Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2747388 A1 2010/06/24

(21) 2 747 388

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2009/12/03
(87) Date publication PCT/PCT Publication Date: 2010/06/24
(85) Entrée phase nationale/National Entry: 2011/06/16
(86) N° demande PCT/PCT Application No.: US 2009/066488
(87) N° publication PCT/PCT Publication No.: 2010/071739
(30) Priorité/Priority: 2008/12/18 (US61/138,757)

(51) Cl.Int./Int.Cl. *A62B 7/00* (2006.01), *A41D 13/11* (2006.01), *A61M 16/06* (2006.01), *A62B 23/02* (2006.01), *B01D 39/00* (2006.01)

(71) Demandeur/Applicant:
3M INNOVATIVE PROPERTIES COMPANY, US

(72) Inventeurs/Inventors:
BILLINGSLEY, BRITTON G., US;
JONES, MARVIN E., US

(74) Agent: SMART & BIGGAR

(54) Titre : BANDE NON TISSEE CONTENANT DES PARTICULES EN COUCHES CONFORMEES
(54) Title: SHAPED LAYERED PARTICLE-CONTAINING NONWOVEN WEB

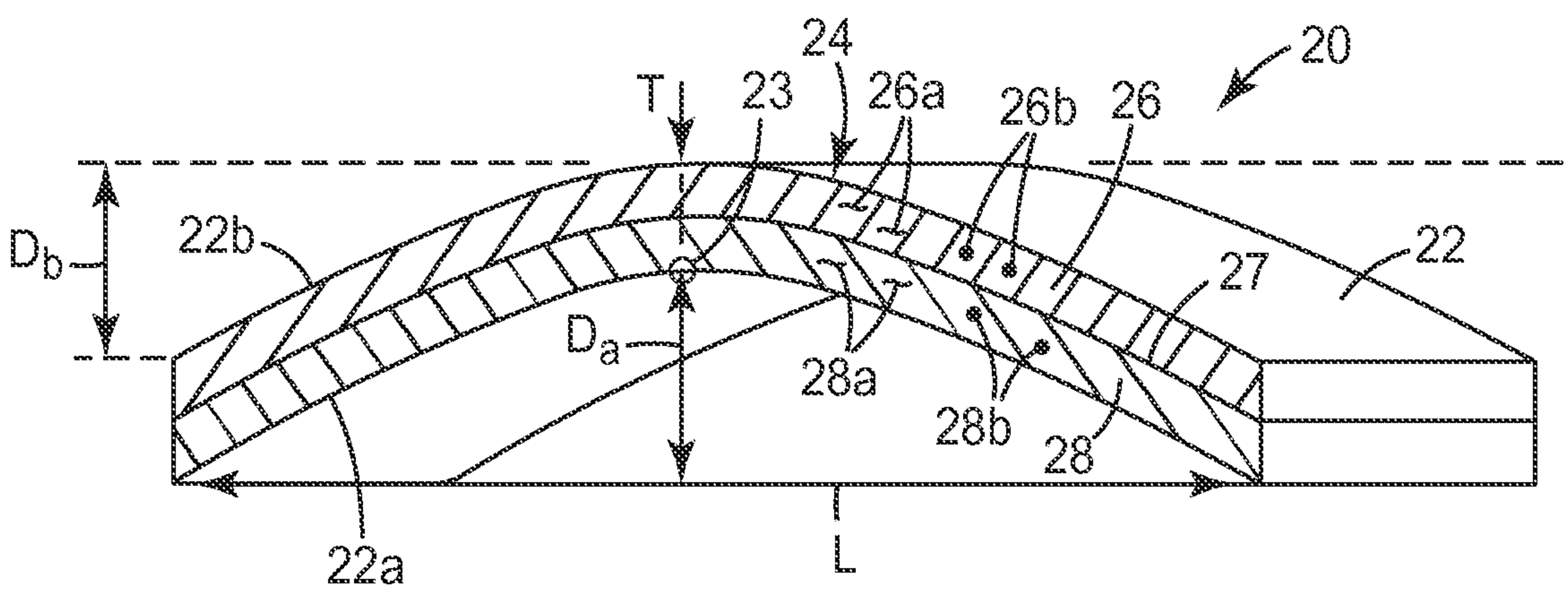

FIG. 2

(57) Abrégé/Abstract:
A filter element includes a porous non-woven web. The porous non-woven web includes a first layer with first thermoplastic elastomeric polymer fibers and first active particles disposed therein and a second layer including second thermoplastic elastomeric polymer fibers and second active particles disposed therein. The web possesses a three-dimensional deformation and the first layer is contiguous with the second layer across the deformation.

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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 June 2010 (24.06.2010)

PCT

(10) International Publication Number
WO 2010/071739 A1

(51) International Patent Classification:
A62B 7/00 (2006.01) *A41D 13/11* (2006.01) *A61M 16/06* (2006.01) *A62B 23/02* (2006.01) *B01D 39/00* (2006.01)

(21) International Application Number: PCT/US2009/066488

(22) International Filing Date: 3 December 2009 (03.12.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/138,757 18 December 2008 (18.12.2008) US

(71) Applicant *(for all designated States except US)*: **3M INNOVATIVE PROPERTIES COMPANY** [US/US]; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **BILLINGSLEY, Britton G.**, [US/US]; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **JONES, Marvin E.**, [US/US]; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

(74) Agents: **WETZELS, Anna A.**, et al.; 3M Center Office of Intellectual Property Counsel Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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

