples to the optic.

20 [0180] Figure 20 is a top view illustrating an exemplary IOL comprising one or more blunt tips 37 and 39 of the haptics. One or both of the tip of a first haptic and the proximal end of the second haptic can be configured to more closely fit together and reduce or eliminate the gap between the free end tip 37 of first haptic 36 and the proximal end of the second haptic 38, and the gap between the free end tip 39 of second haptic 38 and the proximal end of the first haptic 36. The blunt 90° tips 37, 39 can reduce the gaps and reduce PCO effect by preventing or reducing cell migration and proliferation.

25 [0181] In some embodiments the distal tip of a first haptic can overlay, or overlap (in a top view), the proximal portion of the second haptic to reduce or eliminate the gap. For example, the distal tip of a first haptic can be tapered to overlay the second haptic. The free end of the second haptic can also be overlay (e.g., tapered) to overlay the first haptic to reduce or eliminate the gap. The proximal ends of both of these exemplary haptics are tapered towards the coupling location with the optic, so the distal ends of the adjacent haptic can similarly be tapered (such as with a complimentary taper) to form the overlapping regions of first and second haptics. Since the IOL is dialed clockwise, the proximal end can be configured to have a taper while the distal tip can be configured with a variety of shapes. In some other embodiments the distal tips can further comprise a radial barrier to prevent circular migration of LECs which can contribute to LECs growth in the gap.

30 [0182] Figure 21 illustrate a section view of an exemplary IOL with one or more circumferential ridges (e.g., 46a, 46b, 48a, and 48b) on the haptics 46 and 48. Only a section of the ridges are shown, but the ridges extend along at least a portion of the length of the haptics. The haptic / bag contact can be improved with the one or more circumferential ridges (e.g., 46a, 46b, 48a, and 48b) having sharp edges

(i.e., not smooth). For example, the one or more ridges 46a, 46b with sharp edges can extend along at least a portion of the length of and on an outer surface of the haptics 46. The ridge 46a can be disposed on a top surface of the haptic 46 while the ridge 46b can be disposed on a bottom surface of the haptic 46. Similarly, the one or more ridges 48a, 48b with sharp edges can extend along at least a portion of the 5 length of and on an outer surface of the haptics 48. The ridge 48a can be disposed on a top surface of the haptic 48 while the ridge 48b can be disposed on a bottom surface of the haptic 48. In this exemplary embodiment, the “top” is considered the anterior portion and the “bottom” is the posterior portion. Axis (or plane) B-B is considered to divide the IOL between anterior and posterior sides, and axis or plane B 10 can be considered to pass through the “equator” of the haptics (which are generally aligned with the equator of the capsular bag). For example, ridges 48a and 46a are disposed on the anterior side of the haptics, and ridges 46b and 48b are disposed on the posterior side of the haptics.

**[0183]** The ridges (e.g., 46a, 46b, 48a, and 48b) on the haptics 46, 48 can have cross sections with sharp edges, such as square edges. It has been found that square-edged optics can reduce the incidence of PCO effect following cataract surgery. It has been shown in earlier attempts, dating back to the early 15 1990s, that square-edged optics have reduced PCO development. Discontinuous capsular bend may be an important factor for the PCO prevention effect. In general, the proliferating LECs start from the equator and divide and migrate toward the center. The ridges (e.g., 46a, 46b, 48a, and 48b) on the haptics 46 or 48 can create barriers to LECs movement by creating capsular bends, thus creating a square edge effect. Therefore, LECs migration can be significantly reduced or eliminated by one or more of the ridges.

**[0184]** Figure 22 is a bottom (posterior) view of an exemplary IOL, illustrating ridges 46b and 48b of the two haptics (from figure 21), both ridges labeled “R” in figure 22. In figure 22, the ridges extend along the entire length of both haptics, but in some embodiments they do not extend along the entire 20 length. For example, in some embodiments the ridges may extend along at least 75%, 80%, 85%, 90%, or 95% of the length of the haptic. The length of the haptic is measured along an equator of the haptic, from 25 the coupling location with the optic, to the distal free end. The length of the haptic is thus generally measured along a curved line. The length of the haptic, may be, in some cases, considered a straight line measured as the shortest distance from the optic coupling location to the distal free end.

**[0185]** The ridges (e.g., 46a, 46b, 48a, and 48b) can extend along at least a portion of the length of the peripheral portion of the IOL. The peripheral portion can include one or more haptics, for example, 46 30 and 48, but the IOL may include more or less than two haptics. For example, the IOL may have a single annular peripheral portion with one or more ridges. The IOL could also have, for example, four haptics each its own coupling to the optic, wherein one or more of the four haptics includes one or more ridges.

**[0186]** The ridges (e.g., 46a, 46b, 48a, and 48b) can create “square edge effect” although the ridges 35 may not need to be square. A triangular ridge may suffice. However, other shapes with at least one sharp edge can work as well. The phrase “sharp edge” as used herein refers to an edge that is not a rounded edge. In some embodiments the ridges can have at least one 90 degrees edge, in a cross section. In some embodiments the ridges can have at least one edge less than 100 degrees, in a cross section. In some embodiments the ridges can have at least one edge less than 120 degrees, in a cross section. In some other

embodiments the ridge does not have a 90 degree edge in a cross section, for example, the ridge can have a 60 degrees triangle edge. In some embodiments at least two ridges (e.g., 46a and 46b) have the same configuration. In some other embodiments a first ridge has a different configuration than a second ridge (not shown). One or all of the ridges can have the same configuration, or some may have one

5 configuration while others have a different configuration. For example, ridges on one side (e.g., anterior) may have a triangular configuration while ridges on the other side (e.g., posterior) may have a square configuration.

[0187] The height of the ridges (measured in the anterior-to-posterior direction) can be about 50 $\mu$ m to about 500  $\mu$ m in some embodiments, such as about 100 $\mu$ m to about 300  $\mu$ m. When the ridges have a 10 square edge cross section, the width (measured radially) can be can be about 50 to about 500  $\mu$ m in some embodiments, such as about 100 $\mu$ m to about 300  $\mu$ m. The ridges can be configured to be wide enough to prevent the ridge from folding over when implanting. The square edge cross section is defined herein as a cross section includes at least one edge less than 100 degrees. When the ridges have a triangle cross section, the base of the ridge can be similar in size, for example, about 50 $\mu$ m to about 500  $\mu$ m in some 15 embodiments, such as about 100 $\mu$ m to about 300  $\mu$ m. The ridges do not need to be the same size (for example, one or more ridges can have different height and width values). Values outside the above ranges are also possible.

[0188] The haptic (e.g., 46, 48) can comprise a ridge (e.g., 46b, 48b) disposed on a posterior side (a bottom surface) in some embodiments. The haptic (e.g., 46, 48) can comprise a ridge (e.g., 46a, 48a) 20 disposed on an anterior side (a top surface) in some other embodiments. In some embodiments the haptic (e.g., 46, 48) can comprise one or more ridges (e.g., 46a, 48a) disposed on an anterior side and one or more ridges (e.g., 46b, 48b) disposed on a posterior side to block LECs from both sides. The second ridge can further reduce the PCO effect, but in some instances the second ridge may not be required. One or both haptics can have more than one ridge on an anterior side, or more than one ridge on a posterior side. 25 For example, haptic 48 can include two ridges 48b spaced apart from one another on haptic, but both being disposed on the posterior side of haptic.

[0189] In some additional embodiments the haptic (e.g., 46, 48) can comprise one ridge (not shown) 30 disposed on the equator of the peripheral portion. For example, in figure 8, one or both haptics can include a ridge symmetric about axis or plane B-B, extending radially outward to the left or right in the figure. However, ridges on the equator of the haptic can be optional. The numbers of the ridges on a haptic can be, for example, 1, 2, 3, 4, 6, 8, 12, 20 or any numbers therebetween or any other numbers. For example, two ridges can be disposed circumferentially on an anterior portion (top) and on a posterior portion (bottom), 180° apart and optionally with one or more additional ridges between the anterior portion (top) and the posterior portion (bottom). In figure 21, ridge 48a and 48b are 180 degrees part, but 35 they need not be. For example, ridge 48a could be moved 45 degrees toward the equator of haptic 48 while ridge 48b could be in the same position as shown. The ridges can be, but do not need to be symmetrically placed around the haptic.

[0190] The ridges described herein can be thought of generally as extensions that extend away from the natural curvature of the haptic. For example, when a square edge is used, the transition between the haptic curvature and the ridge can be a region where the haptic has a sharp bend, or tight curve, as the ridge extends away from the surface of the haptic. The ridge can be described in this manner at both transition regions with the general curvature of the haptic.

5 [0191] The ridges can be formed in a number of ways. The haptic can be molded with the one or more ridges formed therein (considered integral with the haptic material). Alternatively, separate sections of material can be adhered to the outer surface of the haptic after the haptic is molded (considered non-integral with the haptic material). Any of the ridges can be the same or different material as the haptic 10 material. For example, one or more ridges can be a material that is stiffer than the haptic material that can be adhered (e.g., glued) or co-molded onto the haptic.

[0192] For some intraocular lenses, scattering from the periphery of the optic portion of the intraocular lenses can reduce the optical quality of the intraocular lens. It may be beneficial, but not necessary, for the intraocular lens to be further adapted and configured to reduce peripheral scattering.

15 Figure 23A illustrates a top view of an exemplary IOL comprising an opaque periphery. Figure 23B illustrates a perspective section view of the IOL comprising an opaque periphery from Figure 23A. Referring to Figures 23A-B, an intraocular lens (IOL), for example, an accommodating intraocular lens, can comprise an optic portion 510, an opaque periphery 510b around the optic portion 510, and a peripheral portion optionally including at least two haptics 516 and 518 coupled to the optic portion 510.

20 The opaque periphery 510b can be adapted to absorb the scattered light, thus limit light scattering.

[0193] In some embodiments the opaque periphery 510b comprises a layer of opaque material, optionally a polymer, disposed on a peripheral edge of the optic portion. A layer of opaque polymer may need to meet the requirements for implantable materials. A layer of opaque polymer may also need to be bio-compatible and have stable properties. In some embodiments an opaque polymer can co-molded with 25 the optic portion 10 during the IOL manufacturing process. In some embodiments an opaque polymer can be deposited on a peripheral edge of the optic portion 10 after the IOL has already been manufactured.

[0194] In some embodiments the opaque periphery 510b can comprise a layer of black glue disposed on a peripheral edge of the optic, which could also be used as a glue to adhere the optic and haptics.

[0195] In some embodiments the opaque periphery 510b comprises a layer of black paint disposed 30 on the optic edge.

[0196] In some embodiments the opaque periphery 510b comprises a cylindrical structure, such as a black cylindrical structure, attached to an edge of the optic portion 510. This approach can reduce the complexity in the IOL manufacturing. A variety of methods can be used to attach a cylindrical structure to the IOL.

35 [0197] Figures 24-26C, which will now be described, are related to the full disclosure in WO2014/145562A1, which is incorporated by reference herein. A variety of intraocular lens (“IOL”) loading and delivery devices, systems, and methods of use have been described in recent years. However, the issues related to residual air have not been adequately addressed yet. For example, residual air around

the IOL and in the fluid chambers of the injector system can lead to issues during IOL delivery. For example, air in a viscoelastic stream before and around the IOL during delivery can obscure the visualization of the IOL and eye during delivery and after delivery during the manipulation and final placement of the IOL in the eye, such as in the capsule. Additionally, compressed residual air behind the

5 IOL during the highest pressure of the IOL body delivery can lead to uncontrolled delivery of the IOL into the eye. This can occur as the IOL body passes the most constricted portion of the delivery device, and allows the compressed air proximal of the IOL to expand and push the IOL forward without user input. While this could theoretically be used as an advantage in some types of delivery, uncontrolled IOL delivery is generally undesirable.

10 **[0198]** Loading and delivery devices, systems, and method of use are needed that can effectively perform air management, including residual air removal in loading and pre-delivery.

**[0199]** Figure 24 is a section view of a cartridge 660 with an IOL 640 loaded inside by a push member 630 according to one embodiment of the disclosure. The IOL 640 can be any of the IOLs described above, or may in some embodiments be an IOL not described herein. For example, the IOL 640 can be

15 the same or similar to the IOL 340 in figure 22 in WO2014/145562A1. The IOL 640 can comprise optic portion 643, leading haptic 641 and trailing haptic 642 as shown in figure 24. Leading haptic 641 is disposed distally to optic 643, and trailing haptic 642 is generally proximal to optic 643. The cartridge 660 can be any type of cartridge, such as those described herein or even other cartridges not described herein. For example, the cartridge 660 can be the same as or similar to the exemplary cartridge 360 in

20 figure 18. The carrier 600 can be any type of carrier, shown herein or not. For example, the carrier 600 can be the same as or similar to the cartridge 400 in figures 16, 17 and 18 in WO2014/145562A1. The cartridge 660 can be secured to the distal cartridge receiving area of carrier 600.

**[0200]** Prior to use, the loading carrier 600 can be sterilized and shipped with the IOL 640 disposed therein. Optionally, the cartridge 660 can be attached before sterilization, or the cartridge 660 can be

25 attached at the time of loading. A viscoelastic material 680 can be introduced to the carrier 600 through a port in the side of the loading carrier 600 that has a communicating port adjacent to the IOL 640. For example, the viscoelastic port (not shown) can be the same as or similar to the side port 319 in figures 16 and 17 in WO2014/145562A1. The viscoelastic port can be designed to mate with standard syringes, and has a pathway that leads to the proximity of the IOL 640. The port conveys viscoelastic from a syringe or

30 other viscoelastic delivery aid to the area around the IOL 640 prior to the splaying and loading steps.

**[0201]** The push member 630 can be any type of push member or loading member, shown herein or otherwise. The push member or loading member 630 can move distally to engage with and advance the IOL 640 into the cartridge 660 (or other delivery device or delivery lumen) and placing it at a predefined position in the cartridge 660 to be ready for further assembly of a delivery device, such as a plunger. In

35 some embodiments, the push member 630 can be the same as or similar to the push member 330 in figures 17 and 20 in WO2014/145562A1. The push member or loading member 630 can comprise an elongate body, a first extension extending distally and in an upward direction relative to a top portion of elongate body at a hinge and a second extension extending distally and in a generally linear orientation

with respect to the proximal portions of load body, similar to the loading member in figure 20 in WO2014/145562A1. In some other embodiments, the push member 630 can be the same as or similar to the push member 40 in figure 14 in WO2014/145562A1.

5 [0202] The carrier 600 can comprise a carrier cover, or lid 650, and can be any of the lids herein. Lid 650 can cover the portion of base 610 where the IOL 640 is positioned.

10 [0203] As shown in Figure 24, loading the IOL 640 from the loading carrier 600 and into the cartridge can result in the IOL 640 being disposed in the cartridge 660, surrounded by the viscoelastic material 680, but with localized air bubbles over the anterior portion of the IOL 640 and near the proximal haptic 642. If this air is not removed, it can move forward of the IOL 640 during delivery and obscure visibility during the surgery, as mentioned above.

15 [0204] The disclosure includes exemplary methods of air management in an IOL loading and delivery system. The methods will be described generally without reference to specific parts of the devices herein, although examples will be given in the context of certain embodiments. Not all steps need necessarily be performed, and the order may vary.

20 [0205] Figures 25A-C illustrate a method of removing air (or “de-bubbling”) from around the IOL 640 during loading, and before connecting a delivery device to the cartridge 660. In general, the air over the anterior portion of the IOL 640 and near the proximal haptic 642 can be removed or displaced away from the IOL 640 before mounting the delivery device, for example, a plunger assembly, to the cartridge 660.

25 [0206] In some embodiments, the method can comprise removing the cartridge from the carrier, and passing a syringe with cannula over the top of the IOL, wherein the syringe can be filled with a viscoelastic material. The viscoelastic material can be used to displace the air towards the proximal side of the IOL. The syringe can pass the top of the IOL from the distal end in some embodiments. In some other embodiments, the syringe can pass the top of the IOL from the proximal end. The cannula may be in close proximity to the optic 643 of the IOL 640. Care needs to be taken to avoid damage to the optic 643 of the IOL 640.

30 [0207] In some embodiments, the air over the anterior portion of the IOL 640 and near the proximal haptic 642 can be removed when the loading member or push member 630 is retracted, as shown in figures 25A-C. The carrier lid 650 can comprise an opening 655 to insert the syringe 658 with the cannula as shown in figure 25A. The cannula of the syringe 658 can be inserted through the opening 655 while the push member 630 is still advanced at the last step of the loading and over the anterior portion of the IOL 640. The cannula can be advanced to a position over the anterior portion of the IOL 640. The syringe 658 can insert a viscoelastic material 682 to displace the air over the anterior portion of the IOL 640, or air at any other location within the cartridge. The viscoelastic material 682 can be the same or different than the viscoelastic material 680 inserted from the side port of the carrier 600. In some other embodiments, the base of the carrier 600 can comprise an opening to insert a syringe with a cannula to displace the air adjacent the IOL. In some alternative embodiments, the side of the carrier 600 can comprise an opening to insert a syringe with a cannula to displace the air over the anterior portion of the IOL or other areas adjacent the IOL.

**[0208]** The method of removing air from the IOL 640 during loading can comprise placing a cannula of a viscoelastic syringe over the anterior portion of the IOL 640 while the push member 630 is still advanced at the last step of the loading, and inserting a viscoelastic material over the anterior portion of the IOL 640 while the push member 630 is retracting.

