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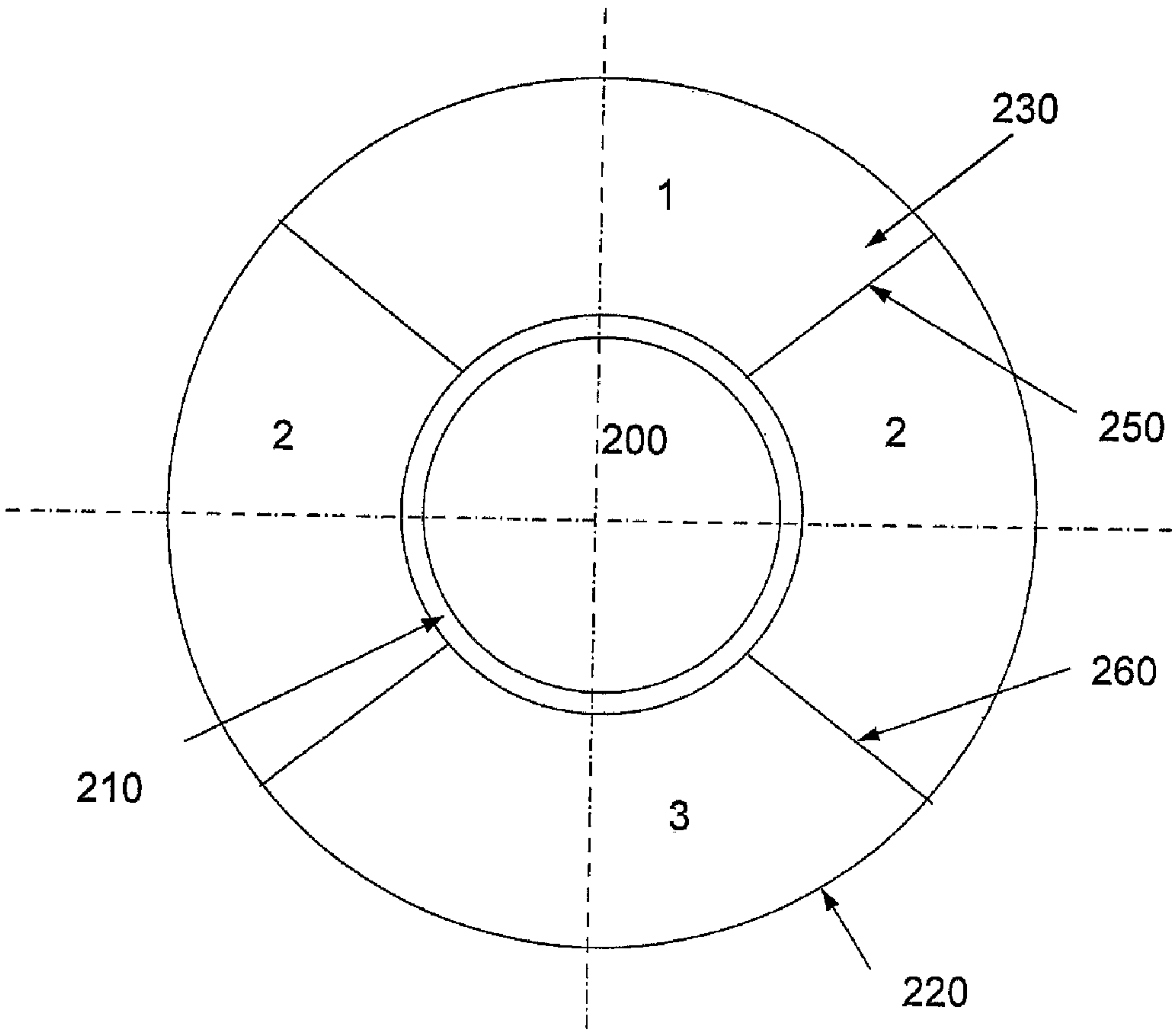
(72) **Inventeurs/Inventors:**
YE, MING, US;
MCKENNEY, CURTIS DEAN, US

(73) **Propriétaire/Owner:**
NOVARTIS AG, CH

(74) **Agent:** FETHERSTONHAUGH & CO.

(54) **Titre : CONCEPTION DE LENTILLE TORIQUE**
(54) **Title: A TORIC LENS DESIGN**



(57) **Abrégé/Abstract:**
This invention is related to contact lenses. In particular, the present invention is related to a toric contact lens design with a plurality thickness zones in the carrier portion of the lens for increased rotational stability.

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(71) Applicant *(for all designated States except AT, US)*: **NOVARTIS AG** [CH/CH]; Lichtstrasse 35, CH-4056 Basel (CH).

(71) Applicant *(for AT only)*: **NOVARTIS PHARMA GMBH** [AT/AT]; Brunner Strasse 59, A-1230 Vienna (AT).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **YE, Ming** [US/US]; 5100 Alaire Dr., Fort Worth, TX 76132 (US). **MCKENNEY, Curtis, Dean** [US/US]; 2466 Stonecroft Way, Duluth, GA 30097 (US).

(74) Agent: **ROTH, Peter**; Novartis AG, Corporate Intellectual Property, CH-4002 Basel (CH).