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

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

(54) Title: SHAPED LAYERED PARTICLE-CONTAINING NONWOVEN WEB

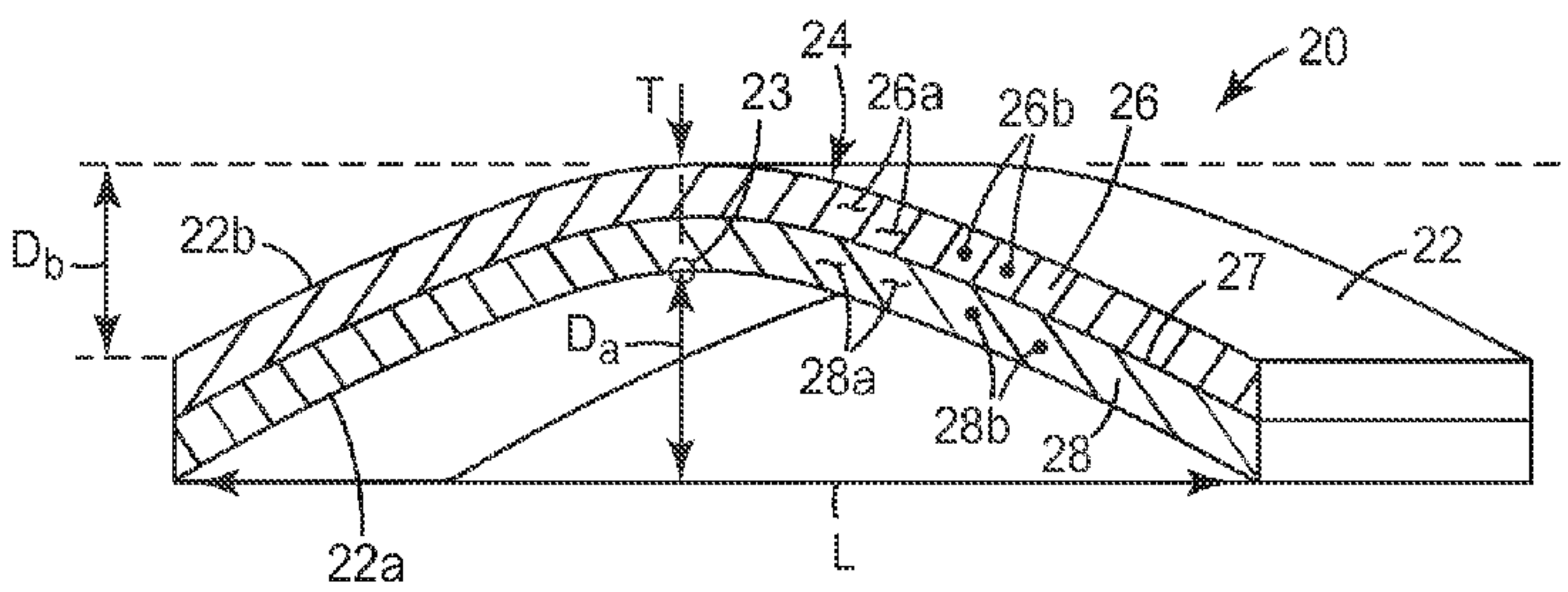

FIG. 2

(57) Abstract: A filter element includes a porous non-woven web. The porous non-woven web includes a first layer with first thermoplastic elastomeric polymer fibers and first active particles disposed therein and a second layer including second thermoplastic elastomeric polymer fibers and second active particles disposed therein. The web possesses a three-dimensional deformation and the first layer is contiguous with the second layer across the deformation.

WO 2010/071739 A1

SHAPED LAYERED PARTICLE-CONTAINING NONWOVEN WEB

Background

The present disclosure generally relates to filter elements utilizing shaped layered particle-containing non-woven webs. The present disclosure is also directed to respiratory protection systems including such filter elements.

Respiratory protection devices for use in the presence of vapors and other hazardous airborne substances often employ a filtration element containing sorbent particles. Design of such filtration elements may involve a balance of sometimes competing factors such as pressure drop, surge resistance, overall service life, weight, thickness, overall size, resistance to potentially damaging forces such as vibration or abrasion, and sample-to-sample variability. Fibrous webs loaded with sorbent particles often have low pressure drop and other advantages.

Fibrous webs loaded with sorbent particles have been incorporated into cup-like molded respirators. See, e.g., U.S. Patent No. 3,971,373 to Braun. A typical construction of such a respiratory protection device includes one or more particle-containing and particle-retaining stacked layers placed between a pair of shape retaining layers. See, e.g., U.S. Patent No. 6,102,039 to Springett et al. The shape-retaining layers typically provide structural integrity to the otherwise relatively soft intermediate layer, so that the assembly as a whole could retain the cup-like shape.

There remains a need for filtration elements that possess advantageous performance characteristics, structural integrity, and simpler construction and are easier to manufacture.

Summary

The present disclosure is directed to a filter element including a porous non-woven web. The web includes a first layer with first thermoplastic elastomeric polymer fibers and first active particles disposed therein and a second layer including second thermoplastic elastomeric polymer fibers and second active particles disposed therein. The web possesses a three-dimensional deformation and the first layer is contiguous with the second layer across the deformation. One exemplary implementation, the three-dimensional deformation is characterized by a thickness that varies by no more than a

factor of 5 along at least one direction across the deformation. Additionally or alternatively, the deformation may comprise a surface characterized by a deviation from a planar configuration of at least 0.5 times the web thickness at that location.