5 **[0209]** Figure 25B illustrates a section view when the push member is being retracted. The volume around the push member can be filled with the viscoelastic material 682 so that after the push member is retracted, the volume that is displaced is replaced with the viscoelastic material 682 instead of air. After the push member is completely retracted, the proximal channel can be left full of the viscoelastic material 682. This method has the advantages of reducing the need for a cannula to be in close proximity to the  
10 IOL optic 643. In some embodiments, the method can further comprise making a mark on the loading carrier 600 to where the viscoelastic material 682 needs to be filled to be effective in a predetermined volume.

15 **[0210]** Figures 25A-C illustrate a method of air venting of IOL during the delivery process. The cartridge 660 with the IOL 640 loaded inside can be connected to a delivery system, which can deliver the IOL 640 into an eye of a patient. For example, the delivery system of the IOL 640 can be the delivery system described in U.S. Patent No. 8,968,396, titled: "Intraocular Lens Delivery Systems and Methods of Use", filed March 15, 2013, which is herein incorporated by reference in its entirety. The delivery system can comprise a plunger assembly 690 as shown in Figure 25A. The plunger assembly 690 can include a lumen extending from a proximal end to a distal end. This allows the viscoelastic fluid, or other  
20 material, to be delivered from the proximal end of the plunger 690 into the cartridge 660, pushing the loaded IOL 640 from within the cartridge 660 out the distal tip (shown with a bevel) and into the patient's eye. Plunger 690 has a proximal portion that is adapted to interact with a fluid delivery device, such as a syringe, so that fluid can be advanced from the fluid delivery device and into the inner lumen within plunger 690. Distal end of plunger 690 is disposed within the cartridge 660, and thus the fluid is  
25 delivered to a location that is radially and axially within the lumen, even if it does not exit the plunger 690.

30 **[0211]** When the IOL 640 is loaded into the cartridge 660 from the carrier, the cartridge 660 is removed from the carrier and the plunger assembly 690 can be mounted to the cartridge 660 proximal to the IOL 640. The IOL 640 in the cartridge 660 at this point is encapsulated in the viscoelastic material. At this point the plunger 690 is not full of a viscoelastic material but only air in the open fluid pathways. There is a void of viscoelastic proximal to the IOL 640.

35 **[0212]** After the IOL 640 is loaded into the cartridge 660 as shown in Figure 26A, a viscoelastic fluid, or other type of fluid, can delivered from a syringe and into lumen of plunger 690 (see Figure 26B). The viscoelastic fluid can delivered from the distal port of plunger 690 and into contact with the IOL 640, forcing the IOL 640 distally within cartridge 660 and out the distal end of the cartridge 660. In general, the delivery of the IOL 640 from the cartridge 660 relies on development of pressure differential in the viscoelastic over the IOL 640 to move it down the reducing section of the cartridge 660 and into the eye.

[0213] The compressed residual air behind the IOL 640 during the highest pressure of the IOL 640 delivery can lead to uncontrolled delivery of the IOL 640 into the eye as the IOL body passes the most constricted portion of the cartridge 660. The compressed air proximal of the IOL 640 can be expanded and push the IOL forward without user input, which can possibly damage the IOL 640 or the capsule in 5 the eye, or even cause the IOL 640 to be delivered outside of the capsule. The purging of air is important for a smooth, controlled delivery of the IOL 640.

[0214] When the cartridge tip is placed in the eye and the screw drive is beginning to be advanced, 10 the viscoelastic fluid of the plunger 690 displaces air forward out of the plunger 690 by filling the luer fitting, support tube, through the semi porous expanded PTFE tubing and then being redirected back around the support tube and down through the exhaust vent 695. The forward direction is towards the tip of the carrier 660. The air is followed by the viscoelastic fluid to the vent 695 due to this being the lowest pressure path since the IOL 640 is fully or partially sealing against the cartridge 660 wall. The forward path to the tip is blocked by the IOL 640 and loading viscoelastic material. When the vent 695 seals with viscoelastic fluid, the system is able to develop pressure to move the IOL 640 forward to the tip of the 15 cartridge 660 without a significant amount of air behind the IOL 640 as shown in Figure 26C.

[0215] As shown in Figures 26A-C, the viscoelastic fluid travels from a syringe through support tube and exits in proximity of the trailing haptic of the IOL 640 within a plug element, for example, an EPTFE 20 membrane. The fluid front travels both distally filling the plug element, and rearward evacuating the volume air through vent 695. The vent 695 will not pass viscoelastic so is able to maintain pressure when fully evacuated. This effect purges the air from the back of the system to reduce spring effects of trapped air during the release of the IOL 640 during delivery.

[0216] In some embodiments the delivery system includes a vent and does not include a plug, or sealing element. In these embodiments fluid such as viscoelastic is delivered towards the IOL 640 as part 25 of the delivery process. Air venting to increase control during delivery while decreasing the volume of air bubbles that are moved forward through the tip into the eye provides a significant advantage even in the absence of a plug element.

[0217] The following disclosure of figures 27-28D is related to the full disclosure of 30 WO2013/142323, which is fully incorporated by reference herein. Intraocular lenses are positioned within a patient's eye, such as in the anterior chamber or posterior chamber. After making a small incision in the eye, a physician typically positions a distal opening of a delivery device within or adjacent to the opening. The physician then delivers the intraocular lens out of the delivery device, through the opening, and into the target location within the eye. In some procedures, but not all, an intraocular lens is delivered into a native capsule after the native lens has been removed.

[0218] Some intraocular lenses, because of their size and/or their configuration, and possibly the 35 desired incision size, need to be reconfigured and/or have at least a first portion reoriented with respect to a second portion to be delivered into an eye. When some intraocular lenses are advanced through a delivery device and/or delivered out of the delivery device, forces on the intraocular lens can damage the intraocular lens.

[0219] What are needed are delivery systems and methods of use that can deliver an intraocular lens without damaging the intraocular lens.

[0220] Figure 27 is a top view of an exemplary cartridge 401, which can be used to deliver an intraocular lens into an eye. Cartridge 401 is an example of any of the cartridges described herein. The 5 cartridge 401 can comprise a proximal opening 405 disposed to be engaged with a loading carrier to accept the intraocular lens (not shown), and a distal tip 411 adapted to deliver the intraocular lens into an eye. The cartridge 401 can comprise a lumen 410 extending from the proximal opening 405 to the distal tip 411. The lumen 410 can comprise a cross section having a first axis X and a second axis Y of an internal ellipse. The lumen 410 can further comprise a first portion 491 adapted to engage with the 10 loading carrier and, without limitation, begin to fold the intraocular lens without stretching the intraocular lens out, a second portion 492 adapted to, without limitation, form a seal (or at least substantial seal) between an inner wall and the intraocular lens, and a third portion 493 adapted to, without limitation, compress the intraocular lens to extend the intraocular lens in length.

[0221] The intraocular lens can be disposed within lumen 410 and positioned to be deployed out of 15 the distal tip 411 of the cartridge 401. The distal end of a plunger, such as any of the plungers herein, can be disposed within the proximal opening 405 in the cartridge 401 when assembled. The cartridge 401 can be adapted to accept the intraocular lens from the loading carrier into the cartridge 401, and have a tapered distal end to deform, compress, and optionally stretch out the intraocular lens in to deliver the intraocular lens into the eye.

[0222] Figures 28A-C illustrate exemplary internal cross sections DD, CC, BB and AA of the 20 cartridge 401 in Figure 27. Section DD represents the proximal opening 405. Section CC represents the intersection of the first portion 491 and the second portion 492. Section BB represents the intersection of the second portion 492 and the third portion 493. Section AA represents the distal end of the third portion 493, and shows the cross section of the distal-most region of cartridge 401. Referring to Figures 27 and 25 Figures 28A-C, as the intraocular lens is pushed through the cartridge 401 (right to left as shown in Figure 27), the cartridge 401 internal cross-section transitions from a lumen 410 large enough to hold the lens without compressing it (assuming the haptics are splayed out away from the lens body) at section DD all the way down to the final, compressing lumen 410 shown in section AA.

[0223] In some embodiments the transition from section DD to CC is that both a first radius 410a 30 along the first axis X and a second radius 410b along the second axis Y on the cross section shrinks from the proximal opening 405 to section CC, which serves to interface with the lens carrier, accept the lens into the cartridge 401, and fold the lens body without stretching it out. In some embodiments, both the first radius 410a and the second radius 410b on the cross section decrease from the proximal opening 405 to the section CC. In some embodiments, the first radius 410a on the cross section at the proximal opening 405 is from about 2 mm to about 7 mm. For example, the first radius 410a on the cross section at the proximal opening 405 can be from about 4.6 mm to about 5.6 mm. Values outside the above range are also possible. In some embodiments a second radius 410b on the cross section at the proximal opening 405 is from about 1 mm to about 6 mm. For example, the second radius 410b on the cross section at the

proximal opening 405 can be from about 3.5 mm to about 4.5 mm. Values outside the above range are also possible.

**[0224]** In some embodiments the first radius 410a is larger than the second radius 410b on the cross section from the proximal opening 405 to the intersection of the first portion and the second portion CC.

5 In some embodiments the first radius 410a on the cross section at an intersection CC of the first portion 491 and the second portion 492 is from about 1.5 mm to about 6.5 mm. For example, the first radius 410a on the cross section at section CC can be from about 4.0 mm to about 5.0 mm. Values outside the above range are also possible. In some embodiments the second radius 410b on the cross section at the intersection CC is from about 0.5 mm to about 5.5 mm. For example, the second radius 410b on the cross 10 section at section CC can be from about 2.6 mm to about 3.6 mm. Values outside the above range are also possible.

**[0225]** Between sections CC and BB the lens is forming a substantial seal against the inner wall of the lumen 410. In some embodiments the first radius 410a and the second radius 410b on the cross section decrease from the intersection CC of the first portion 491 and the second portion 492 to the 15 intersection BB of the second portion 492 and the third portion 493.

**[0226]** In some other embodiments the first radius 410a decrease but the second radius 410b remains the same on the cross section from the intersection CC to the intersection BB. In some embodiments the first radius 410a is larger than the second radius 410b on the cross section at the intersection CC, and the first radius 410a is smaller than the second radius 410b on the cross section at the intersection BB. In 20 some embodiments the first radius 410a on the cross section at the intersection BB of the second portion 492 and the third portion 493 is from about 0.5 mm to about 5 mm. For example, the first radius 410a on the cross section at intersection BB can be about 2.6 mm to about 3.6 mm. In some embodiments the second radius 410b on the cross section at the intersection BB is from about 0.5 mm to about 5.5 mm. For example, the second radius 410b on the cross section at intersection BB can be about 2.2 mm to about 25 3.2 mm. Values outside the above range are also possible.

**[0227]** Between sections BB and AA the lens is being stretched out by the rapid reduction of cross sectional area (to below the minimum cross sectional area of the lens itself). This causes the lens to extend in length. In some embodiments both the first radius 410a and the second radius 410b on the cross section decrease from the intersection BB of the second portion 492 and the third portion 493 to a distal 30 end AA of the third portion 493. In some embodiments the first radius 410a is different than the second radius 410b on the cross section at the intersection BB, and the first radius 410a is the same as the second radius 410b on the cross section at the distal end AA. In some embodiments the cross section changes from an elliptical shape to a circular shape in the third portion.

**[0228]** In some embodiments the first radius 410a and the second radius 410b on the cross section decrease at a first average rate from the proximal opening 405 to the intersection CC, the first radius 410a and the second radius 410b on the cross section decrease at a second average rate from the intersection BB to the distal end AA, and the second average rate is larger than the first average rate. In some embodiments the first radius 410a is the same as the second radius 410b on the cross section at the distal

end AA. In some embodiments a radius of a cross section at a distal end AA of the third portion is from about 0.1 mm to about 4 mm. For example, the radius 410c on the cross section at intersection AA can be about 1.5 mm to about 2.5 mm. Values outside the above range are also possible.

**[0229]** From section AA to the tip there is no change in cross-sectional area. In some embodiments, 5 the apparatus can further comprise a fourth portion extending from the distal end AA of the third portion 493 to the distal tip 411. In some embodiments the cross section remains the same from the distal end AA of the third portion 493 to the distal tip 411.

**[0230]** One aspect of the disclosure is a method of delivering an intraocular lens into an eye. The 10 method can comprise engaging a delivery device to a loading carrier to accept the intraocular lens. The method can comprise folding the intraocular lens without stretching the intraocular lens out. The method can comprise forming a seal between an inner wall of the delivery device and the intraocular lens. The method can comprise compressing the intraocular lens to extend the intraocular lens in length and delivering the intraocular lens into the eye.

**[0231]** In some embodiments the step of folding the intraocular lens comprises decreasing a first 15 radius along a first axis and a second radius along a second axis of an internal ellipse of a cross section of the delivery device at a first average rate. In some embodiments compressing the intraocular lens comprises decreasing a first radius along a first axis and a second radius along a second axis of an internal ellipse of a cross section of the delivery device at a second average rate. In some embodiments the second average rate during the step of compressing the intraocular lens is larger than the first average rate 20 during the step of folding.

**[0232]** Characteristics of the intraocular lenses described herein can similarly be applied to non-fluid 25 driven accommodating intraocular lenses. For example, a non-accommodating intraocular lens can include a peripheral portion with a first stiffer region that provides a region of the peripheral portion with an insensitivity in a first direction. For example, in an intraocular lens with two lenses adapted to be moved apart from one another to change the power of the lens, the peripheral portion of the lens can be adapted such that a first type of capsular reshaping does not cause the distance between the lenses to change, and thus the power of the intraocular lens stays the same.

**[0233]** Additionally, the accommodating intraocular lenses herein can also be adapted to be 30 positioned outside of a native capsular bag. For example, the accommodating intraocular lenses can be adapted to be positioned in front of, or anterior to, the capsular bag after the native lens has been removed or while the native lens is still in the capsular bag, wherein the peripheral portion of the lens is adapted to respond directly with ciliary muscle rather than rely on capsular reshaping.

## CLAIMS

1. A method of manufacturing an optic of an accommodating intraocular lens to have an aspheric lens surface, comprising:

5 providing an optic comprising an anterior element and a posterior element that at least partially define an optic fluid chamber, wherein at least one of the anterior element and the posterior element has an external surface that is spherical; and

10 prior to inserting the accommodating intraocular lens into an eye, changing the shape of the at least one of the anterior element and the posterior element from the spherical configuration to an aspherical configuration.

10

2. The method of claim 1 wherein changing the shape of the at least one of the anterior element and the posterior element from the spherical configuration to an aspherical configuration comprises adding fluid to the optic fluid chamber so as to increase the fluid pressure within the optic chamber and cause the at least one of the anterior element and the posterior element to deform from the spherical configuration 15 to the aspherical configuration.

3. The method of claim 2, further comprising, prior to adding fluid, securing at least one haptic to the optic.

20

4. The method of claim 1 wherein providing the optic comprises bonding the anterior element to the posterior element.

5. The method of claim 1, further comprising machining at least one of the anterior element and the posterior element.

25

6. The method of claim 1 wherein, prior to changing the shape of the at least one of the anterior element and the posterior element from the spherical configuration to an aspherical configuration, the optic has a 10-15D base state.

30

7. A fluid-filled intraocular lens, comprising:

an optic portion comprising an anterior element with an anterior optical surface and a posterior element with a posterior optical surface, the anterior element and the posterior element defining an optic fluid chamber,

35

wherein at least one of the anterior optical surface and the posterior optical surface has an aspherical configuration in an as-manufactured state, prior to insertion in an eye.

8. An intraocular lens, comprising:

an optic portion; and

a peripheral portion including a peripheral fluid chamber, the peripheral portion having a cross section, in a plane passing through an optical axis of the optic portion, in which the fluid chamber is disposed in a radially outer portion of the peripheral portion, and wherein a radially inner portion of the peripheral chamber is non-fluid.

5

9. An intraocular lens, comprising:

an optic portion; and

a peripheral portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, and in a direction orthogonal to an optical axis of the optic portion through a midpoint of the peripheral portion, having a radially inner fluid chamber wall thickness that is between four and twenty times the thickness of a radially outer fluid chamber wall thickness.

10. An intraocular lens, comprising:

15 an optic portion; and

a peripheral portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, has an outer surface that is not symmetrical about every axis passing through the peripheral portion and parallel to an optical axis of the optic portion,

20 and wherein the peripheral portion has, in a direction orthogonal to an optical axis of the optic portion through a midpoint of the peripheral portion, having a radially inner fluid chamber wall thickness greater than a radially outer fluid chamber wall thickness.

25 11. An intraocular lens, comprising:

an optic portion; and

a peripheral portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, having a height dimension measured in an anterior to posterior direction,

30 wherein the greatest height of the peripheral portion in a radially outer half of the peripheral portion is greater than the greatest height of the peripheral portion in a radially inner half of the peripheral portion.

35 12. An intraocular lens, comprising:

an optic portion coupled to a peripheral portion at a coupling, the coupling comprising a radially inner surface of the peripheral portion interfacing a radially outer peripheral edge of the optic portion.

13. An intraocular lens of claim 12, wherein the radially inner surface of the peripheral portion has a first end with a configuration that is different than a second end of the inner surface.

14. An intraocular lens of claim 13, wherein the peripheral portion includes a haptic with a coupled end and a free end, the first end being closer to the haptic free end than the coupled end.

5 15. An intraocular lens of claim 14, the haptic with a configuration that follows a radially outer peripheral curvature of the optic from the haptic coupled end to the free end.

16. An intraocular lens of claim 13, wherein the first end has a greater surface area than the second end of the radially inner surface.

10 17. An intraocular lens of claim 16, wherein the first end has a tapered end configuration, wherein the taper is toward a free end of the peripheral portion.

15 18. The intraocular lens of claim 12, wherein the radially inner surface of the peripheral portion defines a peripheral portion fluid port.

19. An intraocular lens, comprising an optic body, a projection extending radially outwards from a peripheral surface of the optic body, and a peripheral non-optic body having a first portion secured to the projection.