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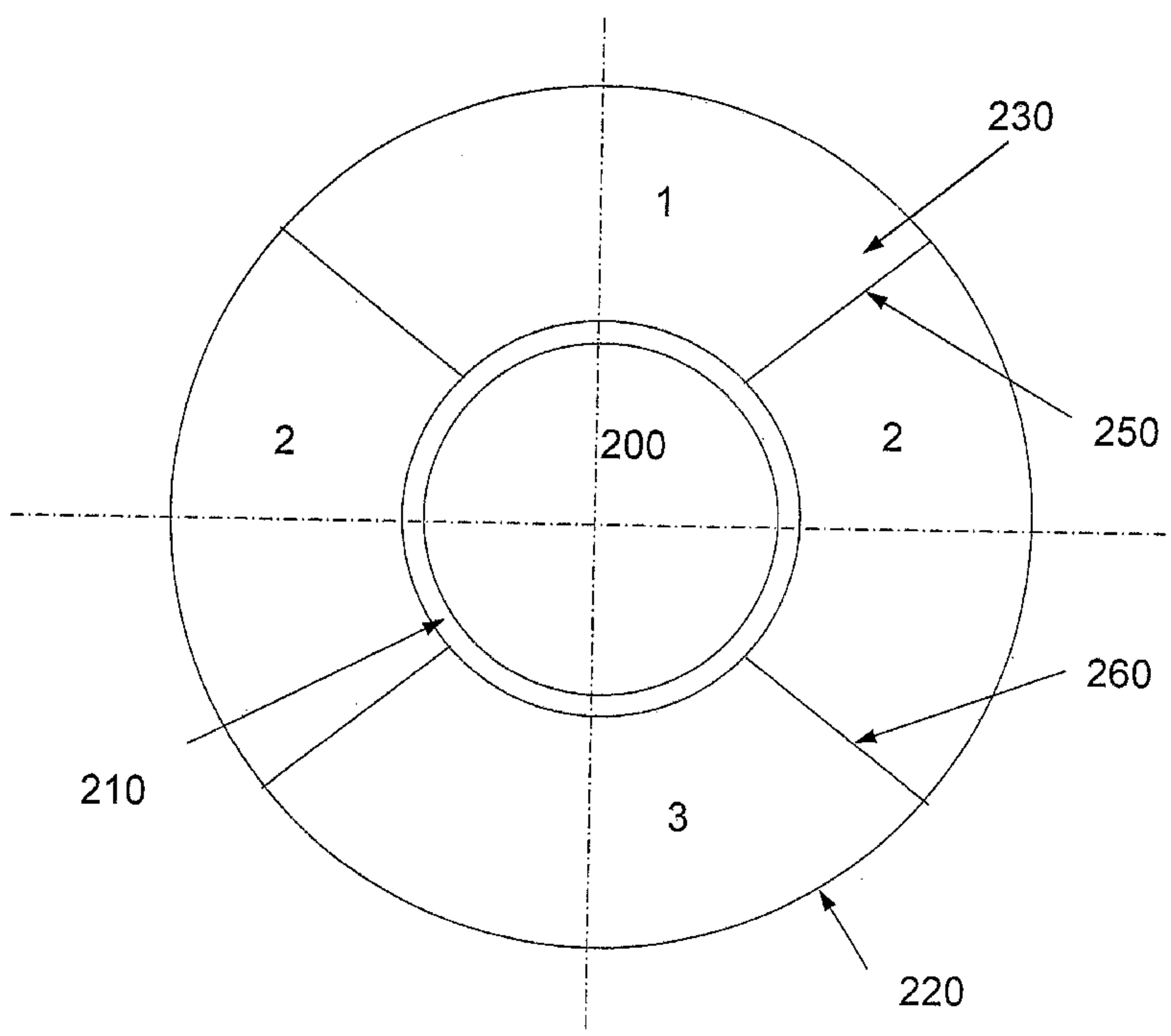
(54) **Title:** A TORIC LENS DESIGN



(57) **Abstract:** This invention is related to contact lenses. In particular, the present invention is related to a toric contact lens design with a plurality thickness zones in the carrier portion of the lens for increased rotational stability.

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A toric lens design

This invention is related to contact lenses. In particular, the present invention is related to a toric contact lens design with a plurality of thickness zones in the carrier portion of the lens for increased rotational stability.

Contact lenses are widely used for correcting many different types of vision deficiencies. These include defects such as near-sightedness and far-sightedness (myopia and hypermetropia, respectively), astigmatism vision errors, and defects in near range vision usually associated with aging (presbyopia).

Astigmatism is optical power meridian-dependent refractive error in an eye. This is usually due to one or more refractive surfaces, most commonly the anterior cornea, having a toroidal shape. It may also be due to one or more surfaces being transversely displaced or tilted. Astigmatism is usually regular, which means that the principal (maximum and minimum power) meridians are perpendicular to each other. People with astigmatism have blurred vision at all distances, although this may be worse at distance or near, depending on the type of astigmatism. These people may complain of sore eyes and headaches associated with demanding visual tasks. Astigmatism can be corrected with an astigmatic ophthalmic lens, which usually has one spherical surface and one toroidal (cylindrical) surface.

Because toric lenses have a cylindrical surface, orientation of the lens is of particular importance. Hence, most contact lenses have one or more orientation features that provide a predetermined orientation on the eye. Typical orientation features include two thin zones at the top and bottom of the lens as well as prism ballast.

US 6113236 discloses a toric contact lens including a posterior surface and an anterior surface, one of said surfaces including a toric optical zone and the other of said surfaces including a spherical optical zone, the anterior and posterior surfaces being shaped to form a ballast oriented about a ballast axis, wherein a diameter of the posterior optical zone and a diameter of the anterior zone are selected to minimize thickness of the lens based on the cylindrical correction of the lens.

US 6595639 discloses a method for designing and manufacturing ophthalmic lenses having one or more substantially smooth, junctionless, three dimensional surfaces, for example, wherein the surface or surfaces may have one or more asymmetrical components. The methods are very well suited for the design of toric contact lenses, for example a toric contact lens including a posterior toric optical zone and an anterior surface shaped to provide the lens with appropriate optical power and a thickness profile facilitating lens orientation and stabilization in the form of a ballast.

US 6467903 discloses a contact lens having a rotational stabilization mechanism thereon, such as prism ballast, and a thickness profile that reduces the torque imparted on the lens by the action of the eyelids, especially for stabilizing toric lenses, wherein the lens body has a uniform thickness of within 10% along horizontal cross-sections. The lens has a peripheral zone, an inner zone circumscribed by the peripheral zone, and a central optic zone. The prism ballast portion increases in thickness along a superior-inferior line parallel to a vertical meridian, and has a substantially uniform thickness perpendicular thereto. The rate of thickness change across any portion of the peripheral zone is less than about 250 µm/mm.

According to an aspect of the present invention, there is provided a toric contact lens comprising a central optical zone, a vertical meridian, a transition zone surrounding said central optical zone, a carrier extending from said transition zone outward and a plurality of thickness zones in said carrier, wherein said plurality of thickness zones comprises at least three thickness zones, including a first thickness zone, a second thickness zone, and a third thickness zone, wherein the first thickness zone is arranged at a top of said toric contact lens and the third thickness zone is arranged at a bottom of said toric contact lens, and wherein the second thickness zone is symmetrical across the vertical meridian on the sides of said toric contact lens, wherein further an upper boundary between the first thickness zone and the second thickness zone is at least 15 degrees from the vertical meridian as measured from the top of said toric contact lens, and wherein a lower boundary between the third thickness zone and the second thickness zone is at least 30 degrees from the vertical meridian as measured from the bottom of said toric contact lens, and wherein there is a relatively consistent thickness section at each angular meridian within the second thickness zone, the width of the relatively consistent thickness section being at least 30% of the zone width of said second thickness zone, with the thickness change in the relatively consistent thickness section being equal to or less than 10% of the maximum thickness at the respective angular meridian.

Some embodiments may seek to complement the toric lens designs of the prior art and to correct the inadequacies of the prior art.

In one aspect the present disclosure provides a toric contact lens design having a plurality of thickness zones in the carrier portion of the lens for increased rotational stability.

One embodiment of the present invention includes a toric contact lens design with a central optical zone, a vertical meridian, a transition zone surrounding said central optical zone, a carrier extending from the central optical zone, and a plurality of thickness zones that are designed to achieve rotational stability. In some embodiments, the toric contact lens may have one or more transition zones. In one embodiment, a transition zone may be located between the central optical zone 1 and the carrier. In another embodiment, two transition zones may be present; one located between the central optical zone 1 and the carrier and another located between the carrier and the lens edge.