Brief Description of the Drawings

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

Fig. 1 is a schematic perspective view of a section of a porous non-woven web according to the present disclosure;

Fig. 2 is a schematic perspective view of a cross-section of one exemplary filter element utilizing a porous non-woven web having a three-dimensional deformation;

Fig. 3 is a schematic perspective view of a cross-section of another exemplary filter element including a porous non-woven web having a three-dimensional deformation;

Fig. 4 is a schematic perspective view of a cross-section of another exemplary filter element including a porous non-woven web having a three-dimensional deformation;

Fig. 5 is a schematic cross-sectional view of yet a cross-section of yet another exemplary filter element including a porous non-woven web having two or more than three-dimensional deformations;

Fig. 6 is a schematic cross-sectional view of an exemplary filter element according to the present disclosure that is disposed in a cartridge;

Fig. 7 is a perspective view of an exemplary respiratory protection system utilizing a filter element shown in **Fig. 6**;

Fig. 8 is a perspective view, partially cut away, of a disposable respiratory protection device utilizing an exemplary filter element according to the present disclosure shown in **Fig. 3**;

Fig. 9 is a cross-sectional view of a radial filtration system, such as those suitable for use in collective protection systems, utilizing an exemplary filter element according to the present disclosure shown in **Fig. 4;**

Fig. 10 illustrates an exemplary method of making porous non-woven webs having a three-dimensional deformation, according to the present disclosure.

The figures are not necessarily to scale. Like numbers used in the figures refer to like components. The use of a number to refer to a component in a given figure, however, is not intended to limit the component in another figure labeled with the same number.

Detailed Description

In the following description, reference is made to the accompanying drawings that form a part hereof, and in which are shown by way of illustration several specific embodiments. It is to be understood that other embodiments are contemplated and may be made without departing from the scope or spirit of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense.

All scientific and technical terms used herein have meanings commonly used in the art unless otherwise specified. Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein.

The recitation of numerical ranges by endpoints includes all numbers subsumed within that range (e.g. 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5) and any range within that range.

As used in this specification and the appended claims, the singular forms "a", "an", and "the" encompass embodiments having plural referents, unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

Exemplary embodiments of the present disclosure utilize two or more layers of porous non-woven webs, at least two of the layers including thermoplastic elastomeric polymer fibers and active particles enmeshed in the fibers. The webs according to the present disclosure are characterized by a three-dimensional shape or deformation, which may be imparted to the web, e.g., by a molding process.

The present disclosure is expected to facilitate production of shaped molded filter elements, including filter elements that may be used in respiratory protection devices, with performance and design features that are difficult to achieve with existing technologies. The primary existing technology for making shaped filter elements, resin bonded carbon particles, involves combining finely ground resin particles with carbon particles and then shaping them under heat and pressure. Such carbon loaded shapes are often used in filter beds. However, this existing technology has various drawbacks. For example, grinding resin into small particles for use in the resin bonding particle process tends to be a relatively expensive procedure. Further, the resin bonding process tends to occlude the surface of the carbon, thereby reducing the activity of the carbon. Moreover, it is very difficult to layer resin-bonded particle masses.

In contrast, exemplary filter elements according to the present disclosure are expected to have lower pressure drop due to the use of fibers instead of bonding resin, lower processing cost, and much better retention of the carbon activity. Other advantages of embodiments of the present disclosure include providing an alternative to a filter bed produced using a storm filling process, and the ability to produce complex shapes of filter elements that are difficult to achieve with traditional packed beds. Further, exemplary embodiments of the present disclosure provide an advantageous way of combining multiple layers of carbon loaded webs in a filter bed. The multiple layers may include thick layers with high large particles for capacity, thin "polishing" layers with smaller particles, or layers treated with different materials in order to achieve a broad range of filtration performance.

Fig. 1 shows schematically a section of a porous non-woven web **10** suitable for use in exemplary embodiments of the present disclosure. As used in this specification, the word “porous” refers to an article that is sufficiently permeable to gases so as to be useable in a filter element of a respiratory protection device. The phrase “nonwoven web” refers to a fibrous web characterized by entanglement or point bonding of fibers. The porous non-woven web **10** includes active particles **12a, 12b, 12c**, disposed in, e.g., enmeshed, in polymer fibers **14a, 14b, 14c**. Small, connected pores formed in the non-woven web **10** (e.g., between the polymer fibers and particles) permit ambient air or other fluids to pass through the non-woven web **10**. Active particles, e.g., **12a, 12b, 12c**, may be capable of absorbing solvents and other potentially hazardous substances present in such fluids. The word "enmeshed" when used with respect to particles in a nonwoven web refers to particles that are sufficiently bonded to or entrapped within the web so as to remain within or on the web when the web is subjected to gentle handling such as draping the web over a horizontal rod. Examples of suitable porous non-woven webs and methods of making thereof are described, for example, in US Application Pub. No. US 2006/0096911.

Examples of active particles suitable for use in some embodiments of the present disclosure include sorbents, catalysts and chemically reactive substances. A variety of active particles can be employed. In some embodiments, the active particles will be capable of absorbing or adsorbing gases, aerosols or liquids expected to be present under the intended use conditions. The active particles can be in any usable form including beads, flakes, granules or agglomerates. Preferred active particles include activated carbon; alumina and other metal oxides; sodium bicarbonate; metal particles (e.g., silver particles) that can remove a component from a fluid by adsorption, chemical reaction, or amalgamation; particulate catalytic agents such as hopcalite or nano sized gold particles (which can catalyze the oxidation of carbon monoxide); clay and other minerals treated with acidic solutions such as acetic acid or alkaline solutions such as aqueous sodium hydroxide; ion exchange resins; molecular sieves and other zeolites; silica; biocides; fungicides and virucides. Activated carbon and alumina are particularly preferred active particles.

Exemplary catalyst materials include Carulite 300 (also referred to as hopcalite, a combination of copper oxide and manganese dioxide (from MSDS)) which removes carbon monoxide (CO), or catalyst containing nano sized gold particles, such as a granular activated carbon coated with titanium dioxide and with nano sized gold particles disposed on the titanium dioxide layer, (United States Patent Application No. 2004/0095189 A1) which removes CO, OV and other compounds.