20 20. The intraocular lens of claim 1, wherein a radially inner surface of the first portion of the peripheral non-optic body follows a radially peripheral surface of the projection.

25 21. The intraocular lens of claim 1 wherein the projection and the first portion interface at a butt joint, with optionally flat or curved relative surfaces.

22. The intraocular lens of claim 1, wherein a radially peripheral surface of the projection comprises a flat surface, optionally entirely flat.

30 23. The intraocular lens of claim 22, wherein a radially inner surface of the first portion of the peripheral non-optic body comprises a flat surface, optionally entirely flat.

24. The intraocular lens of claim 1, wherein a radially peripheral surface of the projection comprises a curved surface, optionally entirely curved.

35 25. The intraocular lens of claim 27, wherein a radially inner surface of the first portion of the peripheral non-optic body comprises a curved surface, optionally entirely curved.

26. The intraocular lens of claim 1, wherein a radially peripheral surface of the projection is between 10 microns and 1 mm, optionally, 10 microns to 500 microns, farther away radially from a center of the optic body than the peripheral surface of the optic body.

5 27. The intraocular lens of claim 1 wherein the projection extends between 10 microns and 1mm, optionally between 10 microns and 500 microns, from the peripheral surface of the optic body.

28. The intraocular lens of claim 1 wherein the optic body and the projection are a single integral body.

10 29. The intraocular lens of claim 1 wherein the projection is attached to the optic body.

30. The intraocular lens of claim 1, wherein the optic body comprises a posterior element and an anterior element, optionally defining a fluid chamber therebetween.

15 31. The intraocular lens of claim 30, wherein the posterior element comprises the projection.

32. The intraocular lens of claim 30, wherein the anterior element comprises the projection.

20 33. The intraocular lens of claim 1, wherein the peripheral non-optic body further comprises a free second portion disposed away from the first portion.

34. The intraocular lens of claim 1, wherein the peripheral non-optic body comprises a peripheral fluid chamber.

25 35. The intraocular lens of claim 1, wherein the projection comprises at least one channel, and optionally at least two channels, in fluid communication with a peripheral fluid chamber in the peripheral non-optic body.

30 36. The intraocular lens of claim 1, wherein the peripheral non-optic body has a radially inner surface, optionally with a slight curve, coupled to the projection, wherein the projection is disposed on a radially outer peripheral edge of the optic body.

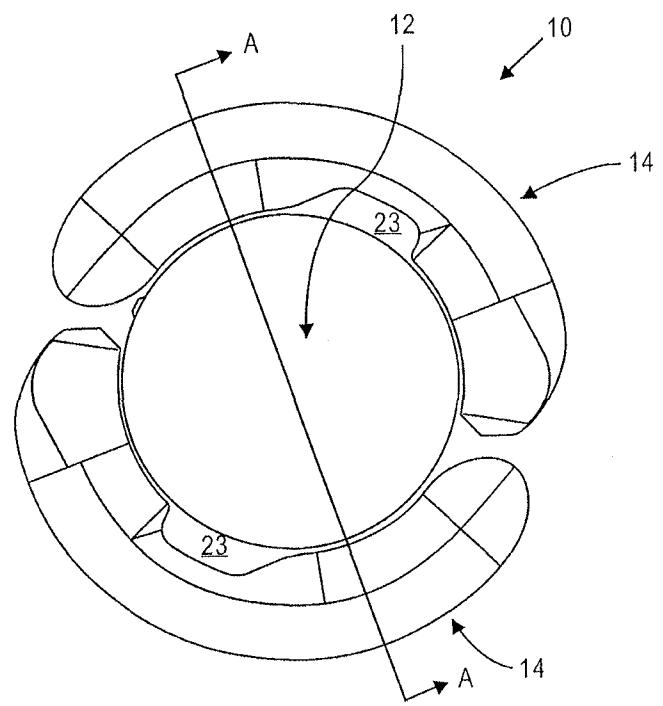
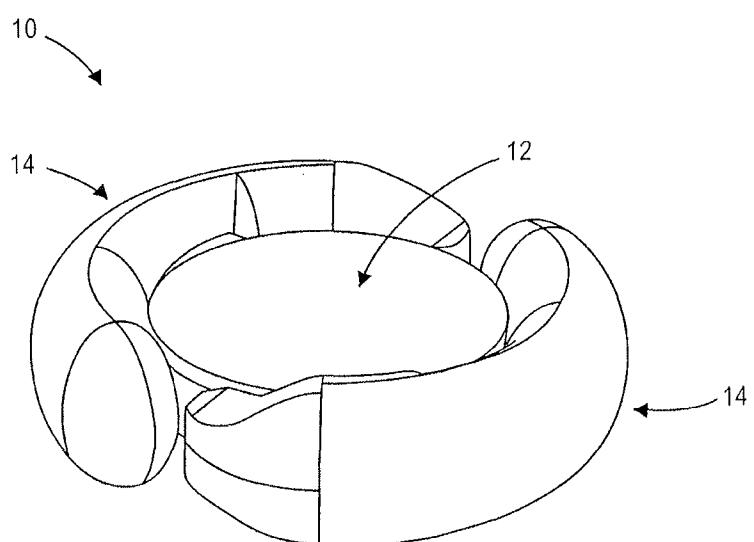
35 37. The intraocular lens of claim 1, wherein the peripheral non-optic body is adapted to deform in response to forces on the peripheral non-optic body due to ciliary muscle movement to thereby move a fluid between a peripheral fluid chamber in the peripheral non-optic body and an optic fluid chamber in the optic body to change an optical parameter of the intraocular lens.

38. The intraocular lens of claim 1, wherein the peripheral non-optic body comprises an opening configured to interface with the projection.

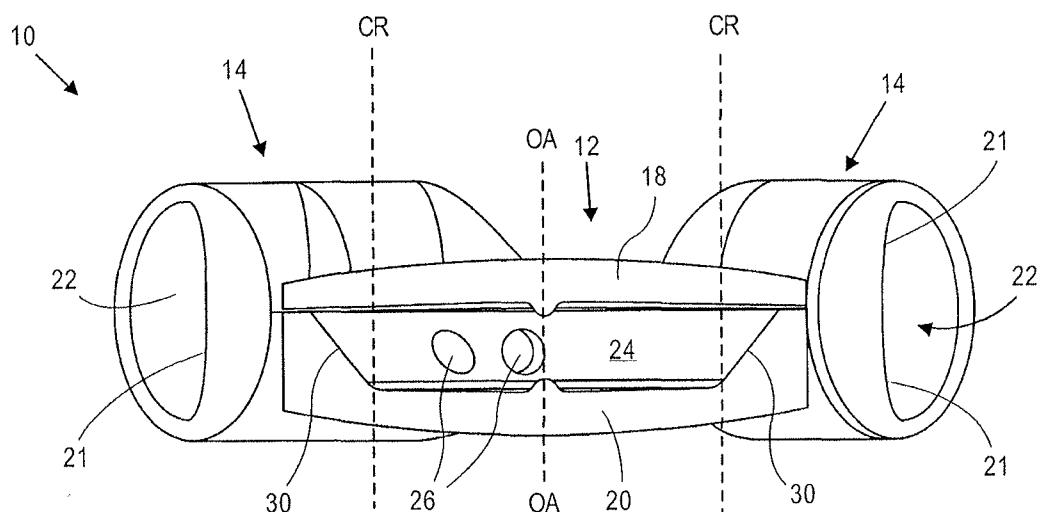
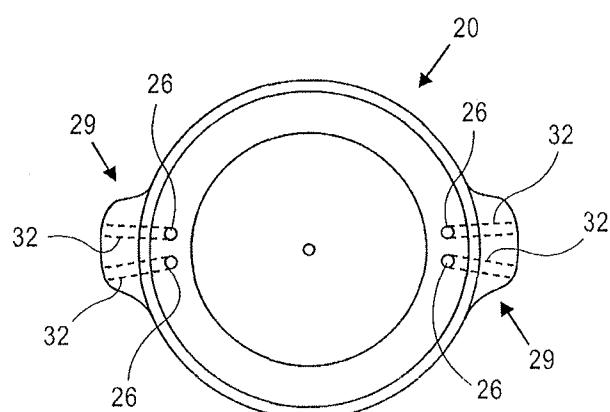
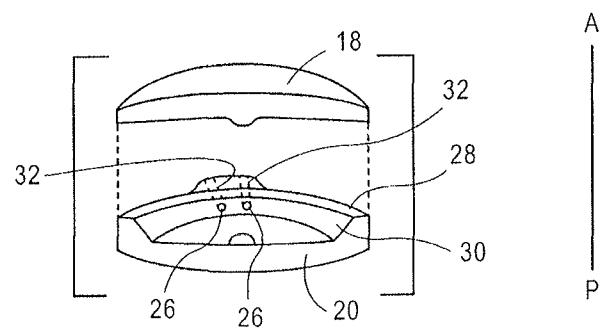
39. The intraocular lens of claim 1, wherein the projection is sized and configured to be disposed within and interface with an opening in the peripheral non-optic body.

40. An intraocular lens comprising an optic body and a peripheral non-optic body, the optic body having, in a top view, an outer edge at least a portion of which is an arc, and wherein the peripheral non-optic body is coupled to the optic body projection at a location radially outward relative to the curve of the arc.

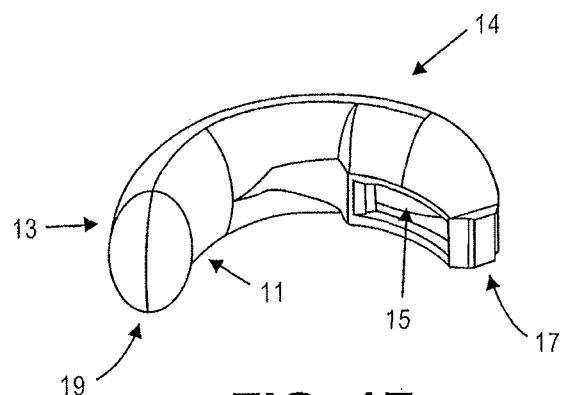
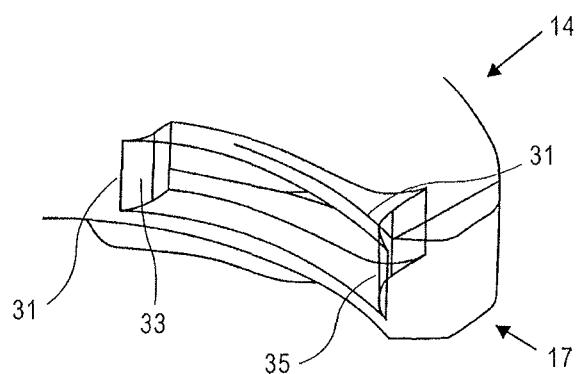
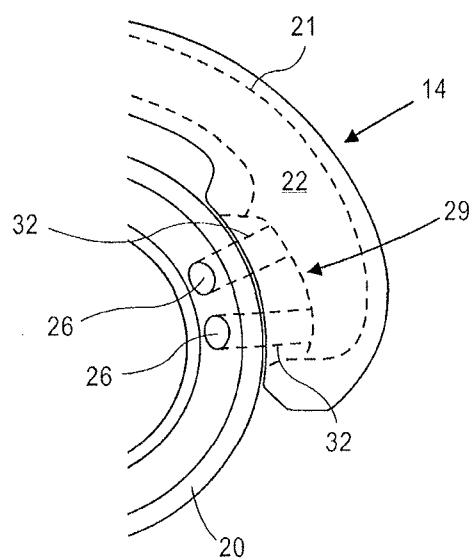
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**FIG. 1A****FIG. 1B**

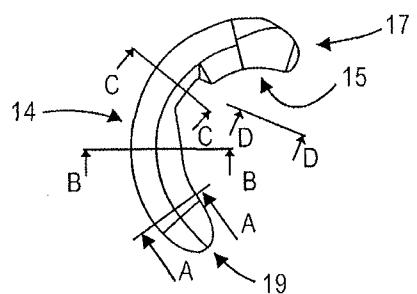
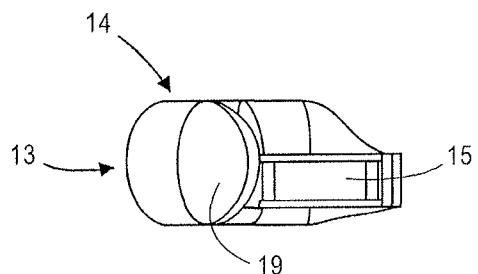
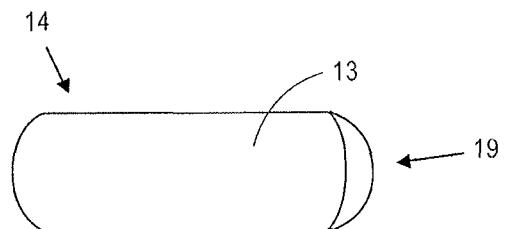
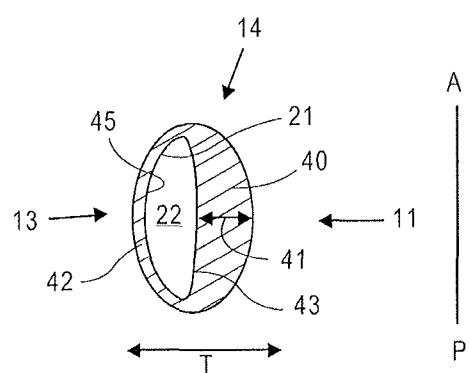
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**FIG. 1C****FIG. 1D****FIG. 1E**

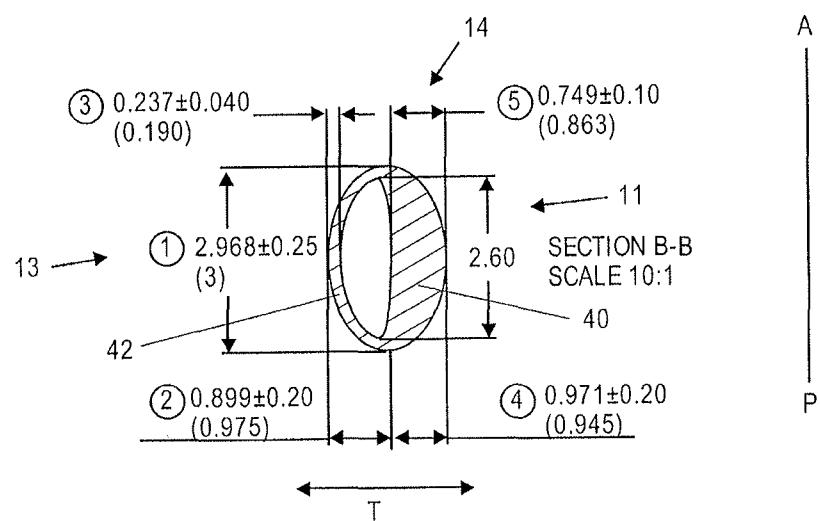
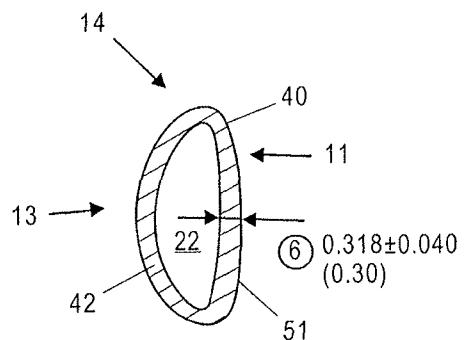
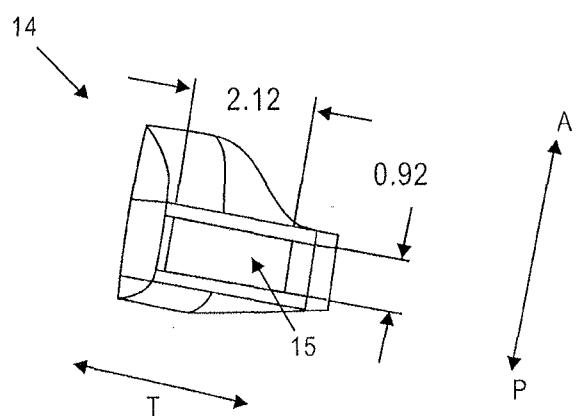
3 / 33

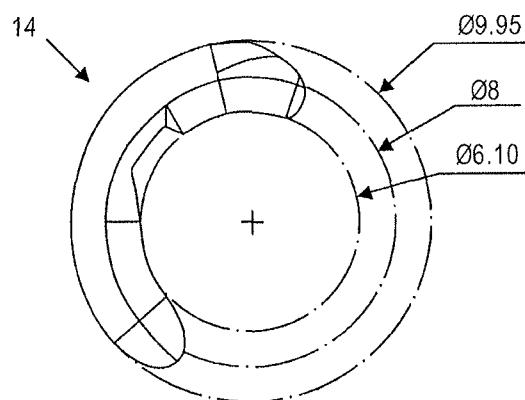
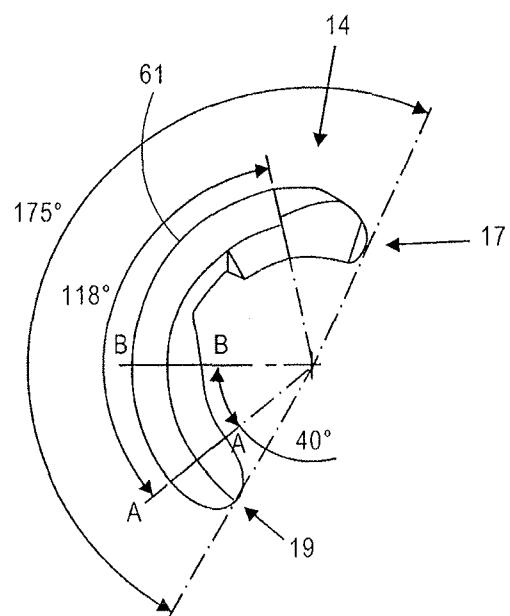
**FIG. 1F****FIG. 1G****FIG. 1H**