In some embodiments, the toric contact lens design preferably includes at least three thickness zones. In a related embodiment, each thickness zone may have two boundaries. In some embodiments, preferably, the second zone is symmetrical across the vertical meridian on the sides of the lens. In another embodiment, the first and third thickness zones may be at the top and bottom of the lens design.

In one embodiment of the present invention, the boundary between the first and second zone is at least 15 degrees from the vertical meridian. In another preferred embodiment, the boundary is at least 25 degrees from the vertical meridian. In still another more preferred embodiment, the boundary is at least 45 degrees from the vertical meridian.

In some embodiments, the thickness profiles of the contact lens are preferably measured along angular meridians.

In one embodiment, the thickness profile of the second zone increases from its upper boundary to its lower boundary. In a related embodiment, the slope of the thickness profile of the second thickness zone may be a linear function, which may be constant or have a positive or negative slope. In another embodiment, the slope of the thickness profile of the second thickness zone may be a step function. In still another embodiment, the slope of the thickness profile of the second thickness zones may also gradually increase and subsequently decrease from the upper boundary to the lower boundary.

In some embodiments, at each angular meridian within the second thickness zone, there is a relatively consistent thickness section. The width of the section preferably is at least 30% of the zone width. The thickness change in the relatively consistent thickness section is equal or less than 10% of the maximum thickness at the meridian. The thickness profile of the second zone may have a range from the upper boundary to the lower boundary of from 0.065 mm to 0.45 mm. In a more preferred embodiment, the range of the thickness profile may be from 0.140 mm to 0.340 mm.

Some embodiments may allow the same carrier to be used for different optical zones on different contact lenses. Some embodiments may also include contact lenses having the designs disclosed herein. In some embodiments such lenses are preferably soft contact lenses.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 schematically shows the components of a basic toric lens design.

FIG. 2 depicts a lens with multiple zones in the carrier according to a preferred embodiment of the invention.

FIG. 3 is a plot showing lens thickness in various zones of a lens according to one embodiment of the present invention.

FIG. 4A is a plot that depicts the thickness profile slope in zone 2 according to one embodiment of the present invention.

FIG. 4B is a plot that depicts the thickness profile slope in zone 2 according to one embodiment of the present invention.

FIG. 4C is a plot that depicts the thickness profile slope in zone 2 according to one embodiment of the present invention.

FIG. 5A is a top view of a lens according to one embodiment of the present invention sectioned for horizontal slicing.

FIG. 5B is a side view of a lens depcited in FIG. 5A.

FIG. 6A is a top view of a lens according to one embodiment of the present invention sectioned for angular (or radial) slicing.

FIG. 6B depicts slices of the lens of FIG. 6A along angular meridians indicated as A', B', C' and D' in FIG. 6A.

In one embodiment, the present invention provides a toric contact lens design for a toric contact lens. The toric contact lens of the present invention has a concave back surface (posterior surface) and a convex front surface (anterior surface). The front surface preferably consists of a center optical zone, a transition zone, and a peripheral carrier. In a preferred embodiment, a rotational stability feature is included in the peripheral carrier. The peripheral carrier is preferably divided into a plurality of thickness zones.

In an alternative embodiment, the toric and/or aberration correction in the central optical zone may be on the posterior surface. In still another embodiment, the optics in the central optical zone may be split between the anterior and posterior surfaces of the lens. For example the toric optics may be located in the anterior surface whereas, for example, progressive optics (for presbyopia) may be located on the posterior surface.

FIG. 1 schematically shows a typical toric contact lens according to a preferred embodiment of the invention. The toric contact lens **100** may preferably have a diameter of around 14.5 mm. The toric contact lens **100** preferably has a concave (or posterior) surface **110** and an opposite convex (or anterior) surface **120**, and a central axis passing through the apex of the convex (anterior) surface.

The convex surface **120** comprises a central optical zone **122**, which is circular in shape and is substantially concentric with a central axis, and a non-optical peripheral zone or carrier **128**.

The central optical zone **122** is a toroidal surface and preferably has a diameter of around 8 mm. The toroidal surface is formed by defining a curve in the Y-Z plane, wherein the Z-axis coincides with or is parallel to the central axis of the lens, and then rotating this curve around an axis parallel to the Y-axis from a distance which is selected to impart a desired cylindrical optical power to the contact lens for correcting astigmatism errors of an eye.

FIG. 2 depicts the zones used in the present invention to provide stability on the front surface of a lens. The carrier **230** may be divided into three zones (1, 2 and 3). Additionally, this same configuration may be considered to have 4 zones as zone 2 may be considered as two zones, as the entire area shown in FIG. 2 is not continuous. In a preferred embodiment, zone 1 is preferably located towards the top of the lens and has the minimum thickness found in carrier **230**. Zone 1 is preferably symmetrical about the vertical meridian. Zone 2 is located beneath zone 1 on opposite sides (left and right sides) of the optical zone 1 and extends between zone 1 and zone 3. Zone 2 is preferably a prism zone with greater thickness and borders **250** and **260**. The thickness of zone 2 preferably increases along the angular meridians, reaching a zone maximum towards the bottom border **260**. The right and left sections of zone 2 are preferably mirrored along the vertical meridian.

Zone 3 is preferably a weight balance zone that has a larger mass than zone 1. The thickness profile of zone 3 along the vertical axis is preferably similar to conventional prism ballast toric lenses. In some embodiments the thickness profile may be thinner than conventional prism ballast toric lenses.

The central portion of the lens, or optical zone **200** is created using ordinary methods known in the art. In one embodiment, there is a transition zone **210** between the optical zone and the carrier. In a related embodiment, there may be a second transitional zone near the lens edge **220**. A transition zone at or near lens edge **220** may as well be a carrier portion **230** of the lens extending to the edge of the lens.

The present invention defines thickness along slices called meridians. Many inventions, such as those disclosed in US 6467903 use meridians that are horizontal slices to define thickness. In the context of the present invention, thickness is preferably defined along angular (or radial) meridians that radiate from the central zone.

Referring back to FIG. 2, zones 1, 2 and 3 may be defined by radial boundaries. For example, the boundary line between zones 1 and 2 may be located at 15 degrees from the vertical meridian as measured from the top of the lens. In another embodiment, the boundary line between zones 1 and 2 may be at 45 degrees from the vertical meridian. In one embodiment, the boundary line between zones 2 and 3 may be approximately 30 degrees from the vertical meridian as measured from the bottom of the lens. In still another embodiment of the present invention, the boundary line between zones 2 and 3 is at 60 degrees as measured from the bottom of the lens.