Exemplary chemically reactive substances include triethylenediamine, hopcalite, zinc chloride, alumina (for hydrogen fluoride), zeolites, calcium carbonate, and carbon dioxide scrubbers (e.g. lithium hydroxide). Any one or more of such chemically reactive substances may be in the form of particles or they may be supported on particles, typically those with large surface areas, such as activated carbon, alumina or zeolite particles.

More than one type of active particles may be used in the same exemplary porous non-woven web according to the present disclosure. For example, mixtures of active particles can be employed, e.g., to absorb mixtures of gases. The desired active particle size can vary a great deal and usually will be chosen based in part on the intended service conditions. As a general guide, the active particles may vary in size from about 5 to 3000 micrometers average diameter. Preferably the active particles are less than about 1500 micrometers average diameter, more preferably between about 30 and about 800 micrometers average diameter, and most preferably between about 100 and about 300 micrometers average diameter. Mixtures (e.g., bimodal mixtures) of active particles having different size ranges can also be employed. In some embodiments of the present disclosure, more than 60 weight percent active particles are enmeshed in the web. In other embodiments, preferably, at least 80 weight percent active particles, more preferably at least 84 weight percent and most preferably at least 90 weight percent active particles are enmeshed in the web.

Examples of polymer fibers suitable for use in some embodiments of the present disclosure include thermoplastic polymer fibers, and, preferably, thermoplastic elastomeric polymer fibers. A variety of fiber-forming polymeric materials can be suitably employed, including thermoplastics such as polyurethane elastomeric materials (e.g., those available under the trade designations IROGRAN™ from Huntsman LLC and ESTANE™ from Noveon, Inc.), thermoplastic elastomeric polyolefins (such as polyolefin thermoplastic elastomers available from ExxonMobil under the trade designation Vistamaxx), polybutylene elastomeric materials (e.g., those available under the trade designation CRASTIN™ from E. I. DuPont de Nemours & Co.), polyester elastomeric materials (e.g., those available under the trade designation HYTREL™ from E. I. DuPont de Nemours & Co.), polyether block copolyamide elastomeric materials (e.g., those available under the trade designation PEBAX™ from Atofina Chemicals, Inc.) and elastomeric styrenic block copolymers (e.g., those available under the trade designations KRATON™ from Kraton Polymers and SOLPRENE™ from Dynasol Elastomers).

Some polymers may be stretched to much more than 125 percent of their initial relaxed length and many of these will recover to substantially their initial relaxed length upon release of the biasing force and this latter class of materials is generally preferred. Thermoplastic polyurethanes, elastomeric polyolefins, polybutylenes and styrenic block copolymers are especially preferred. If desired, a portion of the web can represent other fibers that do not have the recited elasticity or crystallization shrinkage, e.g., fibers of conventional polymers such as polyethylene terephthalate; multicomponent fibers (e.g., core-sheath fibers, splittable or side-by-side bicomponent fibers and so-called "islands in the sea" fibers); staple fibers (e.g., of natural or synthetic materials) and the like. Preferably, however, relatively low amounts of such other fibers are employed so as not to detract unduly from the desired sorbent loading level and finished web properties.

Fig. 2 is a schematic perspective view of a cross-section of one exemplary filter element **20** utilizing a porous non-woven web **22**. The web **22** includes two or more layers, such as first and second layers **26** and **28**, each or both of which may be a porous non-woven web **10**, as shown in **Fig. 1**. In one exemplary embodiment, the first web layer **26** includes first active particles **26a** enmeshed in first polymer fibers **26b**, and the second web layer **28** includes second active particles **28a** enmeshed in second polymer fibers **28b**.

Various combinations of materials of first active particles **26a**, first polymer fibers **26b**, second active particles **28a** and second polymer fibers **28b** may be used in exemplary embodiments of the present disclosure. One exemplary embodiment is a filter element, in which the first layer **26** is designed to filter out the majority of a targeted contaminant (such as a gas), while the second layer **28** is designed to remove small amounts of the targeted contaminant that pass through the first layer **26**. In such exemplary embodiments, the first layer would typically include larger (e.g., 12 x 20 to 6 x 12) sorbent particles. The second layer would typically include smaller sorbent or catalytic particles (e.g., 80 x 325 to 60 x 140).

Another exemplary embodiment is a filter element, in which the first layer **26** and the second layer **28** are both designed to provide a primary filtration function for one component of a multiple component filtration system.. In such exemplary embodiments, the first layer **26** may include appropriate sorbent and/or catalytic active particles to remove one component of a gas stream while the second (and/or third, fourth, etc.) layer **28** would include appropriate active particles to remove a second component of a gas stream. For instance, it may be desirable to design a filter element that could filter both acid gases and basic gases. In that case, the first layer **26** could contain active particles to remove acid gases, while the second layer **28** could contain active particles to remove basic gases. Both types of active particles may be activated carbon particles that are treated for either acidic or basic gases.

In other exemplary embodiments, a filter element may include combinations of the above-referenced constructions. Exemplary embodiments could include multiple sets of large particle/small particle layers, each designed to filter different components of a gas stream. The materials used for the first polymer fibers **26b** and the second polymer fibers **28b** may be the same or different. In one exemplary embodiment, first and second layers may both include the same type of blown microfibers including the same materials.