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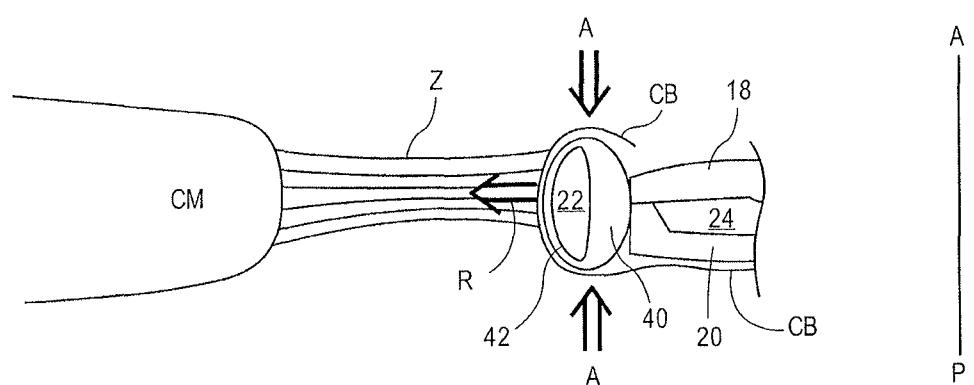
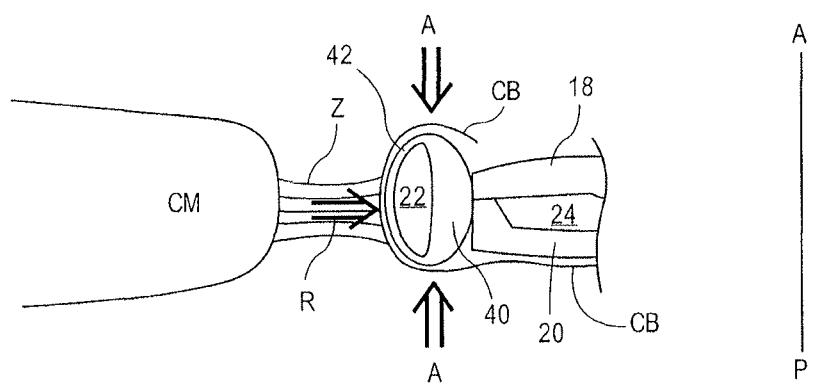
**FIG. 2A****FIG. 2B****FIG. 2C****FIG. 2D**

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**FIG. 2E****FIG. 2F****FIG. 2G**

**FIG. 3****FIG. 4**

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**FIG. 5A****FIG. 5B**

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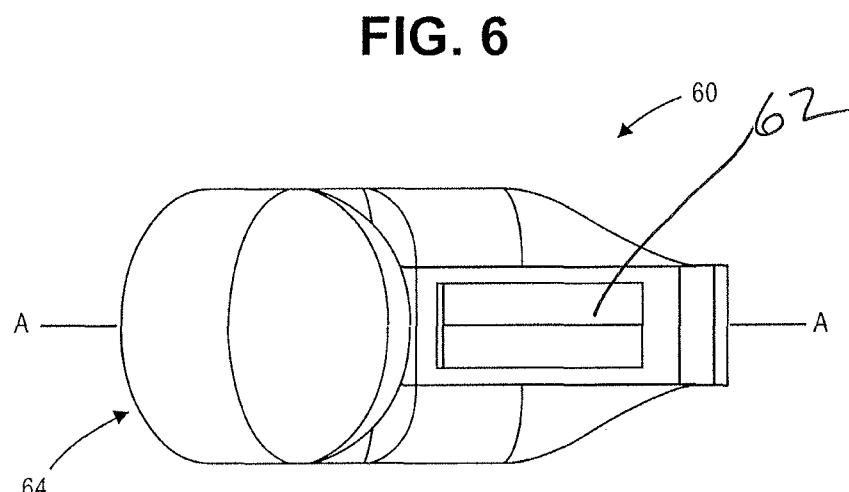
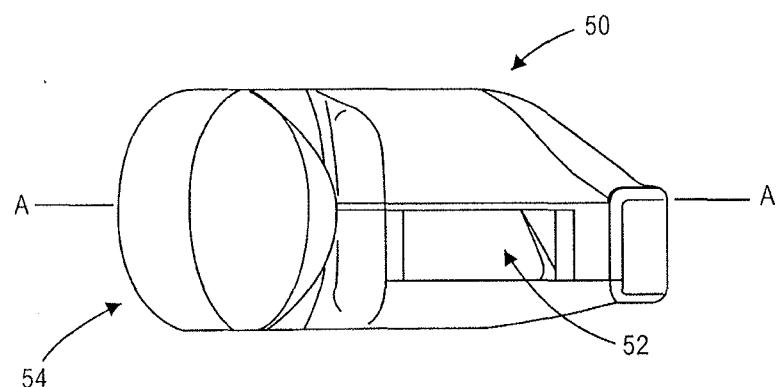


FIG. 7

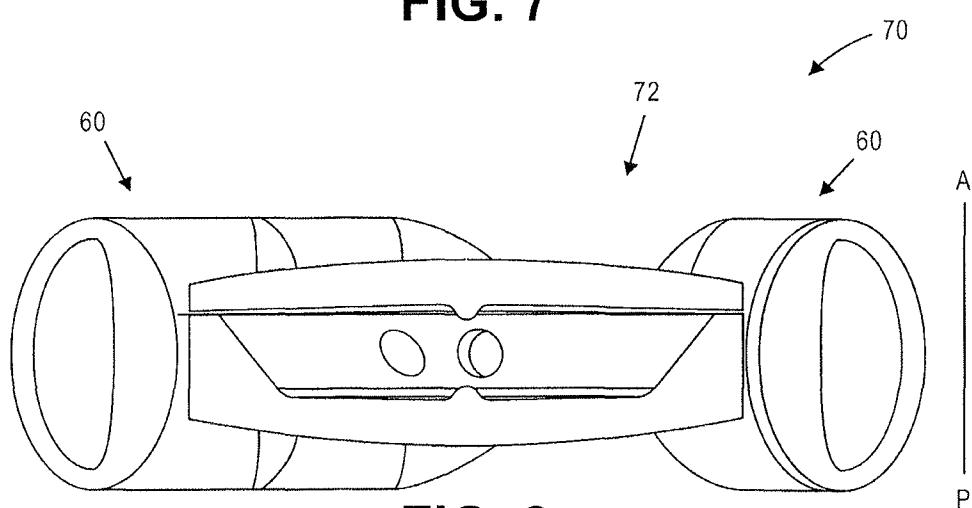
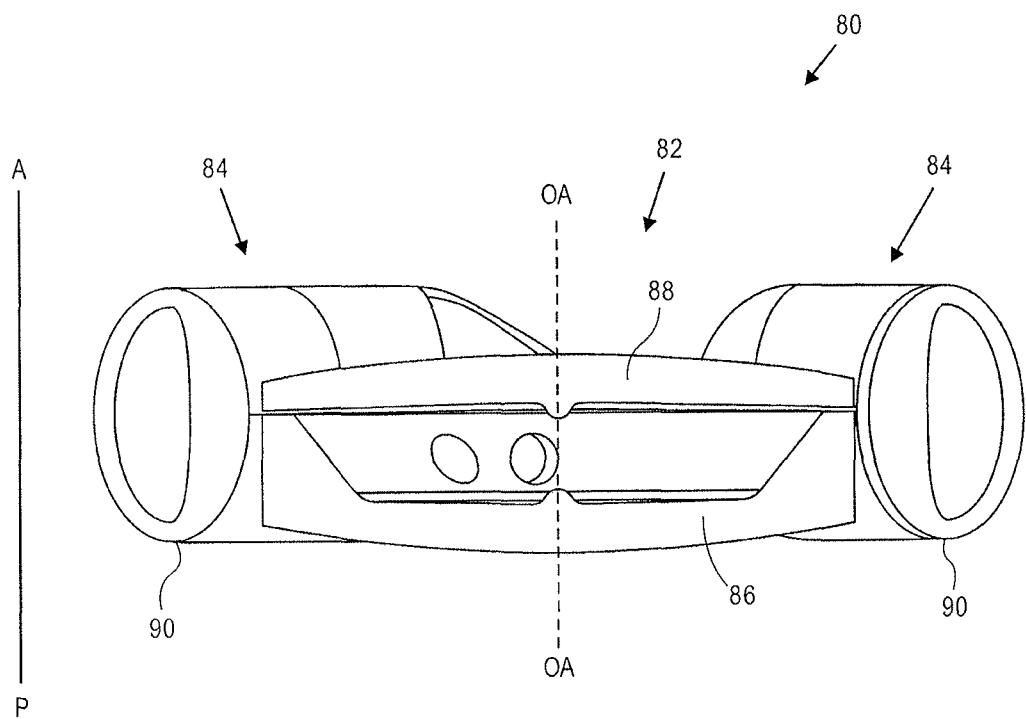


FIG. 8

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**FIG. 9**

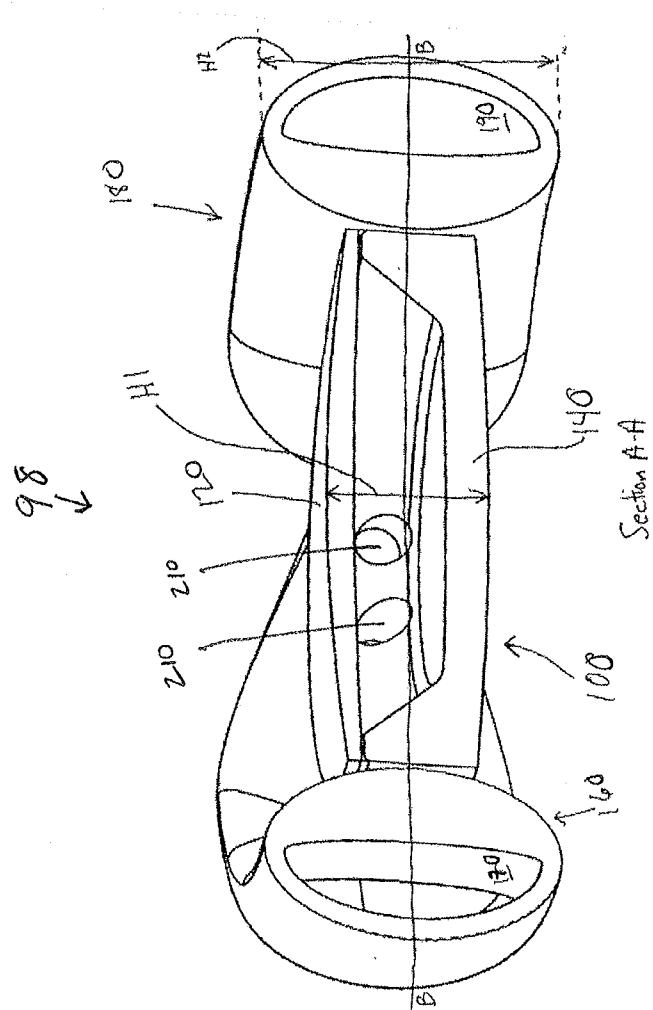
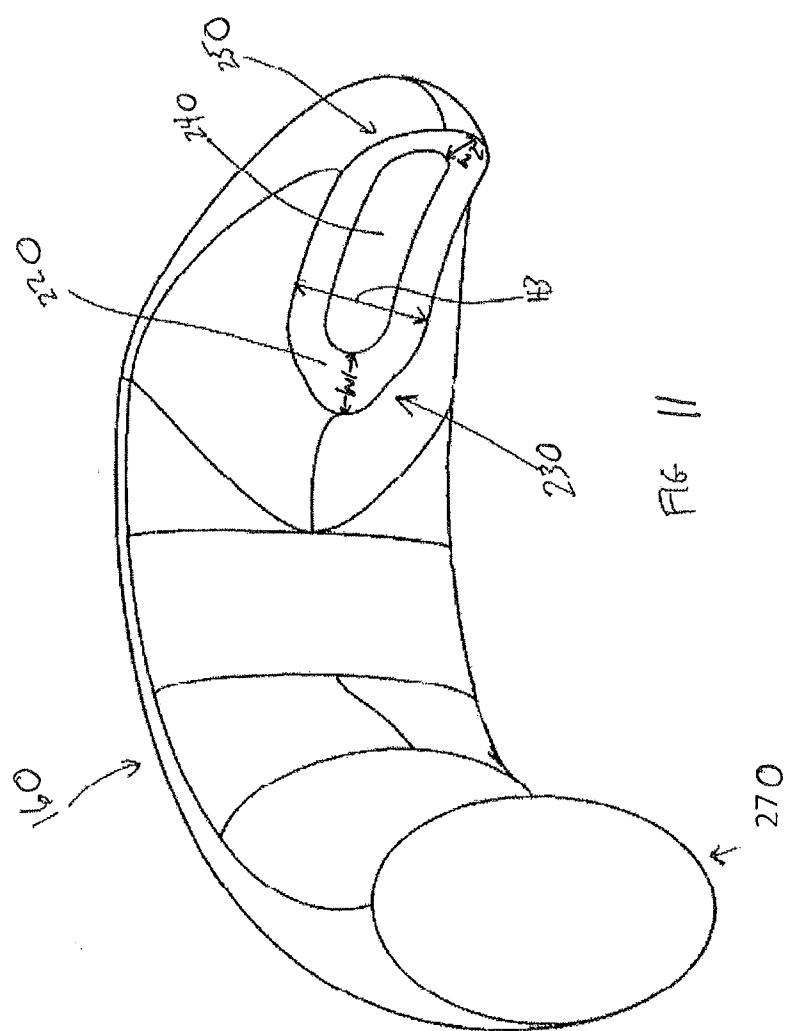
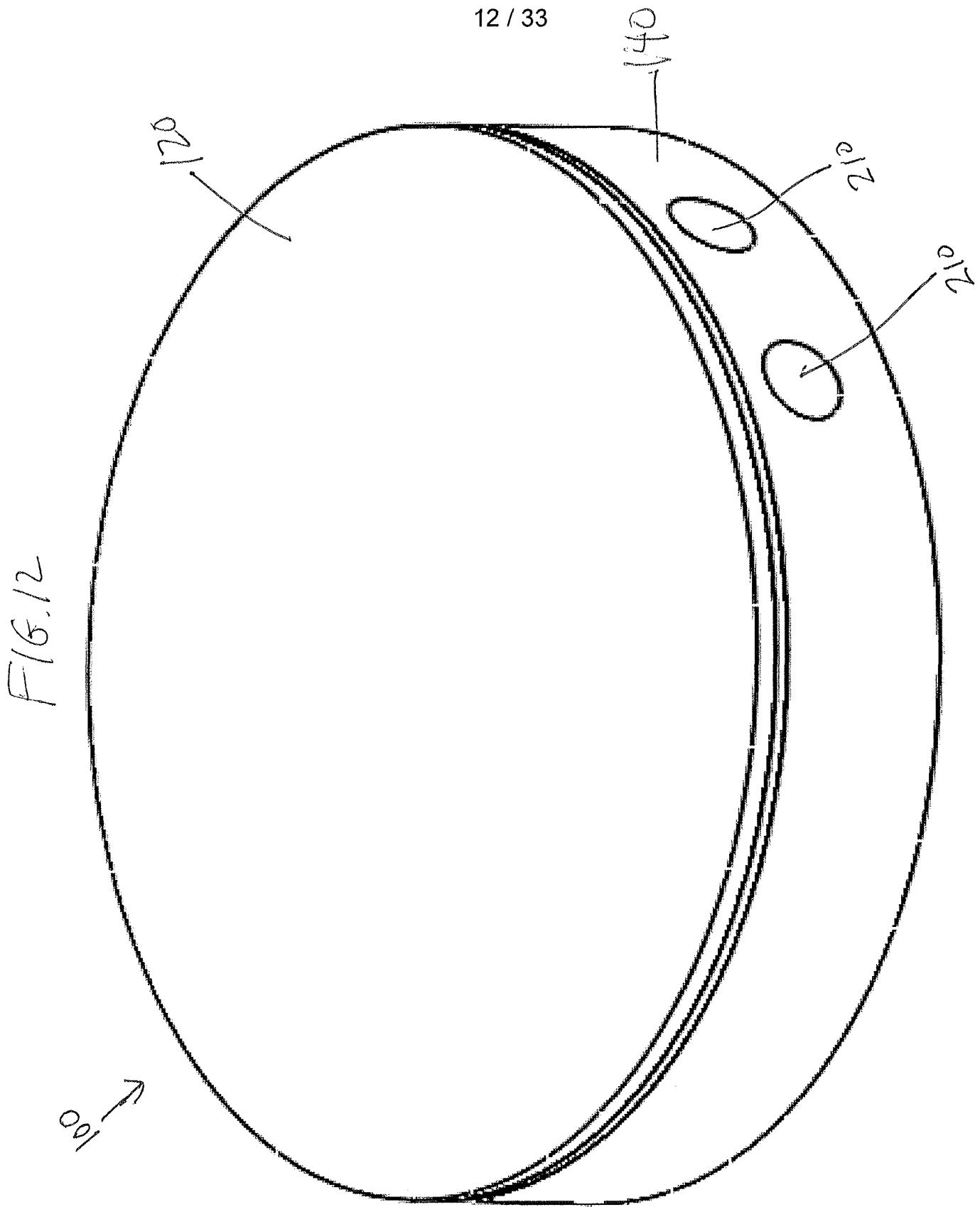
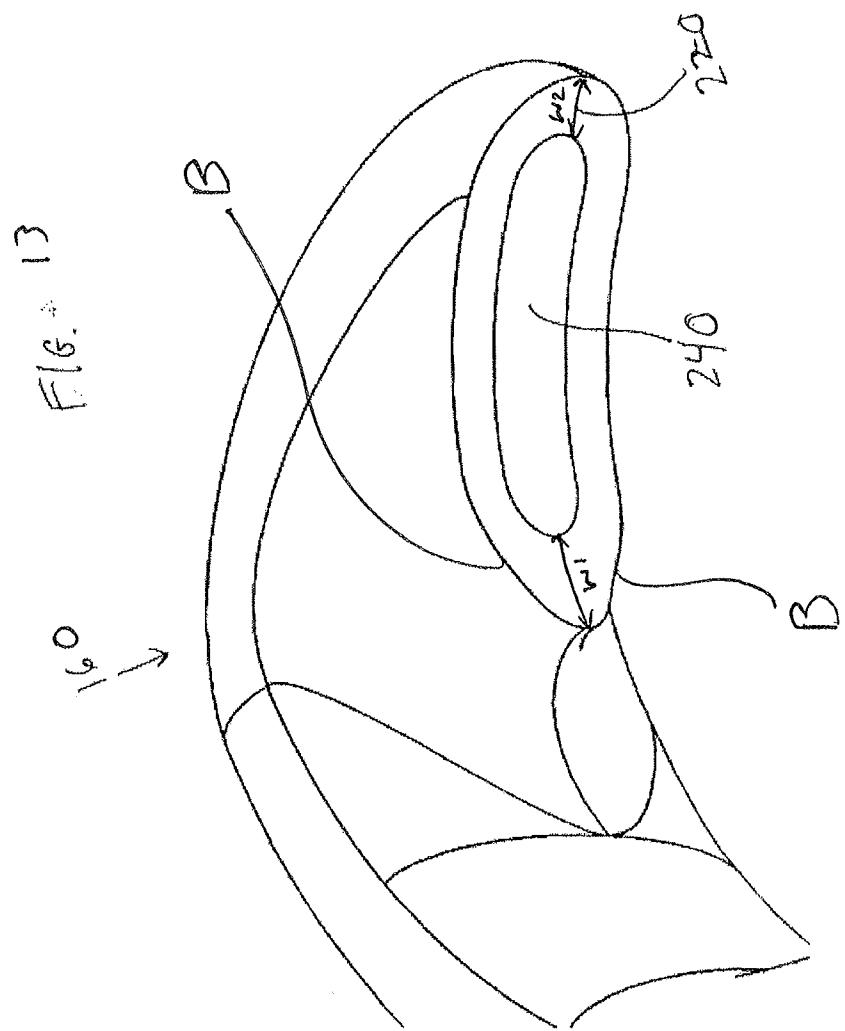