In still another embodiment, the zones may be defined by angles. In this embodiment, if the vertical meridian is used as a reference, with 12 o'clock defined as 0 (zero) degrees, the right side of zone 2, as shown in FIG. 2, can be defined between 15 degrees (upper boundary) and 150 degrees (lower boundary). In a preferred embodiment, the right side of zone 2 can be defined between 45 degrees (upper boundary) and 120 degrees (lower boundary). The lens thickness is preferably greatest near or at the borders between zones 2 and 3 as shown in the graphs depicted in FIG. 3. In one embodiment, the thickness range of zones 2 may be from 0.065 mm to 0.45 mm. In a preferred embodiment, the thickness range may be from 0.140 mm to 0.340 mm.

FIG. 3 depicts the thickness profile within zone 2 of the carrier. The horizontal axis represents the radial distance from the junction of the transition zone and the carrier **230** to the lens edge **220**. In this embodiment, the maximum thickness was located at the border **260** and the minimum thickness was at the border **250**. At each angular meridian, there is a relatively consistent thickness section, i.e., the thickness changes less than or equal to 10% of the maximum thickness at the meridian. The width of the section may be at least 30 % of the carrier zone width and preferred 50% of the carrier zone width. The thickness of zone 2 is preferably used to stabilize the lens.

FIG. 4 represents plots of thickness profile slope in zone 2 for various embodiments of the present invention. For example, in an embodiment depicted by FIG. 4A, the slope of the thickness profile may remain constant. In an embodiment depicted by FIG. 4B, the slope of the thickness profile may be similar to a step-type function. In an embodiment depicted by FIG. 4C, the slope may increase and decrease, reaching a maximum between boundaries **250** and **260**.

FIG. 5A maps vertical and horizontal slices taken from a lens. FIG. 5B represents a section of the lens taken at the vertical meridian. Notably, the lens has a prism-type ballast that is similar to a conventional prism ballast toric lens. In the embodiment depicted in FIG. 5B, the maximum thickness may be approximately 0.321mm.

FIG. 6A maps angular (or radial) slices taken from the lens shown in FIG. 5A. The thickness is preferably greatest in zones 2 and 3. The sections A', B', C' and D' in FIG. 6B are angular (or radial) sections to better reflect the preference that the lens be thickest along the border between zones 2 and 3.

Although FIGs 5 and 6 contain dimensions, these dimensions are exemplary only and are not meant to be limiting.

The changes in thickness that create rotational stability may form a geometric thickness pattern that is annular in shape. This ring preferably has an open end towards the top of the lens, where the thickness is preferably minimal. In this embodiment, the annular geometry begins along the boundary between zones 1 and 2 and continues down through zone 3. The ring preferably has a width of relatively consistent thickness, i.e. the thickness changes is less than or equal to 10% of the maximum thickness at the angular meridian. The annular width region is preferably 1.5 mm wide in zones 2 and 3 along angular meridians.

Another parameter that may be used to define the boundaries of the annular region is the percentage of a zone occupied by the annular region. In a preferred embodiment, the width of annular region may occupy at least 30 percent of zone 2.

Unless stated otherwise the thickness is measured normal from the posterior surface to the anterior surface. Additionally, all distances are measured along the curved surface rather than planar projections of the lens.

The present design may be used for various powers. In some embodiments, the thickness profiles of the carrier zones are consistent irrespective of the power used. In other words, the same carrier may be used although the optical zone differs. Additionally, the first derivative is preferably continuous on the entire front surface, thus eliminating junctions between zones and areas. This feature may provide greater comfort to the user.

Any known, suitable optical computer aided design (CAD) system may be used to design an optical model lens, including the carrier zones. Exemplary optical computer aided design systems include, but are not limited to Advanced System Analysis program (ASAP) from Breault Research Organization and ZEMAX from Focus Software, Inc. Preferably, the optical design will be performed using Advanced System Analysis program (ASAP) from Breault Research Organization with input from ZEMAX (Focus Software, Inc.).

After completing a desired design, a toric contact lens can be produced in a computer-controlled manufacturing system. The lens design can be converted into a data file containing control signals that is interpretably by a computer-controlled manufacturing device. A computer-controlled manufacturing device is a device that can be controlled by a computer system and that is capable of producing directly an ophthalmic lens or an optical tool for producing an ophthalmic lens. Any known, suitable computer controllable manufacturing device can be used in the invention. Preferably, a computer controllable manufacturing device is a numerically controlled lathe, preferably a two-axis lathe with a 45° piezo cutter or a lathe apparatus as disclosed in US 6122999, more preferably a numerically controlled lathe from Precitech, Inc., such as Optoform ultra-precision lathes (models 30, 40, 50 and 80) having Variform piezo-ceramic fast tool servo attachment.

Toric contact lenses of the invention may be produced by any convenient means, for example, such as lathing and molding. Preferably, toric contact lenses are molded from contact lens molds including molding surfaces that replicate the contact lens surfaces when a lens is cast in the molds. For example, an optical cutting tool with a numerically controlled lathe may be used to form metallic optical tools. The tools are then used to make convex and concave surface molds that are then used, in conjunction with each other, to form the lens of the invention using a suitable liquid lens-forming material placed between the molds followed by compression and curing of the lens-forming material.

Toric contact lenses of the invention can be either hard or soft contact lenses. Soft toric contact lenses of the invention are preferably made from a soft contact lens material, such as a silicon hydro-gel or HEMA.

CLAIMS:

1. A toric contact lens comprising a central optical zone, a vertical meridian, a transition zone surrounding said central optical zone, a carrier extending from said transition zone outward and a plurality of thickness zones in said carrier, wherein said plurality of thickness zones comprises at least three thickness zones, including a first thickness zone, a second thickness zone, and a third thickness zone, wherein the first thickness zone is arranged at a top of said toric contact lens and the third thickness zone is arranged at a bottom of said toric contact lens, and wherein the second thickness zone is symmetrical across the vertical meridian on the sides of said toric contact lens, wherein further an upper boundary between the first thickness zone and the second thickness zone is at least 15 degrees from the vertical meridian as measured from the top of said toric contact lens, and wherein a lower boundary between the third thickness zone and the second thickness zone is at least 30 degrees from the vertical meridian as measured from the bottom of said toric contact lens, and wherein there is a relatively consistent thickness section at each angular meridian within the second thickness zone, the width of the relatively consistent thickness section being at least 30% of the zone width of said second thickness zone, with the thickness change in the relatively consistent thickness section being equal to or less than 10% of the maximum thickness at the respective angular meridian.

2. The toric contact lens of claim 1, wherein a thickness profile of the second thickness zone increases from the upper boundary to the lower boundary.

3. The toric contact lens of claim 1, wherein a slope of a thickness profile of the second thickness zone gradually increases and subsequently decreases from the upper boundary to the lower boundary.

4. The toric contact lens of claim 1, wherein the range of the thickness profile from the upper boundary to the lower boundary of the second thickness zone is from 0.065 mm to 0.45 mm.