Referring further to **Fig. 2**, the web **22** possesses a three-dimensional deformation **24,** which is illustrated in cross-section. Particularly, rather than having a planar configuration, in which major surfaces **22a** and **22b** of the web **22** would have planar configurations and would be generally parallel to each other, as would be the case for typical non-woven particle-containing webs, the web **22** is shaped, such that at least one of its major surfaces **22a** and **22b** deviates from a planar configuration. In this exemplary embodiment, the first surface **22a** is displaced from a planar configuration by as much as **Da**, while the second surface **22a** is displaced from a planar configuration by as much as **Db**. Preferably, the first layer **26** is contiguous with the second layer **28** across the deformation, as shown in **Fig. 2**. As shown in **Fig. 2**, the first and second layers **26** and **28** are disposed immediately adjacent to one another. Furthermore, the first and second layers **26** and **28** are in actual contact (without any air gaps or intermediate layers) along a boundary **27**.

The web **22** is further characterized by a web thickness **T**, which may be defined as a distance between the first surface **22a** and the second surface **22b**. Some exemplary dimensions of deformations according to exemplary embodiments of the present disclosure include a web thickness **T** of 5 to 10 mm or more. The value of T will depend on the intended end use of the filter element and other considerations. The deformation **24** is further characterized by a linear length **L**, which may be defined as a length of a projection onto a planar surface underlying the deformation **24** of a cross-section of the deformation **24** in a plane that includes the displacement **Da**. In some exemplary embodiments, at least one of **Da** and **Db** is at least 0.5 times the web thickness **T** at the web location where the displacement is measured. In the exemplary embodiment shown, thickness **T** and displacement **Da** are both measured at a location **23**. In other exemplary embodiments, at least one of **Da** and **Db** may be at least 1 to 10, 2 to 10, 4 to 10, 5 to 10, or more than 10 times the web thickness **T** at the web location where the displacement is measured, depending on the intended end use of the filter element or other considerations.

Referring further to **Fig. 2**, major surface **22a** of the web **22** of the exemplary filter element **20** may be characterized as a concave surface, while the major surface **22b** may be characterized as a convex surface. In some such exemplary embodiments, the concave surface **22a** is characterized by a deviation **Da** from a planar configuration of at least 0.5 times the web thickness **T** at the web location where the displacement is measured. In other exemplary embodiments, **Da** of the surface **22a** may be at least 1 to 10, 2 to 10, 4 to 10, 5 to 10, or more than 10 times the web thickness **T** at the web location where the displacement is measured, depending on the intended end use of the filter element or other considerations.

In some typical exemplary embodiments, the linear deformation length **L** may be at least 3 to 4, or 3 to 5 times the thickness **T**. In other exemplary embodiments, the linear deformation length **L** may be at least 10 to 50, 20 to 50, 30 or more, 40 or more, or 50 or more. Some exemplary absolute values of L include 2 cm, 4 cm or 10 cm or more. The value of **L** and its ratio to **T** will depend on various factors, including the end use of the filter element. Those of ordinary skill in the art will readily appreciate that deformations of the web **22** may have any other suitable shape and size, including but not limited to those shown in **Figs. 3-4**.

In some exemplary embodiments of the present disclosure, the web **22** may be shape-retaining. In the context of the present disclosure, the term “shape-retaining,” referring to an article, signifies that the article possesses sufficient resiliency and structural integrity so as to (i) resist deformation when a force is applied or (ii) yield to the deforming force but subsequently substantially return to the original shape upon removal of the deforming force, wherein the amount and type of the deforming force is typical for the ordinary conditions in which the article is intended to be used. In some exemplary embodiments of the present disclosure, the web **22** may be self-supporting. The term “self-supporting,” referring to an article, signifies that the article possesses sufficient rigidity so as to be capable of retaining a non-planar configuration on its own, that is, in the absence of any additional supporting layers or structures.

Fig. 3 is a schematic perspective view of a cross-section of another exemplary filter element **30** utilizing a porous non-woven web **32**. The web **32** includes two or more layers, such as first and second layers **36** and **38**, each or both of which may be a porous non-woven web **10**, as shown in **Fig. 1**. In one exemplary embodiment, the first web layer **36** includes first active particles **36a** enmeshed in first polymer fibers **36b**, and the second web layer **38** includes second active particles **38a** enmeshed in second polymer fibers **38b**.

The web **32** possesses a three-dimensional deformation **34**. Preferably, the first layer **36** is contiguous with the second layer **38** across the deformation, as shown in **Fig. 3**. In this exemplary embodiment, the first surface **32a** is displaced from a planar configuration by as much as **Da'**, while the second surface **32a** is displaced from a planar configuration by as much as **Db'**. The web **32** is further characterized by variable web thickness **T1, T2, T3** and **T4**, each being defined as a distance between the first surface **32a** and the second surface **32b**. The deformation **34** is further characterized by a linear length of the line **L'**. **L'** is a projection of a cross-section of the deformation **34**, in a plane that includes the displacement **Da'**, onto a planar surface underlying the deformation **34**. In some exemplary embodiments of the present disclosure, the web **32** may be self-supporting and/or shape-retaining.

Preferably, in the embodiments that have a variable web thickness, the thickness varies no more than a factor of 10 times an average thickness **Tav**, along at least one direction across the deformation **34**. More preferably, the thickness varies no more than a factor of 5 times an average thickness **Tav**, along at least one direction across the deformation **34**, and, even more preferably, no more than a factor of 2, 1, and, most preferably, no more than a factor of 0.5. An average thickness may be calculated by choosing a particular direction across the deformation **34**, such as along the cross-section of the web **32** and the deformation **34** by the plane of the page of **Fig. 3**, measuring values of the web thickness, preferably, for at least 4 different locations (e.g., **1, 2, 3** and **4**) along the chosen direction (i.e., values of **T1, T2, T3** and **T4**), and averaging these values as follows:

$$Tav = (T1+T2+T3+T4)/4$$

In some exemplary embodiments, the locations 1, 2, 3, and 4 can be selected by dividing **L** into 5 about equal parts and taking thickness measurements at the 4 internal points. Some exemplary embodiments of the web **32** the three-dimensional deformation **34** may be characterized by a density gradient that has a relatively small value. In one exemplary embodiment, the three-dimensional deformation **34** is characterized by a density gradient of less than 20 to 1. In other exemplary embodiments, the three-dimensional deformation **34** may be characterized by a density gradient of less than 10 to 1, 3 to 1, or 2 to 1.