FIG. 10

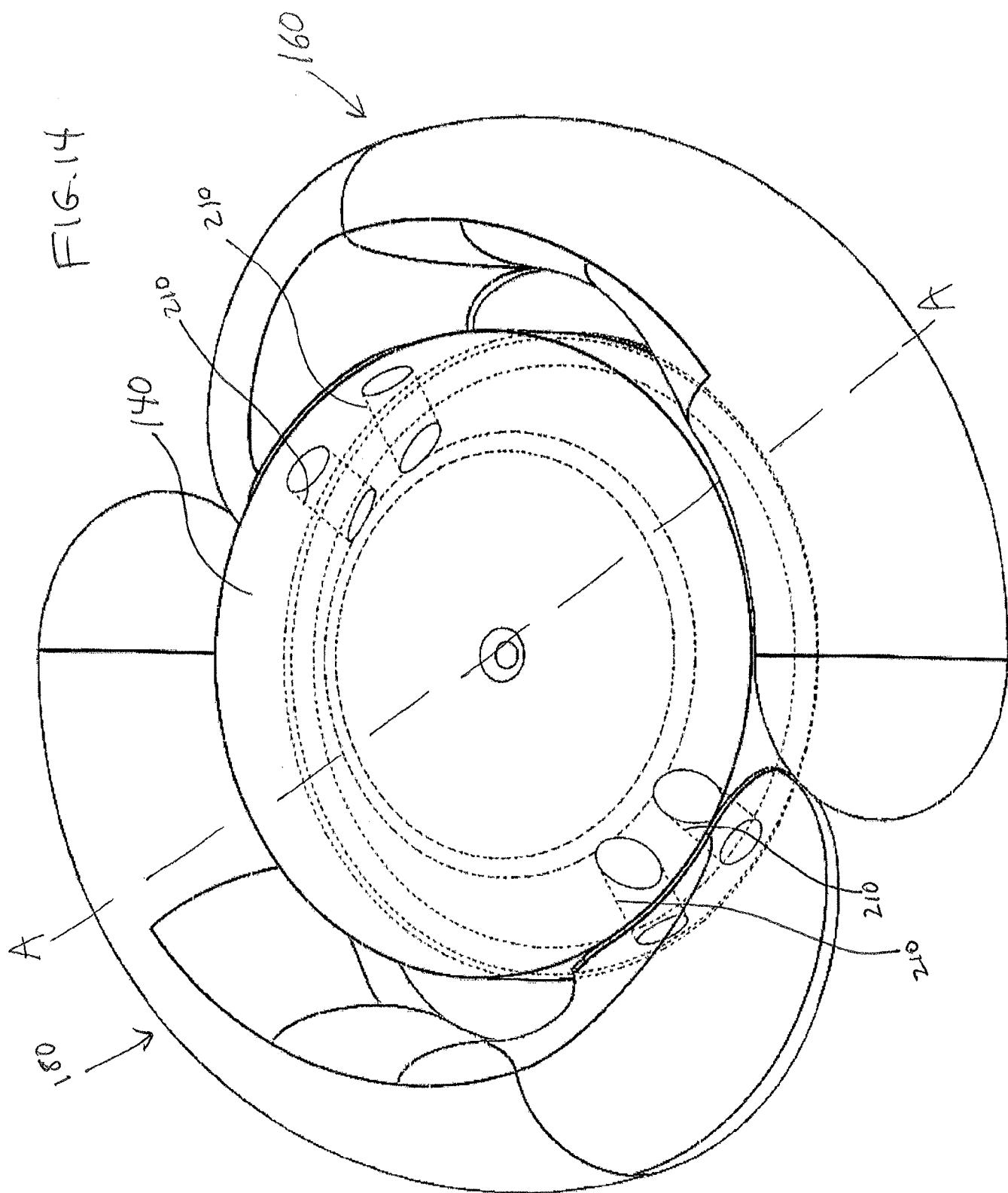


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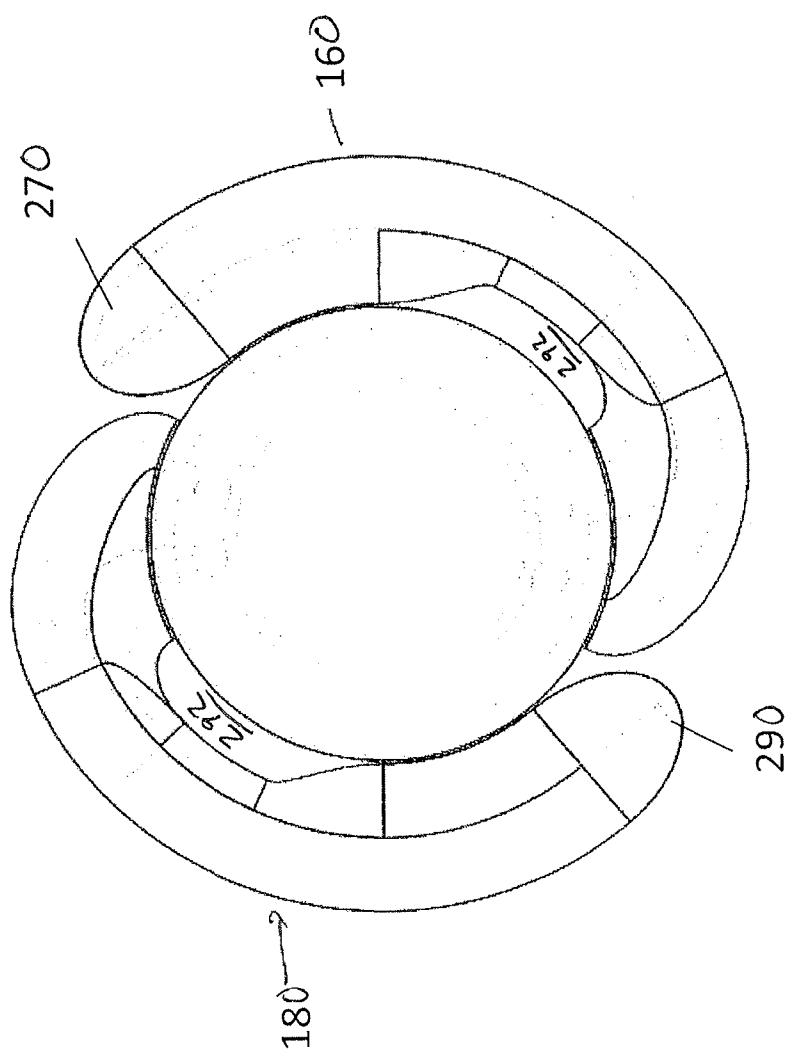
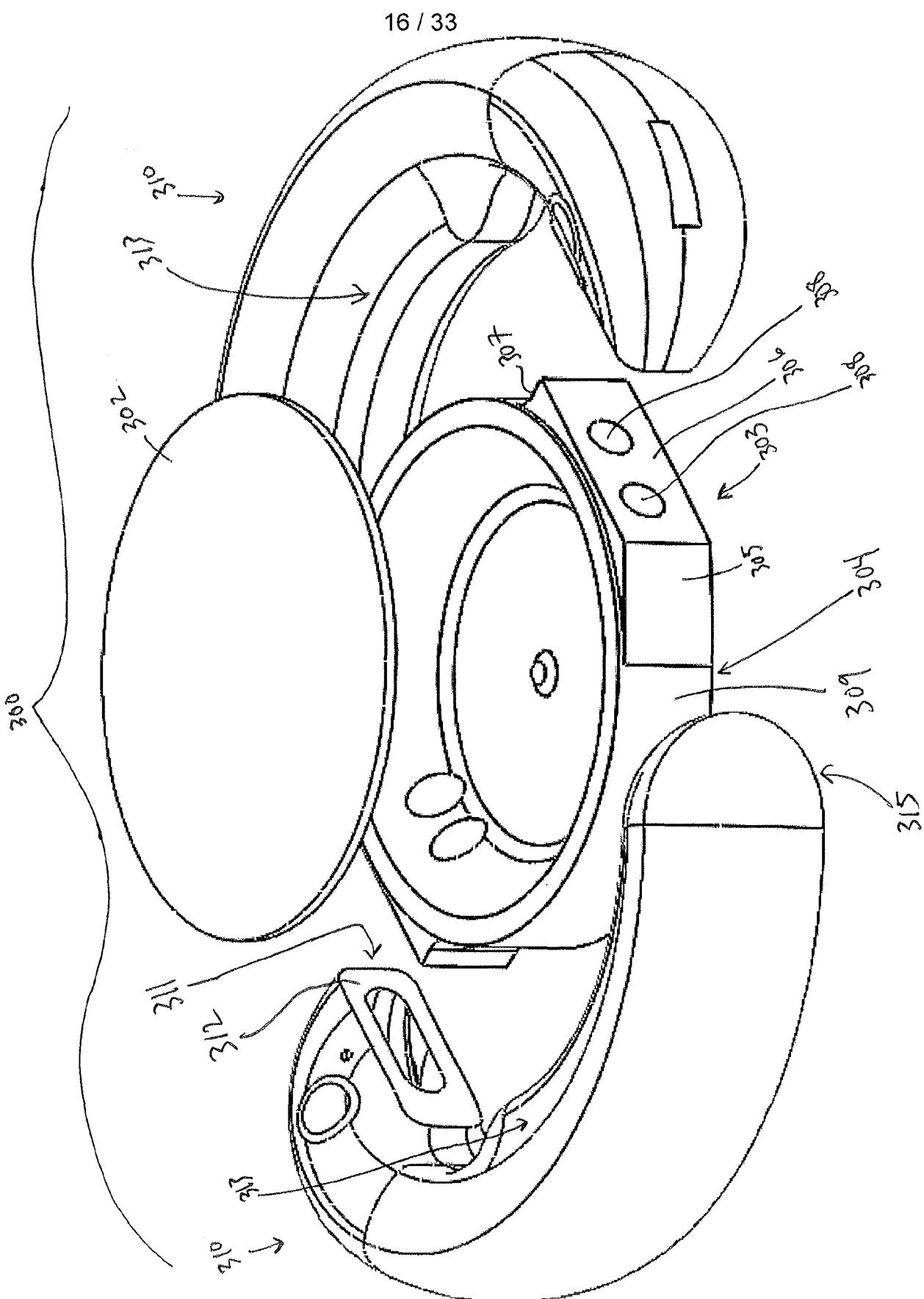