5. The toric contact lens according to any one of claims 1 to 4, wherein the contact lens is a soft contact lens.

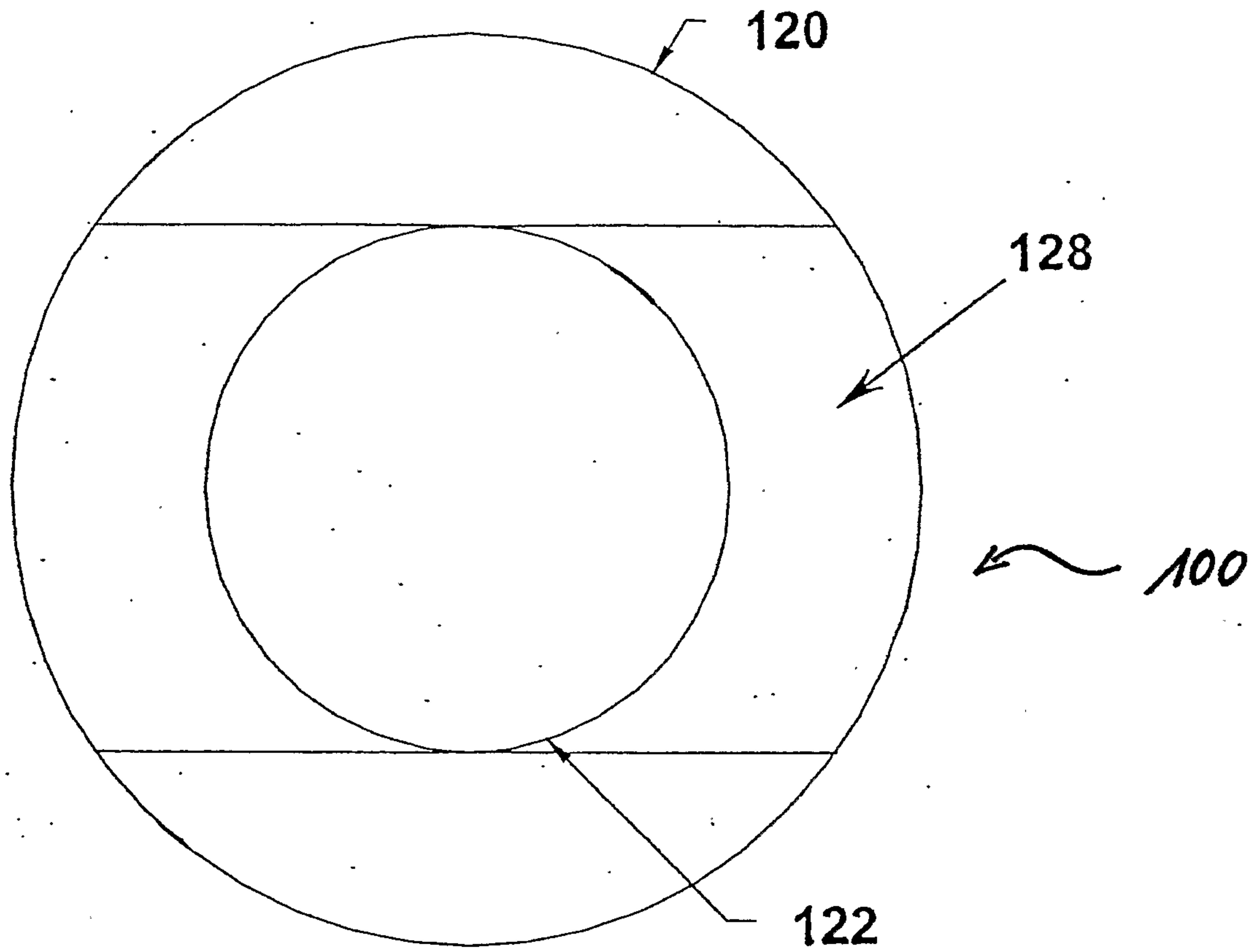


Fig. 1

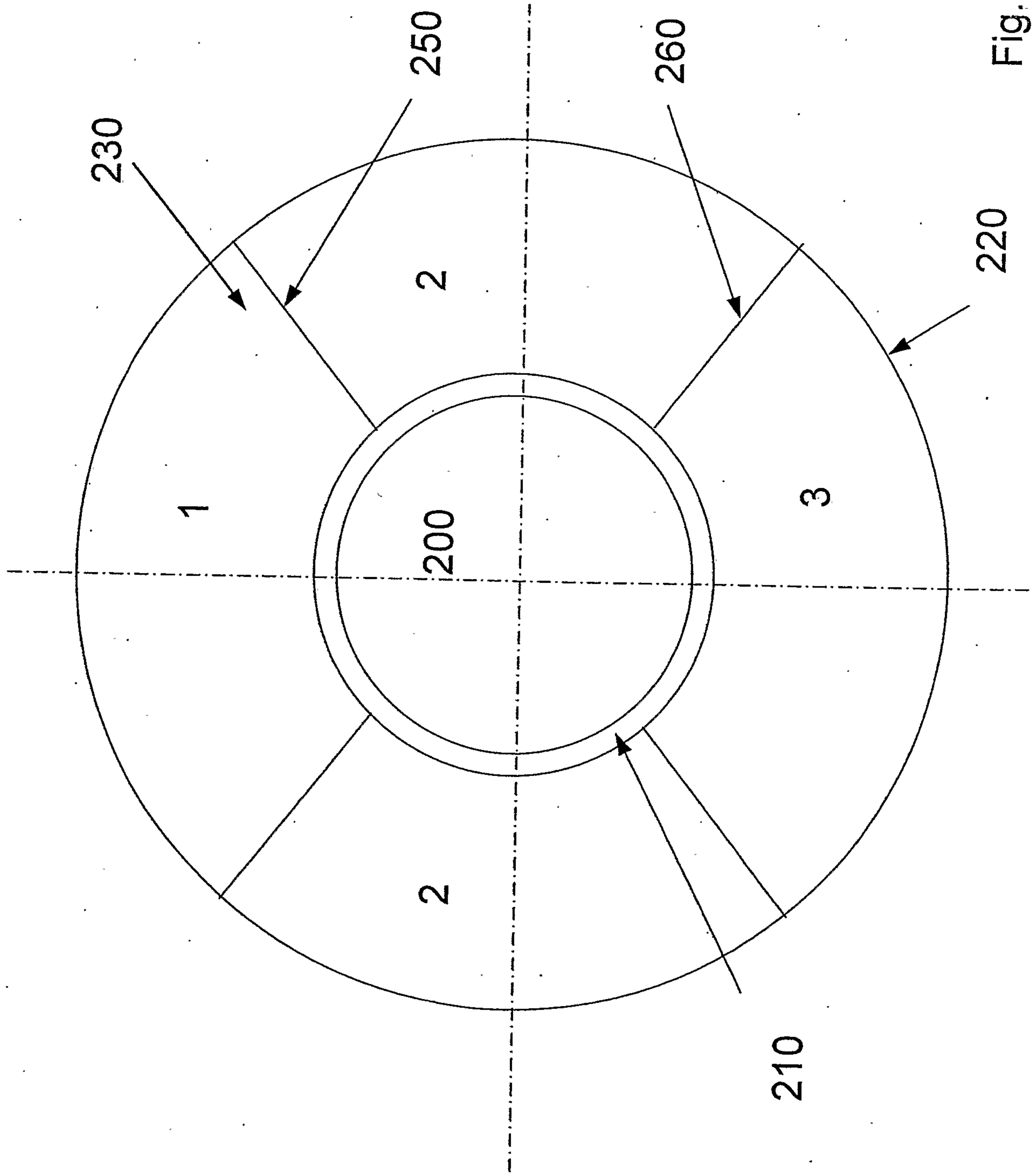


Fig. 2

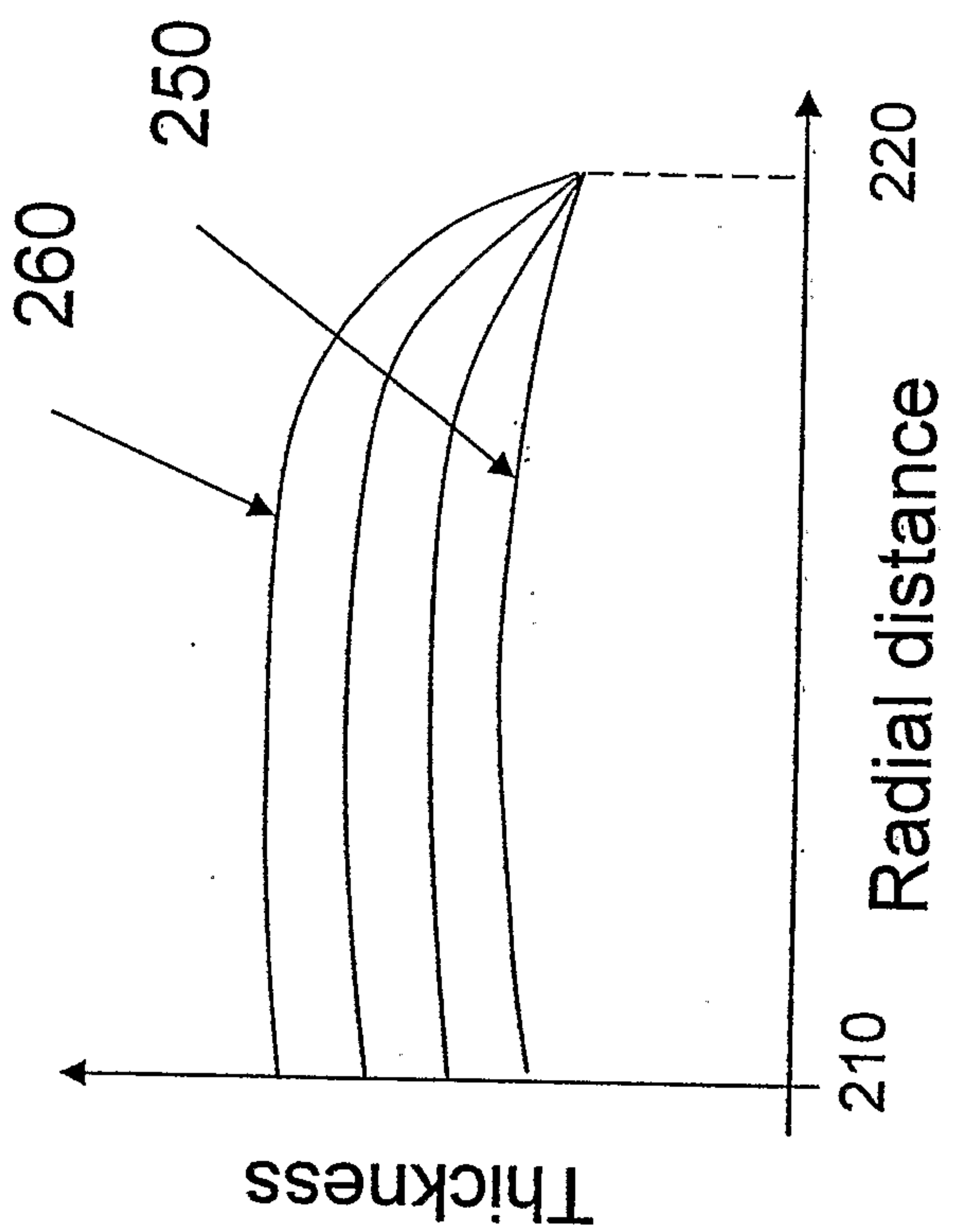


Fig. 3