The density gradient can be determined as follows. Two samples are taken from two different locations of the three-dimensional deformation **34** of the web **32**, such as any two of the locations **1, 2, 3** and **4** shown in **Fig. 3**. Densities δ1 and δ2 can then be determined using the procedure described below and density gradient δg determined as a ratio of a larger density value δ2 to a smaller density value δ1.

Fig. 4 is a schematic perspective view of another exemplary filter element **40** utilizing a porous non-woven web **42**. The web **42** possesses a three-dimensional deformation **44**. In this exemplary embodiment, the first surface **42a** and the second surface **42b** of the web **42** is displaced from a planar configuration such that the web **42** forms a generally cylindrical shape. The web **42** includes two or more layers, such as first and second layers **46** and **48**, each or both of which may be a porous non-woven web **10**, as shown in **Fig. 1**. In one exemplary embodiment, the first web layer **46** includes first active particles **46a** enmeshed in first polymer fibers **46b**, and the second web layer **48** includes second active particles **48a** enmeshed in second polymer fibers **48b**. Preferably, the first layer **46** is contiguous with the second layer **48** across the deformation, as shown in **Fig. 4**. Such exemplary filter elements are particularly advantageous for use in respiratory protection devices designed for use against mixed gas challenges, e.g. ammonia and organic vapor.

Fig. 5 is a cross-sectional view of another exemplary filter element **50** utilizing a porous non-woven web **52**, such as webs described in connection with other exemplary embodiments of the present disclosure. The web **52** possesses two or more three-dimensional deformations **54**. In this exemplary embodiment, the first surface **52a** and the second surface **52b** of the web **52** is displaced from a planar configuration such that the web **52** forms a series of three-dimensional deformations. In the embodiment shown, the deformations **54** form a linear array (the deformations **54** form a repeating sequence along one direction). In other exemplary embodiments, the deformations **54** form a two-dimensional array (the deformations **54** form a repeating sequence along two different directions). In other exemplary embodiments, the deformations **54** may form any type of a distribution, such as a random array. The individual deformations may be similar in size and/or shape or they may be different from each other. The web **52** includes two or more layers, such as first and second layers **56** and **58**. Preferably, the first layer **56** is contiguous with the second layer **58** across the deformation, for example, along the boundary **57** as shown in **Fig. 5**.

Fig. 6 shows a schematic cross-sectional view of another exemplary filter element **150** according to the present disclosure. The exemplary filter element **150** includes a housing **130**. A porous non-woven web **120** constructed according to the present disclosure, such as the exemplary web shown in **Fig. 2**, is disposed in the interior of the housing **130**. The web **120** includes two or more layers, such as first and second layers **126** and **128**, each or both of which may be a porous non-woven web as described above. The web **32** possesses a three-dimensional deformation **34**. Preferably, the first layer **36** is contiguous with the second layer **38** across the deformation, as shown in **Fig. 3**. The housing **130** includes a cover **132** having openings **133**. Ambient air enters the filter element **150** through the openings **133**, passes through the web **120** (whereupon potentially hazardous substances in such ambient air are processed by active particles in the web **120**) and exits the housing **130** past an intake air valve **135** mounted on a support **137**.

A spigot **138** and bayonet flange **139** enable filter element **150** to be replaceably attached to a respiratory protection device **160**, shown in **Fig. 7**. Device **160**, which is sometimes referred to as a half mask respirator, includes a compliant face piece **162** that can be insert molded around relatively thin, rigid structural member or insert **164**. Insert **164** includes exhalation valve **165** and recessed bayonet-threaded openings (not shown in **Fig. 7**) for removably attaching housings **130** of filter elements **150** in the cheek regions of device **160**. Adjustable headband **166** and neck straps **168** permit device **160** to be securely worn over the nose and mouth of a wearer. Further details regarding the construction of such a device will be familiar to those skilled in the art.

Fig. 8 shows another exemplary respiratory protection device **270**, in which exemplary embodiments of the present disclosure may find use. Device **270** is sometimes referred to as a disposable or maintenance free mask, and it has a generally cup-shaped shell or respirator body **271** including an outer cover web **272**, a porous non-woven web **220** constructed according to the present disclosure, such as exemplary webs shown in **Figs. 2** and **3**, and an inner cover web **274**. Welded edge **275** holds these layers together and provides a face seal region to reduce leakage past the edge of the device **270**. Device **270** includes adjustable head and neck straps **276** fastened to the device **270** by tabs **277**, a nose band **278** and an exhalation valve **279**. Further details regarding the construction of such a device will be familiar to those skilled in the art.

Fig. 9 shows another exemplary respiratory protection device **300**, in which exemplary embodiments of the present disclosure may find use, particularly, exemplary embodiments illustrated in **Fig. 4**. Device **300** is sometimes referred to as a radial flow filtering system, such as those used in air handling systems for collective protection. In the illustrated embodiment, the inlet **314** is located at the inner periphery **310a** of the housing **310**. The outlet **316**, which is in fluid communication with the inlet **314**, may be located at the outer periphery **310b** of the housing **310**. An exemplary filter element **320** disposed within the interior of the housing includes a porous non-woven web **322** according to the present disclosure and three layers of a porous non-woven web **324** according to the present disclosure.