FIG. 15

FIG. 16



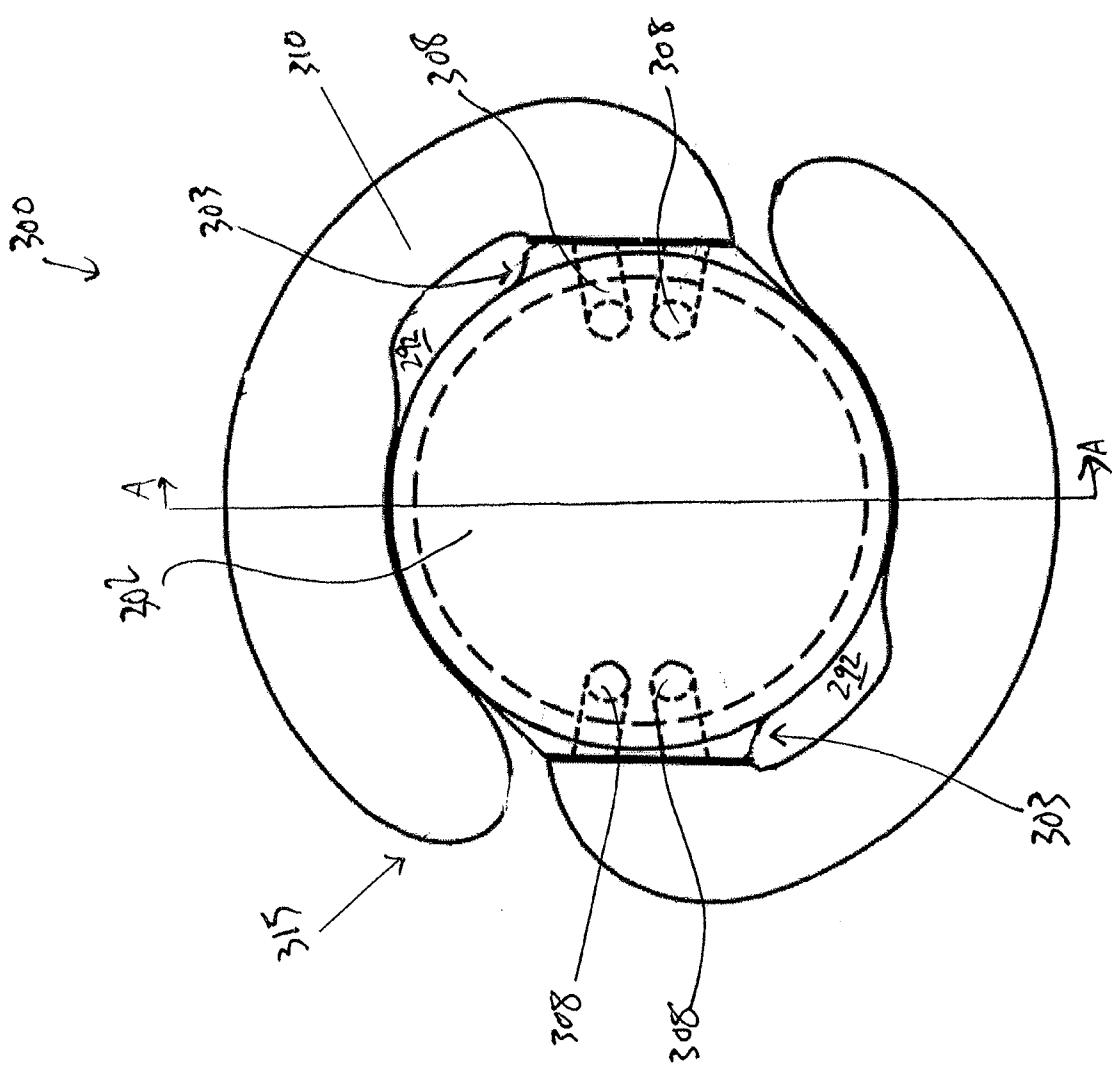


FIG. 17

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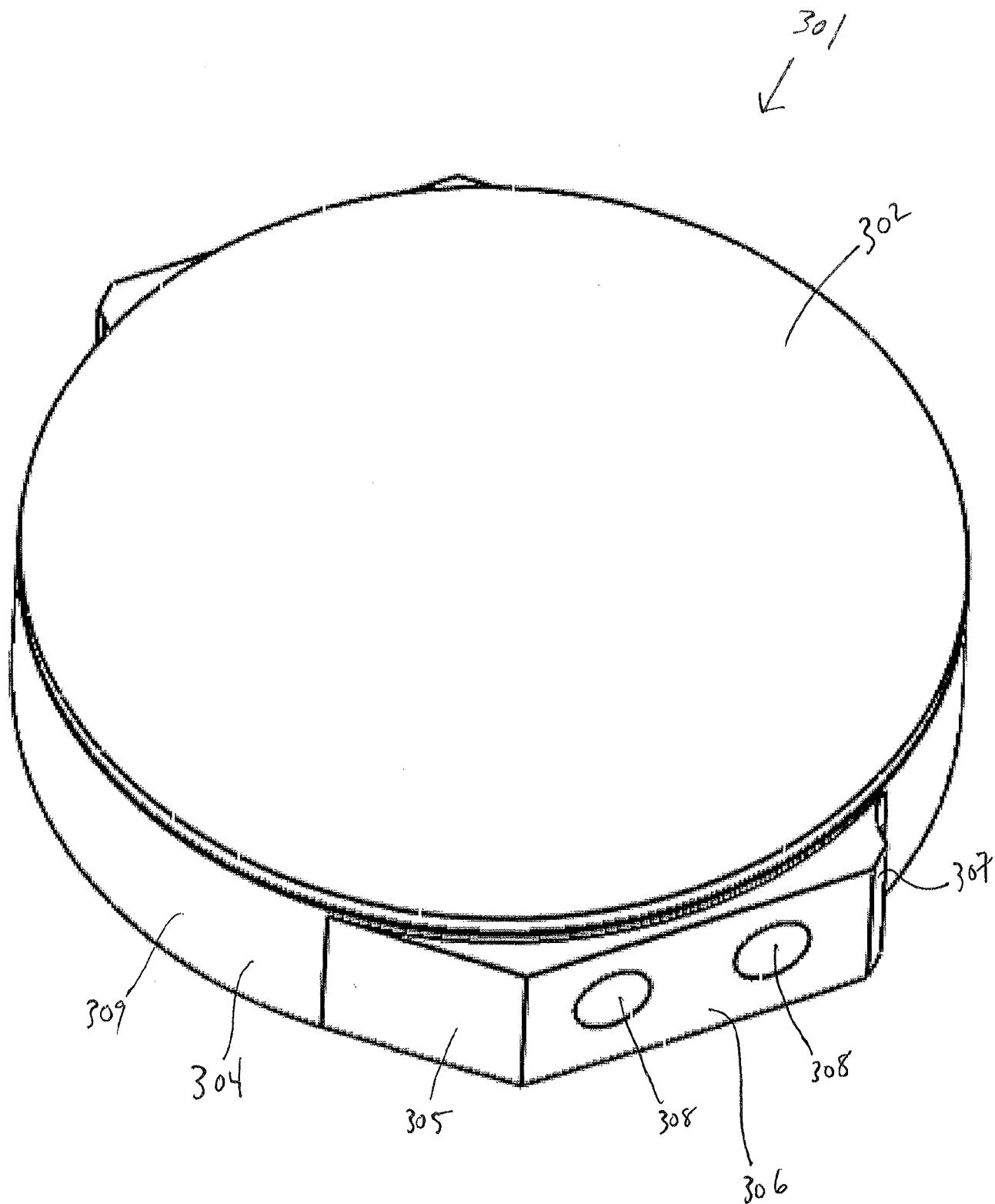
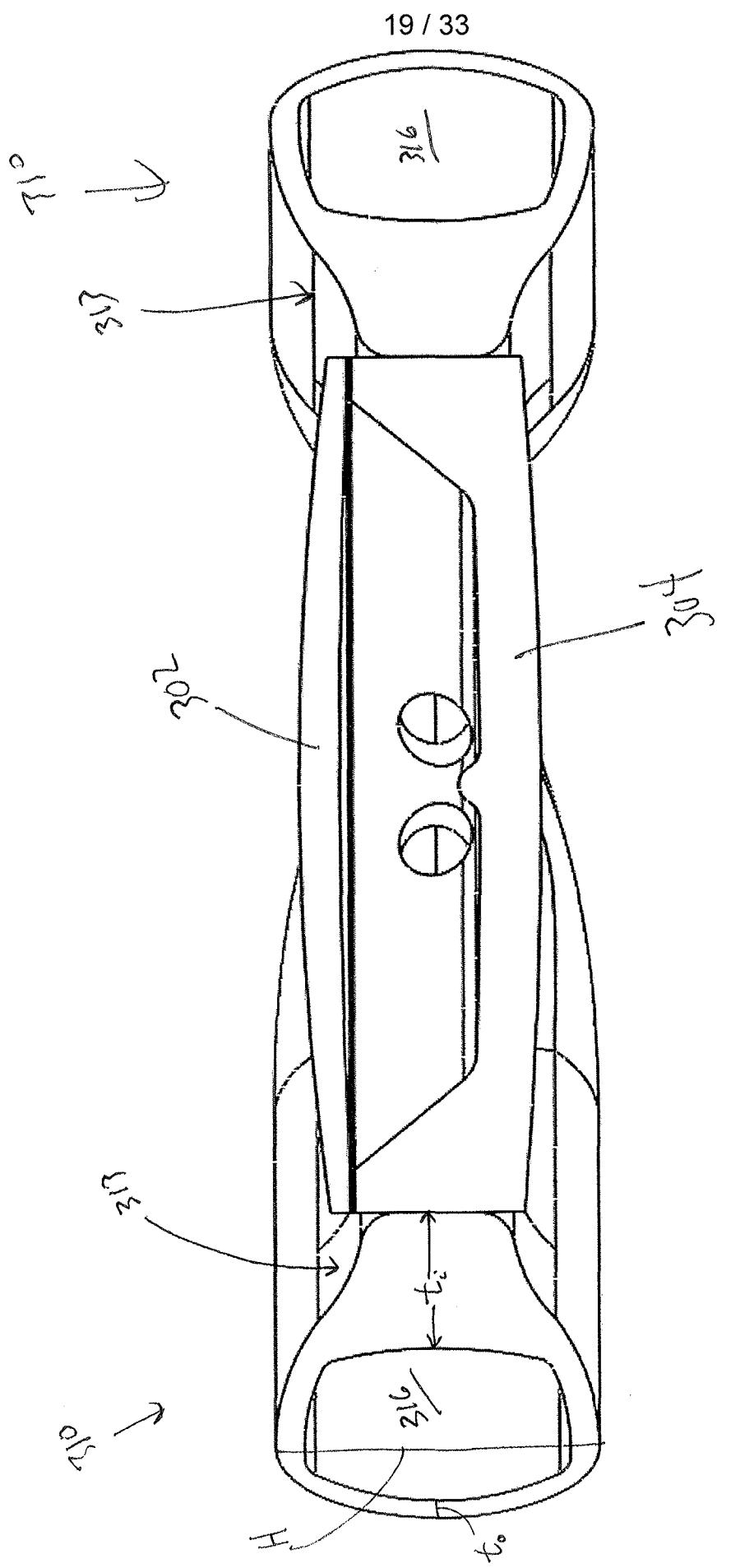


FIG. 18



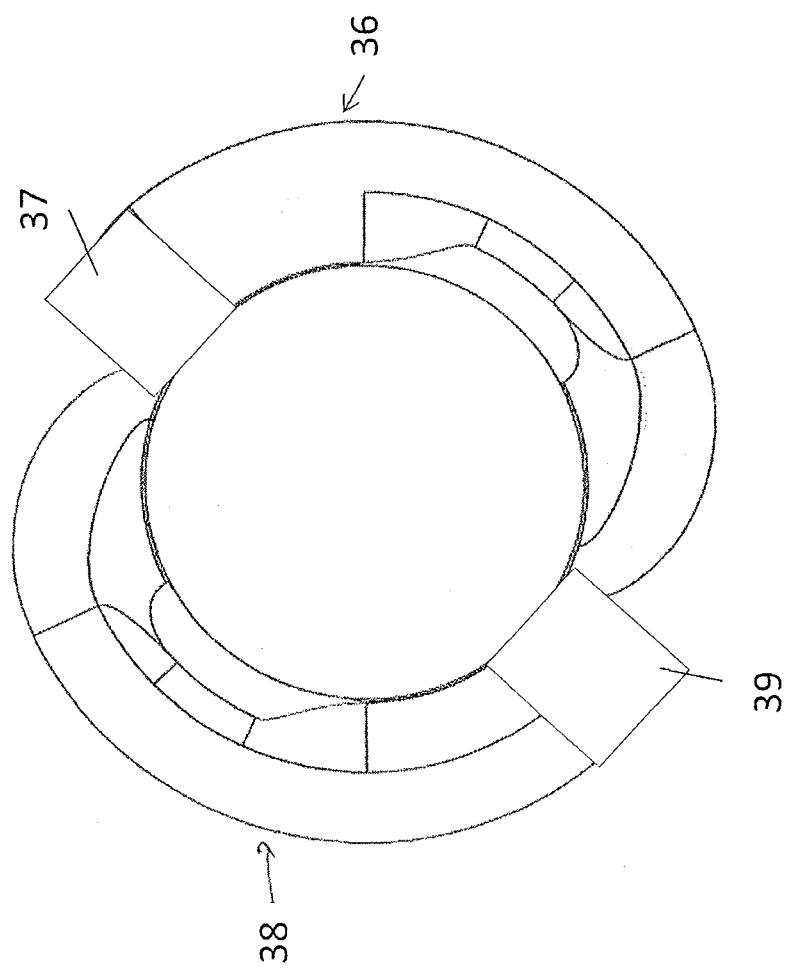


FIG. 20

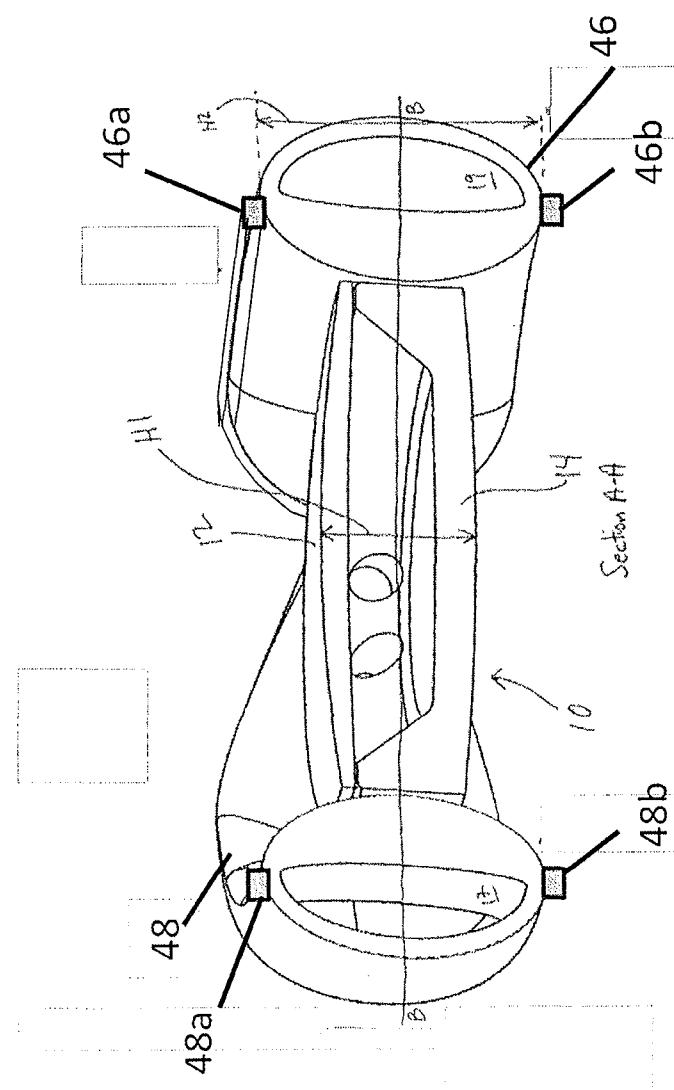


FIG. 2 |

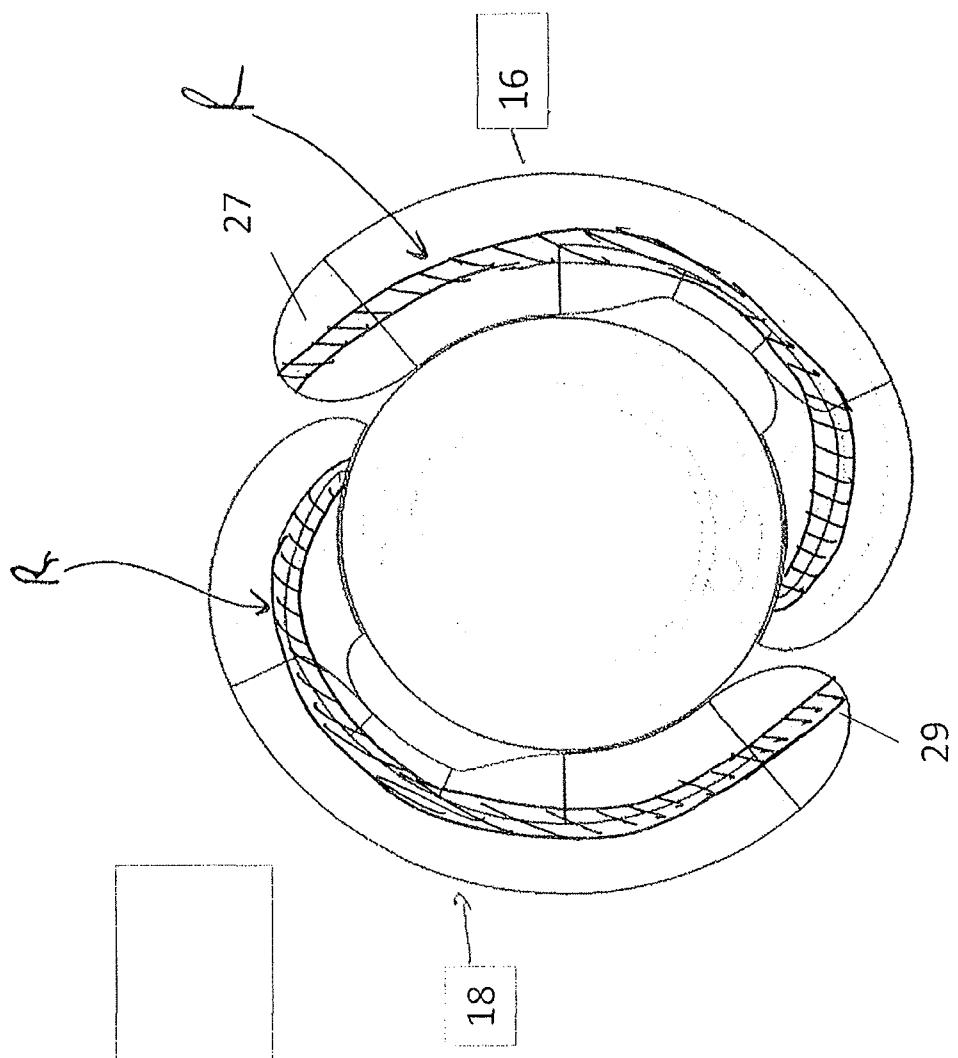
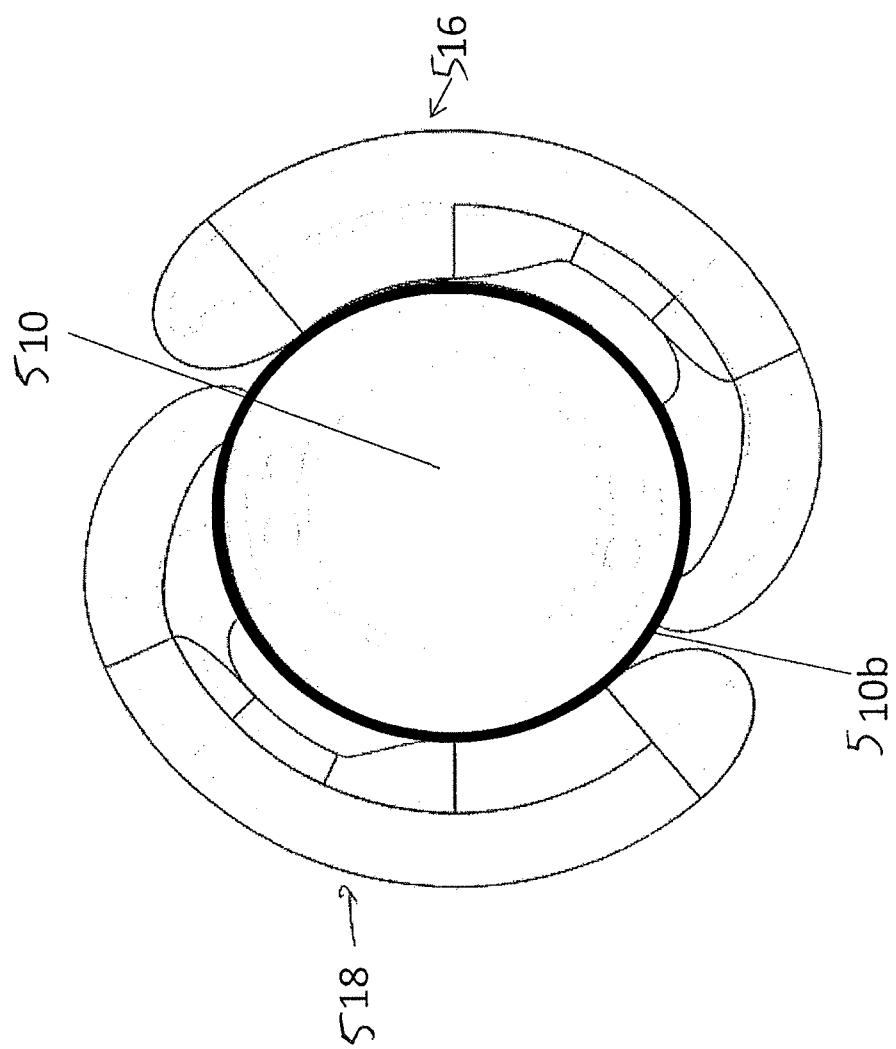


FIG. 22



23A

FIG.