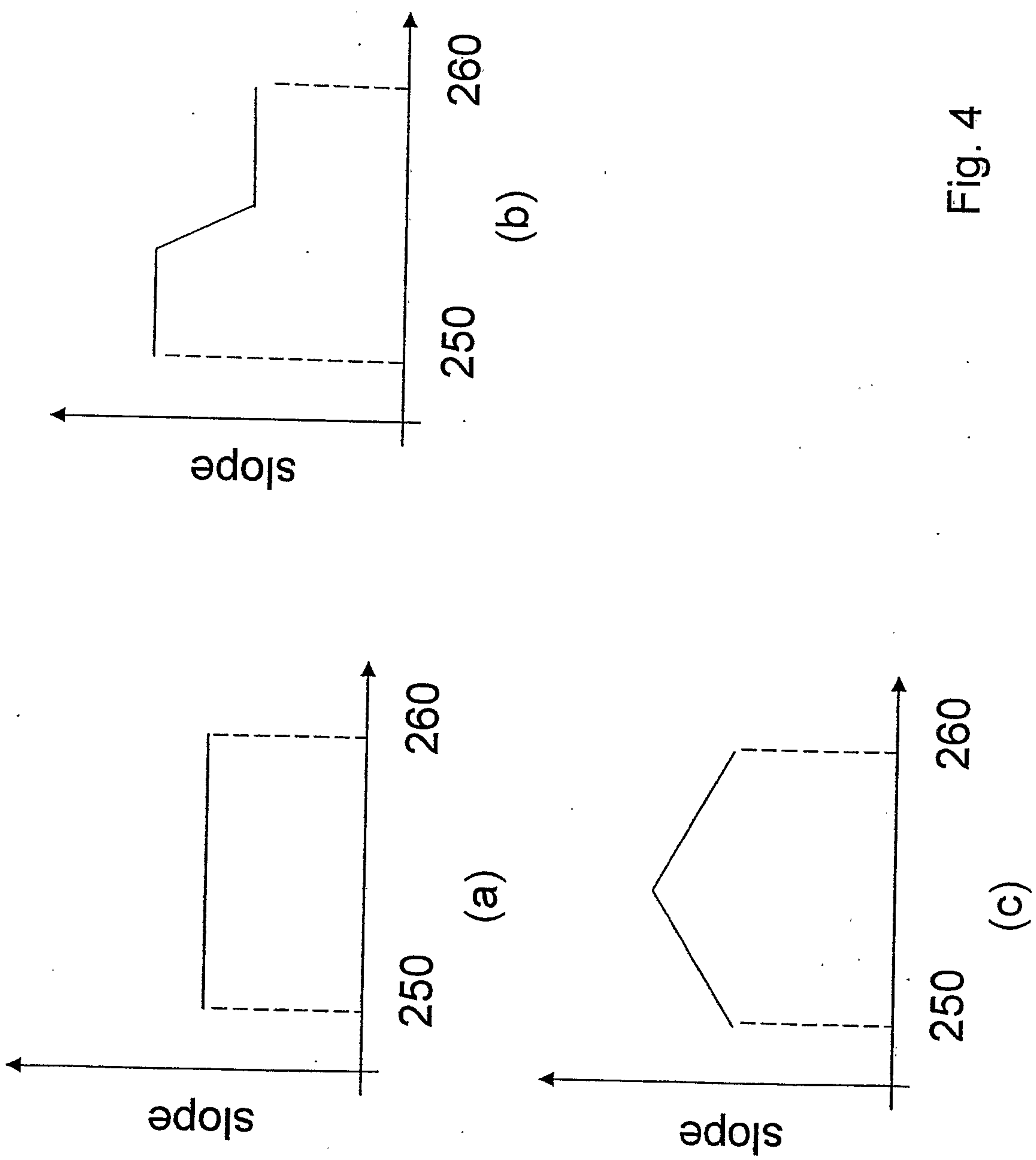


Fig. 4

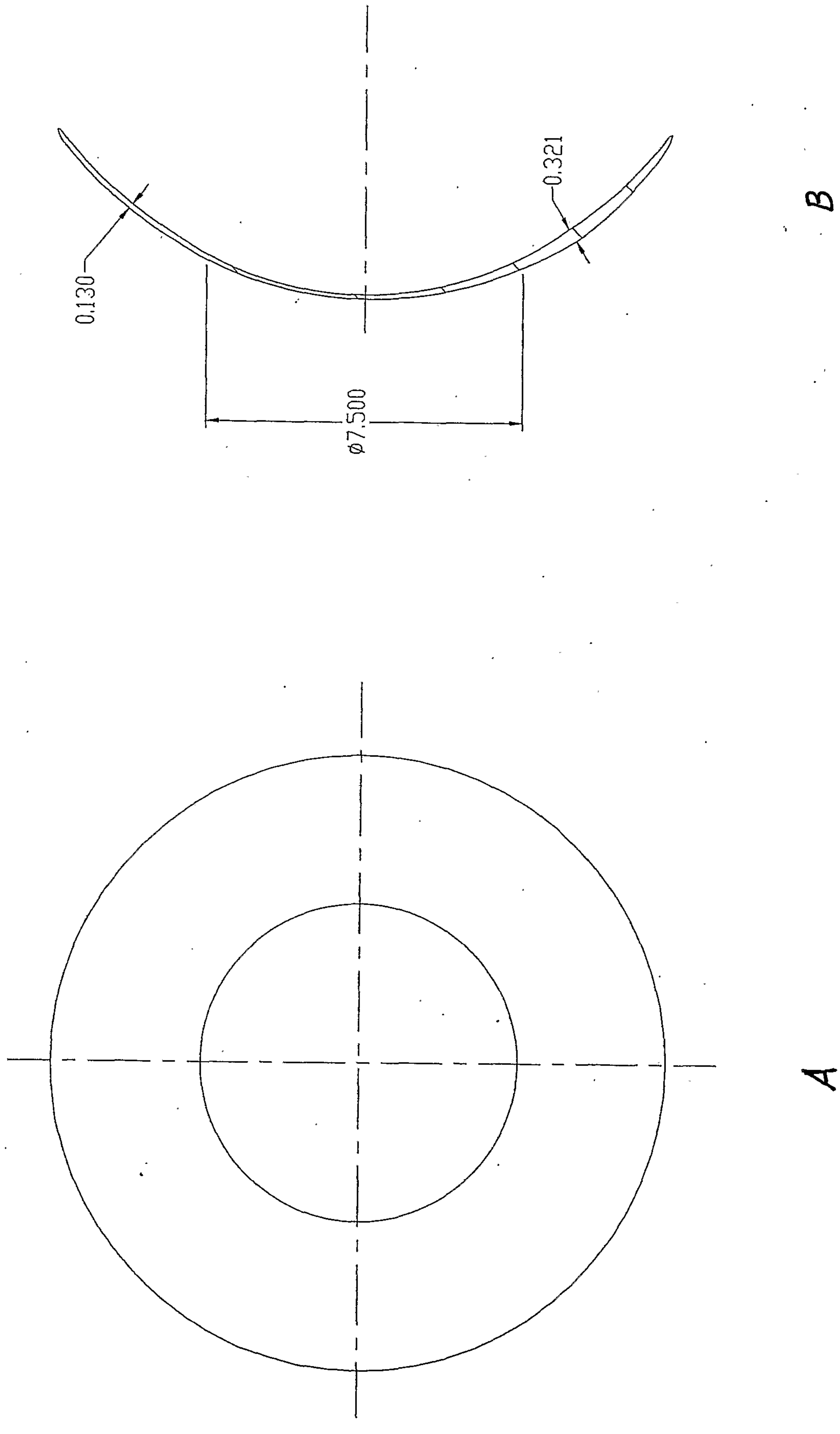
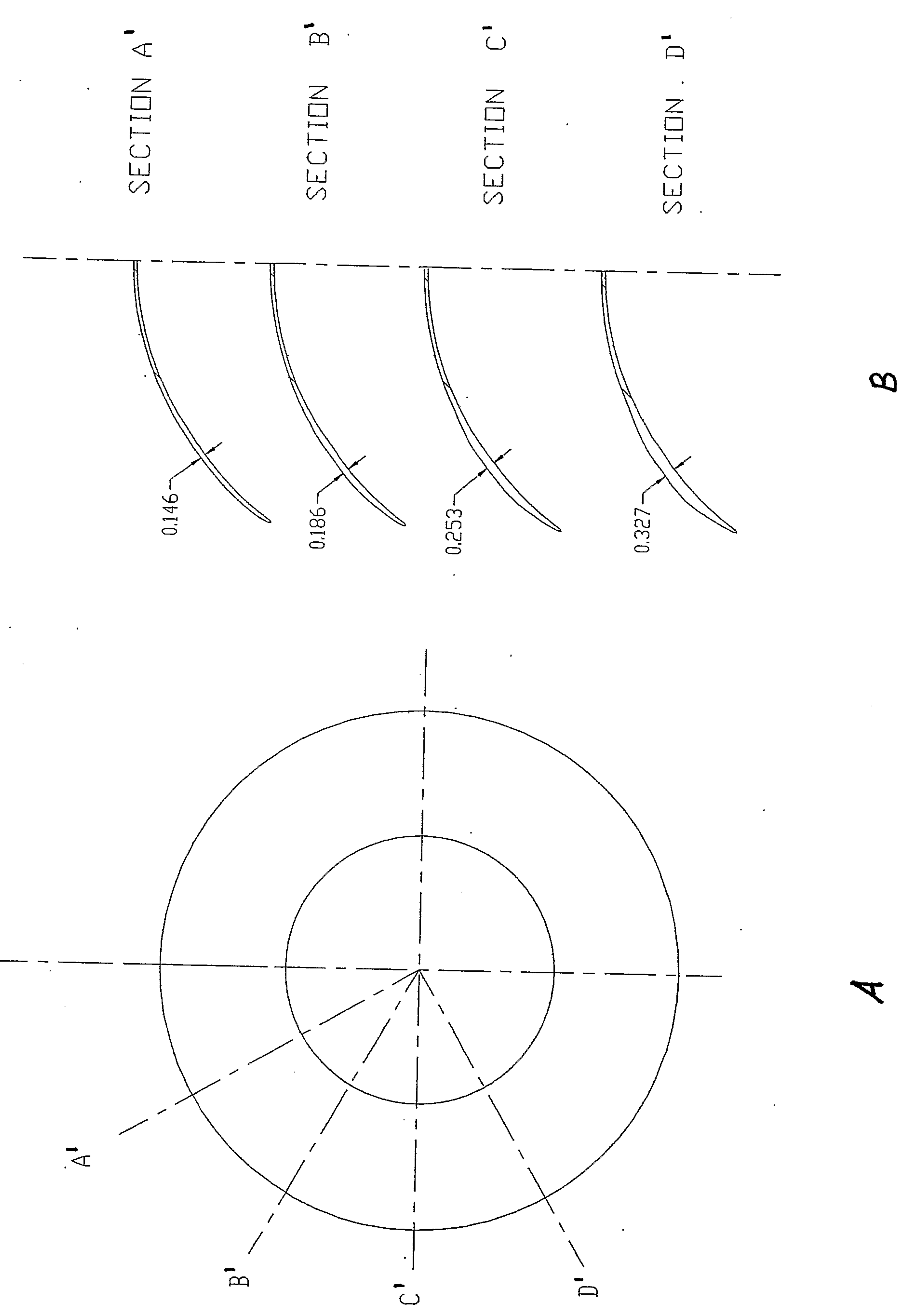