The web **322** may include materials that are different from one or more of the layers of the web **324** and/or it may have different filtration properties than one or more of the layers of the web **324**. In some exemplary embodiments, a layer of the web **324** may include materials that are different from a material of one or more of the other layers of the web **324** and/or it may have different filtration properties than one or more of the layers of the web **324**. An additional filter element, such as a particulate filter element **330,** may also be provided in the interior of the housing **310**. A particulate filter element is preferably provided upstream from the filter element **320**.

In one embodiment, the air or another fluid is routed to the inlet **314** located in the inner periphery of the housing **310**. The air then may pass through each of the filter elements as shown by the arrow **F** until it passes through the outlet **316**. The present disclosure may also be used in other fluid handling systems, and embodiments of the present disclosure may have different configurations and locations of the inlet **314** and outlet **316**. For example, the locations of the inlet and outlet may be reversed.

Fig. 10 illustrates an exemplary method and apparatus **900** for making shape-retaining self-supporting non-woven webs having a three-dimensional deformation, according to the present disclosure. A particle-containing web **920** may originally have a planar configuration. A three-dimensional deformation according to the present disclosure may be imparted to the web **920**, for example, by molding the web **920** using an exemplary apparatus **900**. The apparatus **900** includes a first temperature controlled mold **904a** and a second temperature controlled mold **904b**. The shapes of the molds depend on the shape of the deformation desired to be imparted to the web **902**. An air actuator piston **906** may be used to control the movement of the first mold **904a** toward the second mold **904b**. A frame **902** supports the molds **904a**, **904b** and the piston **906**.

In an exemplary method of making a shape-retaining self-supporting non-woven webs having a three-dimensional deformation, the web layers **922** and **924** are placed between the molds **904a** and **904b**, the molds are brought together such that they subject the web layers **922** and **924** to pressure and heat such that the web layers **922** and **924** are molded together such that they are contiguous and also form a desired shape. Temperatures of the molds **904a** and **904b** can be similar or different and are expected to be dependent on the polymer(s) used in the fibers of the web layers **922** and **924**. If ExxonMobil Vistamaxx brand 2125 thermoplastic polyolefin elastomer is used, mold temperatures that are expected to work would be 75 C to 250 C, and, more preferably, 95 C to 120 C. Pressures exerted by the molds **904a** and **904b** on the web layers **922** and **924** are expected to be dependent on the polymer(s) used in the fibers of the web layers **922** and **924** and may also depend on the type and amount of the active particles. For example, if ExxonMobil Vistamaxx brand 2125 resin is used, pressures that are expected to work would be 20 gr / cm^2 to 10000 gr / cm^2, and more preferably 300 to 2000 gr /cm2. Exemplary molding times under such conditions are expected to be 2 seconds to 30 minutes. Generally, molding times will depend on temperatures, pressures and polymers and active particles.

The molding process is believed to soften and form thermoplastic elastomeric polymer fibers of the web, such that the resultant web having a three-dimensional deformation of a desired shape also includes contiguous layers formed from the web layers **922** and **924.** Such contiguous layers formed by an exemplary process of the present disclosure are more difficult to separate and contribute to an increased durability of the filter element construction. The molding process is also believed to be effective in producing webs that are capable of being self-supporting and shape-retaining. Other exemplary methods may include molding the web layers **922** and **924** on or in a press with heated platens or by placing fixtures with weights in an oven.

TEST METHODS

In order to calculate the density of a sample of a filter element according to the present disclosure, one would typically begin by acquiring a relatively undamaged and a reasonably characteristic piece of the filter element. This can be accomplished, for example, by cutting a piece out of the sample under study, preferably such that at least a portion of the three-dimensional deformation according to the present disclosure is included into the sample. It is important that the piece be large enough in all dimensions that it be considered "characteristic." More particularly, the sample must be much larger than the active particles dispersed in the web, and, preferably, at least 5 times the largest dimension of the particulate in the web, and, more preferably, at least 100 times the largest dimension of the particulate in the web.

The sample shape may be chosen such that it would be easy to measure the dimensions and calculate the volume, such as rectangular or cylindrical. In the case of curved surfaces, it may be advantageous to allow the device (rule die) used to cut the sample to define the diameter, e.g. a rule die. In order to measure the dimensions of such a sample one can use ASTM D1777-96 test option #5 as a guide. The presser foot size will have to be adjusted to accommodate the available sample size. It is desirable not to deform the sample during the measuring process, but higher pressure than specified in option #5 may be acceptable under some circumstances. Because the structures to be measured are porous, contact should be spread over an area that is relatively large with respect to a single active particle. After the volume of the characteristic piece is determined, one should weigh the characteristic piece. The density is determined by dividing the weight by the volume.

It is also possible to characterize density of exemplary embodiments of the present disclosure by comparing the density of the particulate component in the non-woven web to that of a "packed bed" of the same particulate material. This would involve removing the particulate from a known volume of the "characteristic piece" and weighing that resulting particulate sample. This particulate could then be poured into a graduated cylinder in order to get its "packed bed" volume. From these data one can calculate the "packed or apparent" density by dividing the weight by the measured volume. However, the result may be skewed by residual polymer adhering to the particulate.

EXAMPLE

The following layers were assembled and molded into a filtering facepiece respirator shape (resembling a cup) according to the methods of the present disclosure:

1. Outer shell: a layer of non woven material layer - 20% Kosa Co. Type 295 1.5 inch cut 6 denier polyester staple fibers and 80% Kosa Co. Type 254 1.5 inch cut, 4 denier bico-polyester staple fibers.