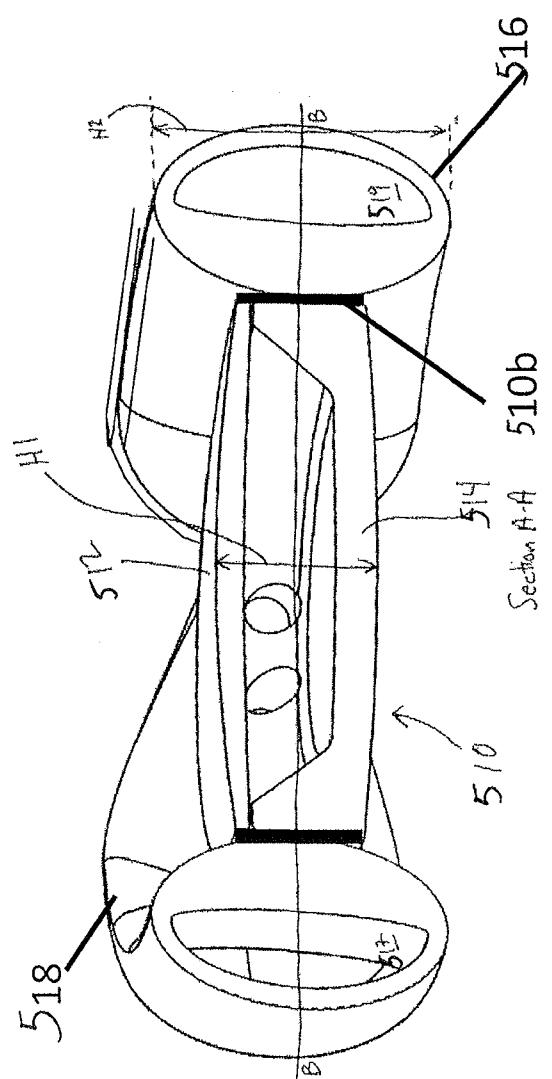


FIG.  
23B

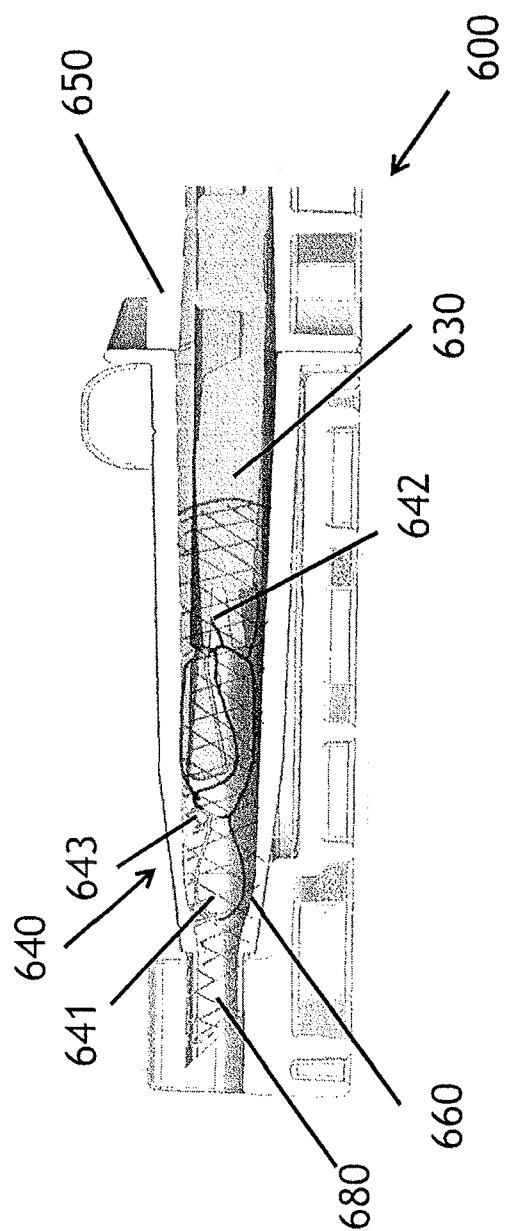
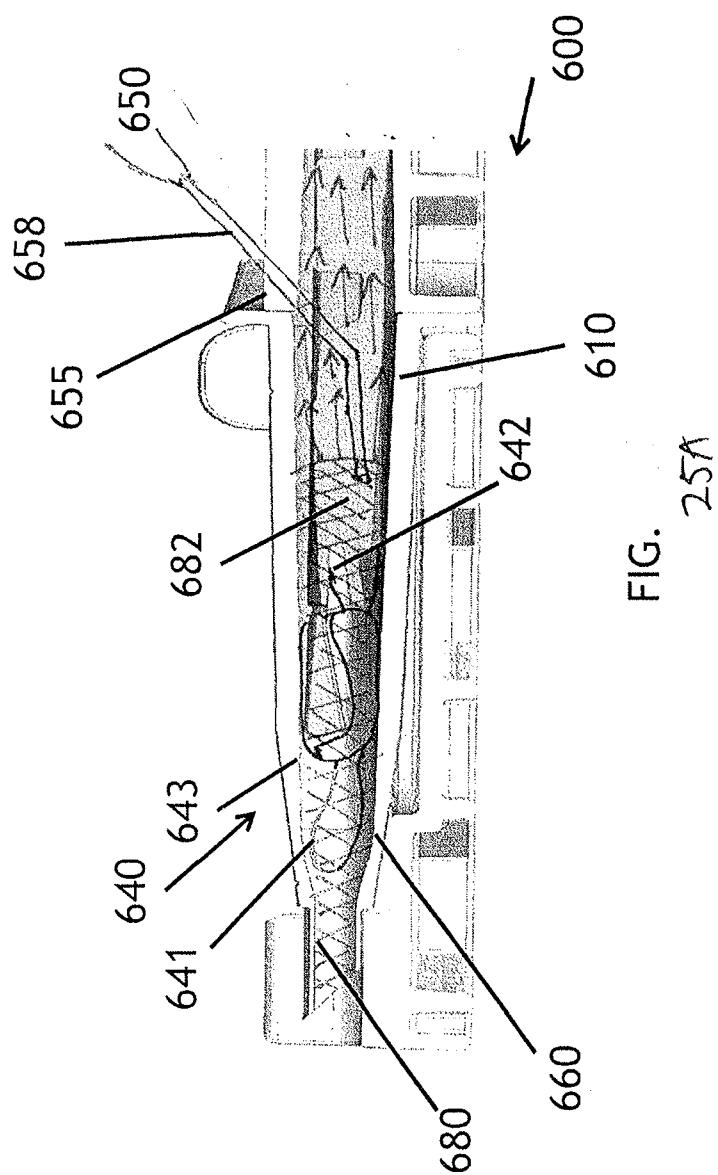


FIG. 24



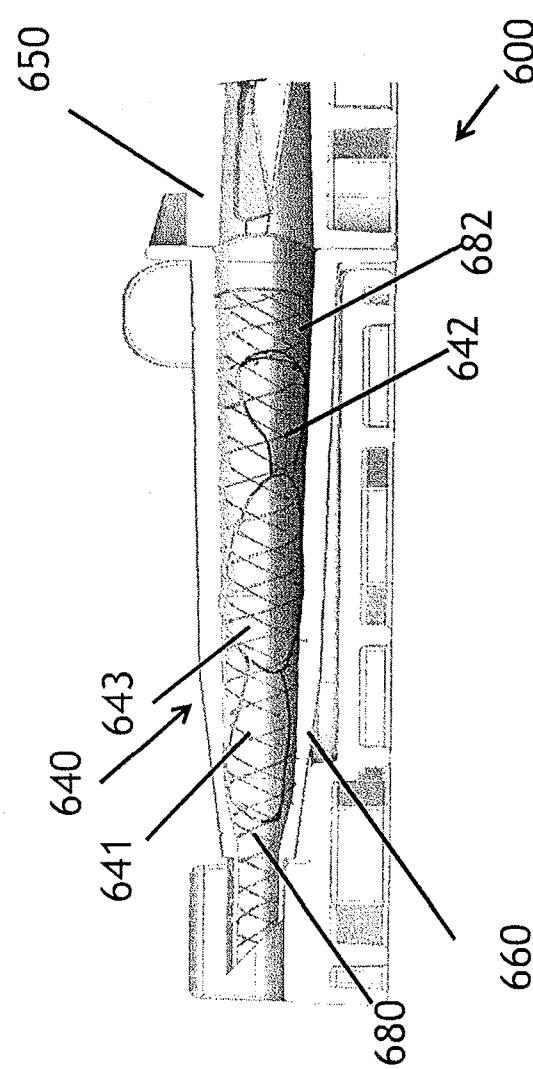


FIG. 25β

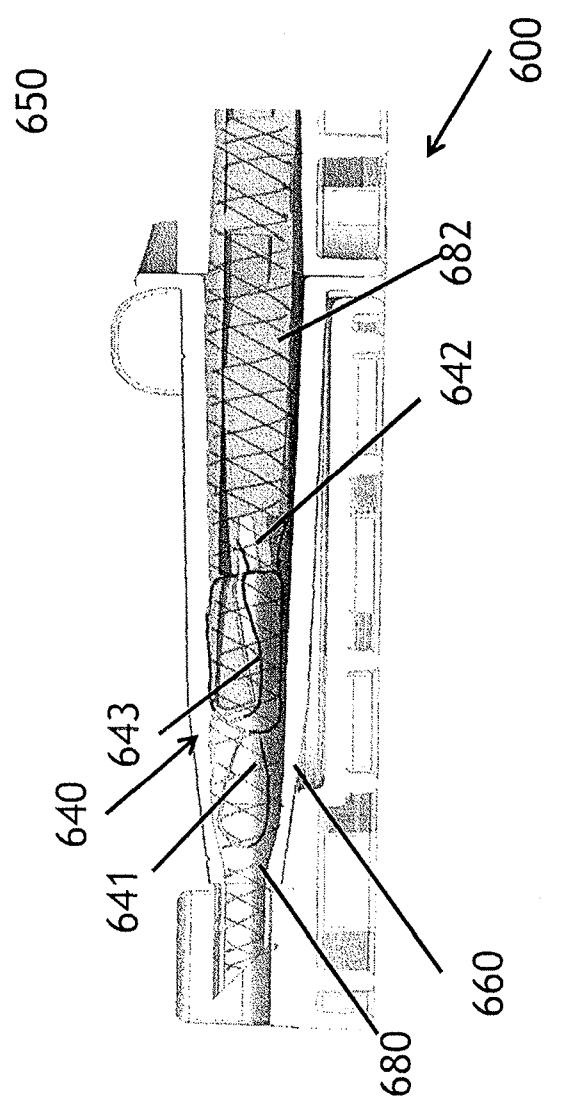
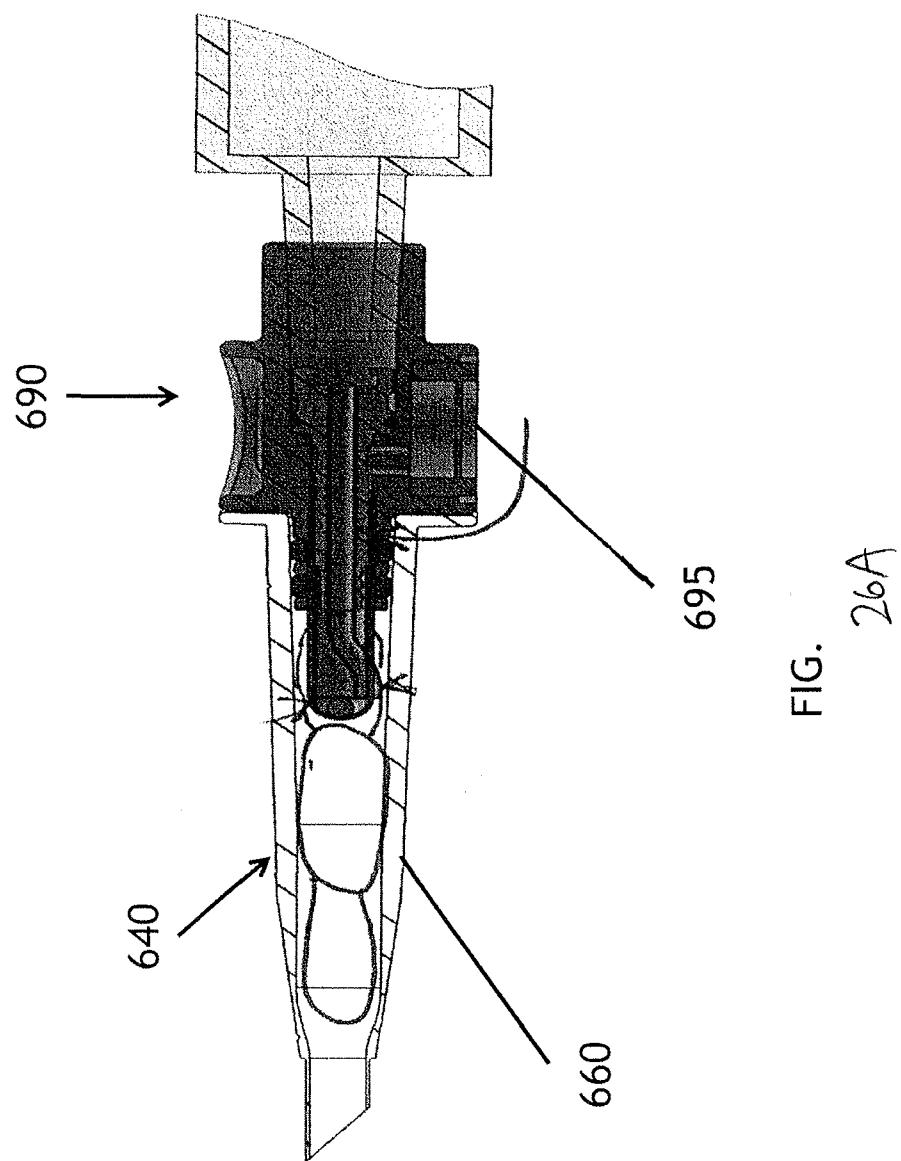
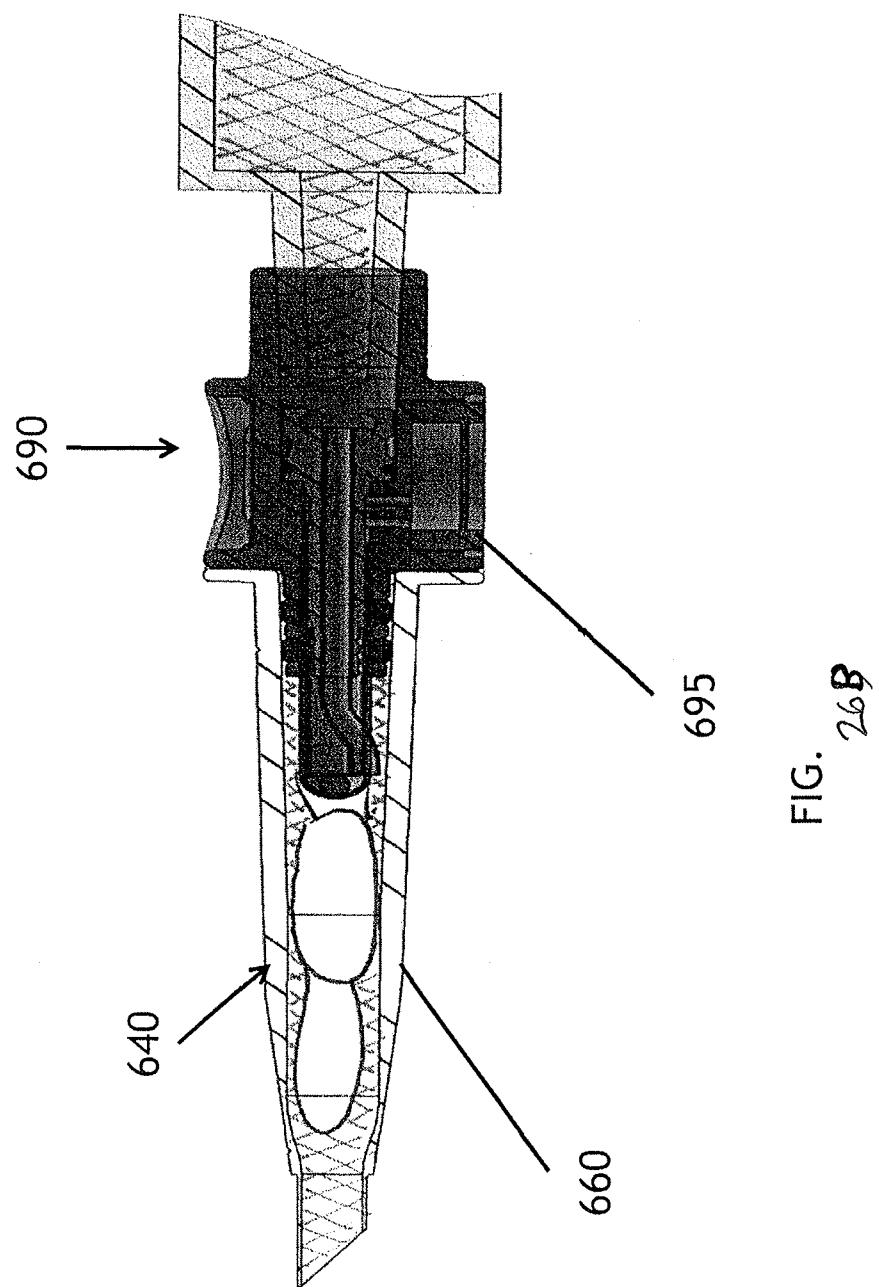
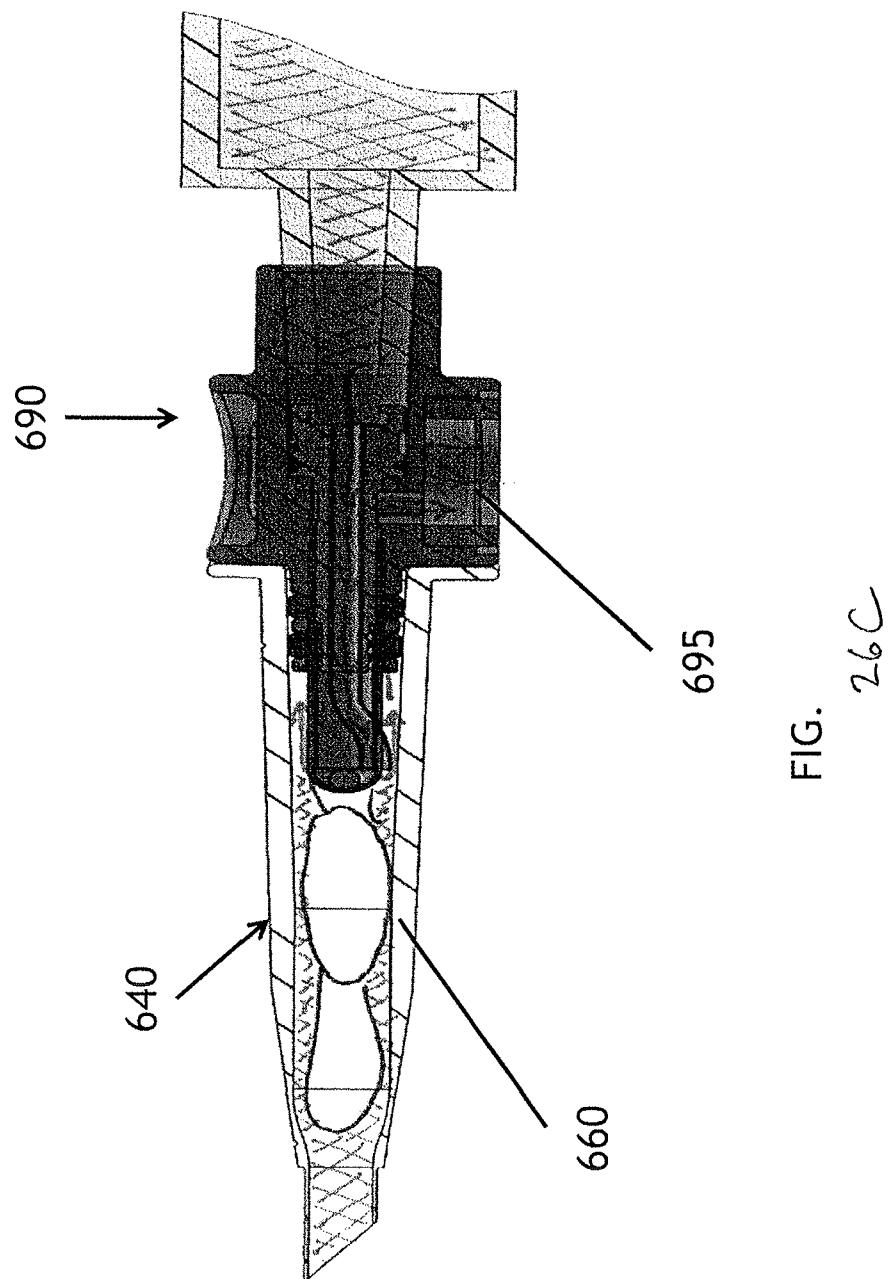