Fig.5

Fig.6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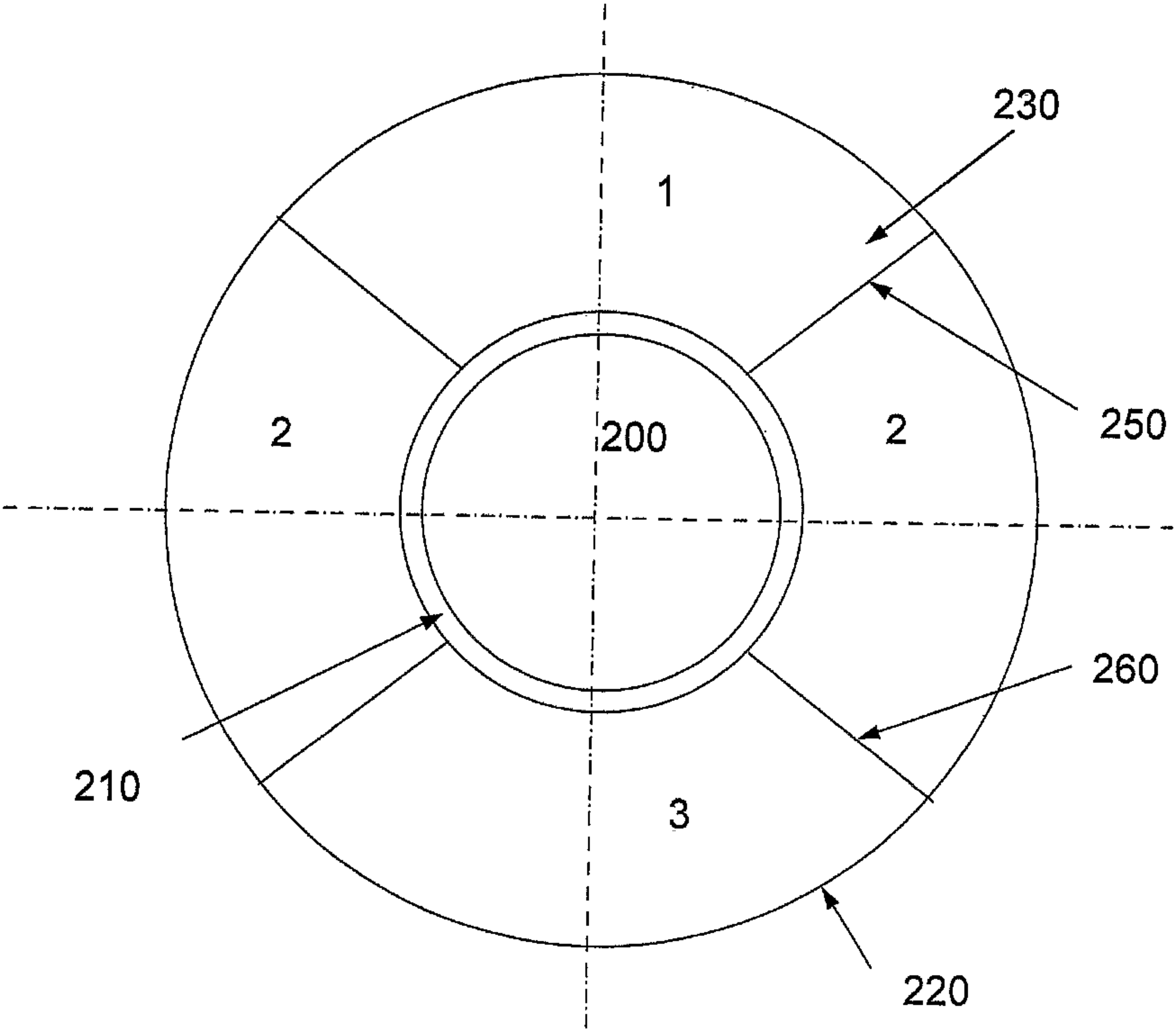
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