Fig. 25c







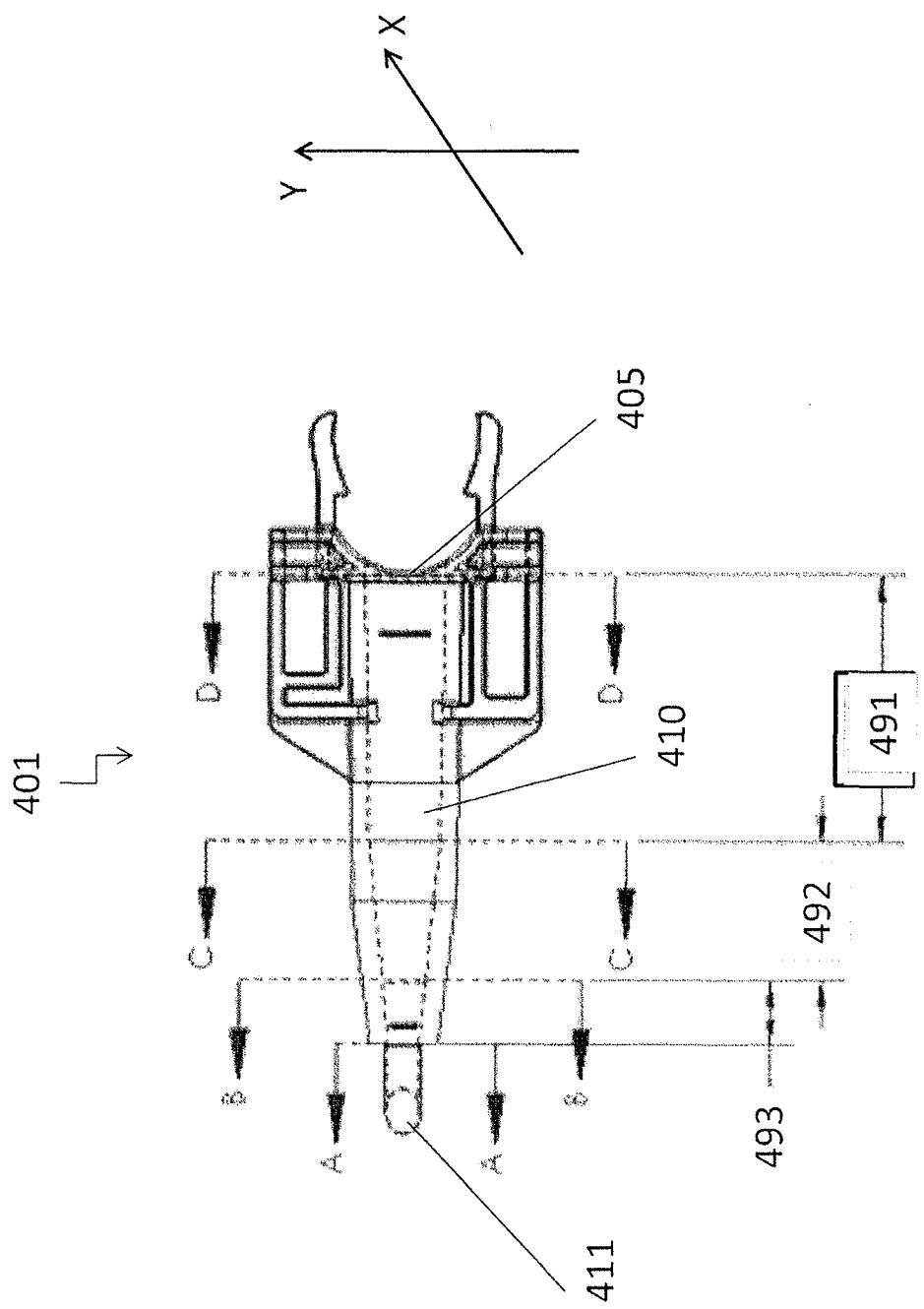
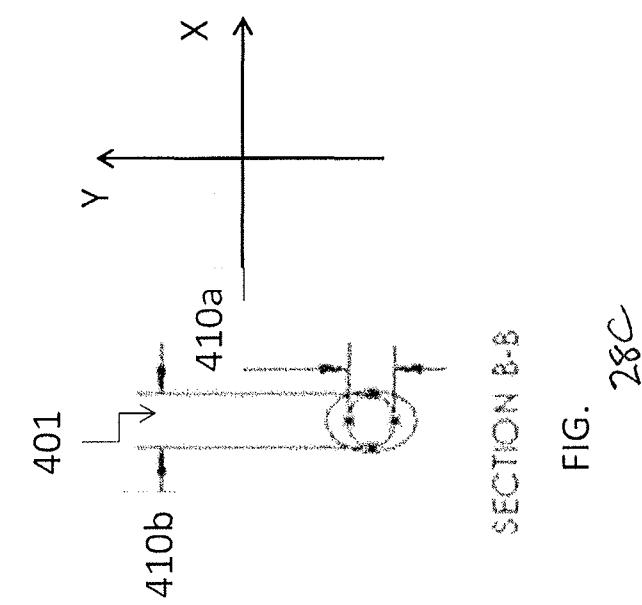
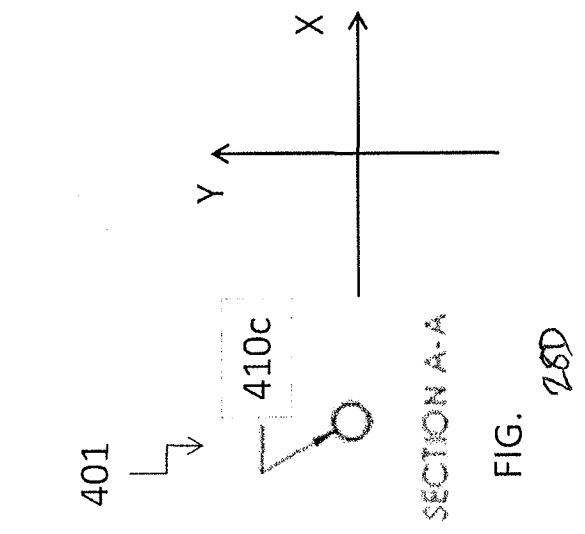
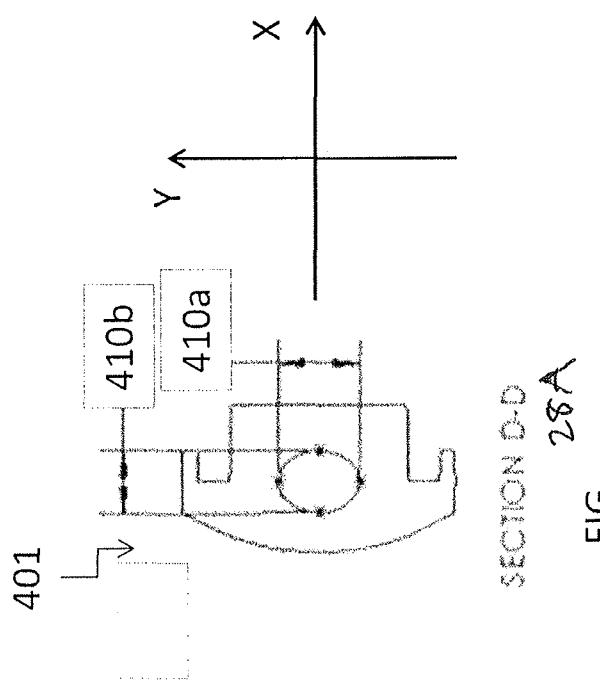
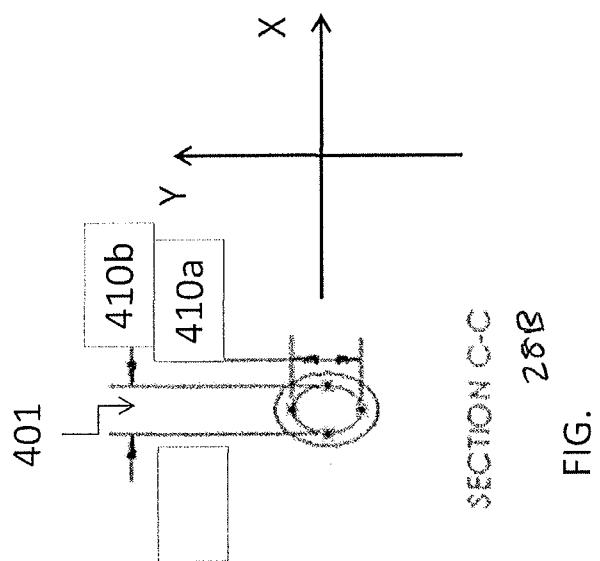


FIG.  
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**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US16/60799

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(8) - A61F2/16; G02B1/06, 3/04, 3/06, 3/12; G02C7/04 (2017.01)

CPC - A61F2/164, 2/1602, 2/1613, 2/1624, 2/1635, 2/1637, 2/1648; B29D11/023; G02B3/14; G02C7/049

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)

IPC(8) Classification(s): A61F2/14, 2/16; B29D11/02; G02B1/06, 3/04, 3/06, 3/12, 3/14, 26/00, 27/00; G02C7/04 (2017.01)

CPC Classification(s): A61F2/16, 2/164, 2/1602, 2/1613, 2/1618, 2/1624, 2/1627, 2/1629, 2/1635, 2/1637, 2/1648, 2002/1681, etc.

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)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, Other Countries (INPADOC), RU, AT, CH, TH, BR, PH), Public Patent Application Information Retrieval (PAIR); EBSCO; Google/Google Scholar; Pubmed/Medline; accommodating, optical, contact, intraocular, ocular, lens, IOL, aspherical, spherical, non-spherical, toric, oval, prior, before, after, deform, change, alter, configure, etc.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/0317607 A1 (DEBOER, C et al.) November 28, 2013; figure 5; paragraphs [0043]-[0044]	1-2, 7
---		-----
Y		4-5
X	US 2009/0005865 A1 (SMILEY, TW et al.) January 1, 2009; figures 4a-b; paragraphs [0064]-[0067], [0069], [0071], [0075]	1-3, 6-7, 20-25, 28, 30-31, 33-34, 36-37
---		-----
Y		26-27, 29, 32, 35, 38-39
Y	US 2013/0128368 A1 (FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV) May 23, 2013; figure 12a; paragraphs [0087]-[0088]	4-6
Y	US 2003/0135273 A1 (CALLAHAN, WB) July 17, 2003; figure 7; paragraphs [0118], [0140]	26-27
Y	US 2007/0106377 A1 (SMITH, DJ et al.) May 10, 2007; figure 11a; paragraphs [0027], [0100]-[0101]	26-27, 29, 32, 35
Y	WO 95/02378 A1 (KABI PHARMACIA OPHTHALMICS, INC.) January 26, 1995; figures 11-12; page 19, lines 1-37	38-39
X; P	US 2016/0106534 A1 (DEBOER, C et al.) April 21, 2016; figures 8a-b; paragraphs [0058]-[0059]	1, 7

Further documents are listed in the continuation of Box C.

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

13 February 2017 (13.02.2017)

Date of mailing of the international search report

09 MAR 2017

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents  
P.O. Box 1450, Alexandria, Virginia 22313-1450  
Facsimile No. 571-273-8300

Authorized officer

Shane Thomas

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US16/60799

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

-\*\*\*-Continued Within the Next Supplemental Box-\*\*\*-

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-7, 20-39

**Remark on Protest**

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
PCT/US16/60799

-\*\*\*-Continued from Box No. III Observations where unity of invention is lacking-\*\*\*-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

**Group I:** Claims 1-7 and 20-39 are directed toward a device and method comprising: a fluid-filled intraocular lens, comprising: an optic portion: comprising an anterior element with an anterior optical surface and a posterior element with a posterior optical surface, the anterior element and the posterior element defining an optic fluid chamber, wherein at least one of the anterior optical surface and the posterior optical surface has an aspherical configuration in an as-manufactured state, prior to insertion in an eye.

**Group II:** Claims 8-18 are directed toward an intraocular lens, comprising: an optic portion; and a peripheral portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, having a height dimension measured in an anterior to posterior direction, wherein the greatest height of the peripheral portion in a radially outer half of the peripheral portion is greater than the greatest height of the peripheral portion in a radially inner half of the peripheral portion.

**Group III:** Claims 19 and 40 are directed toward an intraocular lens comprising an optic body, a projection extending radially outwards from a peripheral surface of the optic body and a peripheral non-optic body, having a first portion secured to the projection.

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include an anterior element with an anterior optical surface and a posterior element with a posterior optical surface, the anterior element and the posterior element defining an optic fluid chamber, wherein at least one of the anterior optical surface and the posterior optical surface has an aspherical configuration in an as-manufactured state, prior to insertion in an eye which are not present in Groups II or III.

The special technical features of Group II include the peripheral portion including a peripheral fluid chamber, the peripheral portion, in a cross section of a plane passing through an optical axis of the optic portion, having a height dimension measured in an anterior to posterior direction, wherein the greatest height of the peripheral portion in a radially outer half of the peripheral portion is greater than the greatest height of the peripheral portion in a radially inner half of the peripheral portion which are not present in Groups I or III.

The special technical features of Group III include a projection extending radially outwards from a peripheral surface of the optic body which are not present in Groups I or II.

The common technical features of Groups I-III are an intraocular lens comprising an optic body portion and a peripheral body. These common technical features are disclosed by US 2007/0106377 A1 (SMITH, DJ et al.). Smith discloses a fluid-filled intraocular lens (IOL, intraocular lens, 120; figures 11a-b; paragraph [0099]), comprising: an optic body portion (121; figures 11a-b; paragraph [0099]); and a peripheral body (122; haptic portion is disposed at the periphery of optic portion; figures 11a-b; paragraphs [0029], [0099]).

Since the common technical features are previously disclosed by Smith, these common features are not special and so Groups I-III lack unity.