2. A layer of blown microfiber filter medium.

3. A layer of 4000 gsm (gram per square meter) porous non-woven web according to the present disclosure, including 12 x 20 organic vapor activated carbon particles Type GG, available from Kuraray, enmeshed in thermoplastic elastomeric polyolefin fibers.

4. A layer of 600 gsm porous non-woven web according to the present disclosure including 40 x 140 organic vapor activated carbon particles enmeshed in thermoplastic elastomeric polyolefin polymer fibers.

5. A layer of dense melt-blown microfiber smooth non woven web.

6. Inner shell: a layer of non woven material layer - 20% Kosa Co. Type 295 1.5 inch cut, 6 denier polyester staple fibers and 80% Kosa Co. Type 254 1.5 inch cut, 4 denier bico-polyester staple fibers.

The above layers were put into a molding apparatus intended to mold filtering face piece respirators. The top mold was set at the temperature of 235F, while the bottom mold was set at the temperature of 300F.

The pressure drop of the respirator constructions thus formed, when measured at 85 l/m, was between 14.9 mm water and 33.7 mm water. When tested against the CEN test method for cyclohexane (Test Conditions: 1000 ppm, 30 lpm, 20C, 70% RH, 10 ppm breathrough), the molded respirator construction had a service life of 40-59 minutes. A pertinent CEN test is described in British Standard BS EN 141:200 "Respiratory protective devices - Gas filters and combined filters - Requirements, testing, marking."

Thus, embodiments of the SHAPED LAYERED PARTICLE-CONTAINING NONWOVEN WEB are disclosed. One skilled in the art will appreciate that the present invention can be practiced with embodiments other than those disclosed. For example, more than two layers according to the present disclosure can be used. The disclosed embodiments are presented for purposes of illustration and not limitation, and the present invention is limited only by the claims that follow.

What is claimed is:

1. A filter element comprising:

a porous non-woven web, the web comprising a first layer including first thermoplastic elastomeric polymer fibers and first active particles disposed therein and a second layer including second thermoplastic elastomeric polymer fibers and second active particles disposed therein;

wherein the web possesses a three-dimensional deformation and the first layer is contiguous with the second layer across the deformation.

2. The filter element of claim 1, wherein the first active particles are different from the second particles.

3. The filter element of claim 1, wherein the first fibers comprise the same polymer as the second fibers.

4. The filter element of claim 1, wherein the first active particles comprise particles configured to target a first contaminant and the second particles comprise particles configured to target a second contaminant, different from the first contaminant.

5. The filter element of claim 1, wherein the first active particles are larger than the second active particles.

6. A filter element comprising:

a porous non-woven web, the web comprising a first layer including first thermoplastic elastomeric polymer fibers and first active particles disposed therein and a second layer including second thermoplastic elastomeric polymer fibers and second active particles disposed therein;

wherein the web possesses a three-dimensional deformation and the first layer is contiguous with the second layer across the deformation; and

wherein the three-dimensional deformation is characterized by a thickness that varies by no more than a factor of 5 along at least one direction across the deformation.

7. The filter element of claim 6, wherein the three-dimensional deformation is characterized by a thickness that varies by no more than a factor of 2 along at least one direction across the deformation.

8. A filter element comprising:

a porous non-woven web, the web comprising a first layer including first thermoplastic elastomeric polymer fibers and first active particles disposed therein and a second layer including second thermoplastic elastomeric polymer fibers and second active particles disposed therein;

wherein the web possesses a three-dimensional deformation and the first layer is contiguous with the second layer across the deformation; and

wherein the deformation comprises a surface characterized by a deviation from a planar configuration of at least 0.5 times the web thickness at that location.

9. The filter element of claim 8, wherein the deformation comprises a surface characterized by a deviation of at least 1 times the web thickness from a planar configuration.

10. The filter element of claim 8, wherein the deformation comprises a concave surface characterized by a deviation of at least 5 times the web thickness from a planar configuration.

11. The filter element of claim 1, 6 or 8, wherein the web is shape-retaining.

12. The filter element of claim 1, 6 or 8, wherein the web is self-supporting.

13. The filter element of claim 1, 6 or 8, wherein the web is characterized by a density of at least 30% of a density of a packed bed made with similar active particles.

14. The filter element of claim 1, 6 or 8, wherein the deformation comprises a curvature.

15. The filter element of claim 1, 6 or 8, wherein the web comprises more than 60 weight percent sorbent particles enmeshed in the web.

16. The filter element of claim 1, 6 or 8, wherein the web comprises at least 80 weight percent sorbent particles enmeshed in the web.

17. The filter element of claim 1, 6 or 8, wherein the fibers comprise at least one of: a thermoplastic elastomeric polyolefin, a thermoplastic polyurethane elastomer, a thermoplastic polybutylene elastomer, a thermoplastic polyester elastomer, and a thermoplastic styrenic block copolymer.

18. An article according to claim 1, 6 or 8, wherein the active particles comprise at least one of: a sorbent, a catalyst and a chemically reactive substance.

19. A filter cartridge comprising a housing and the filter element as recited in claim 1, 6 or 8, disposed within the housing.

20. A respiratory protection system comprising an interior portion that generally encloses at least the nose and mouth of a wearer, an air intake path for supplying ambient air to the interior portion, and the filter element as recited in claim 1, 6 or 8 disposed across the air intake path to filter such supplied air.

21. The respiratory protection system of claim 20, wherein the respiratory protection system is a maintenance free respirator.

22. The respiratory protection system of claim 20, wherein the respiratory protection system is a powered air purifying respirator.

23. A respiratory protection system comprising a pair of filter cartridges, each filter cartridge comprising a housing and a filter element as recited in claim 1, 6 or 8, disposed within the housing.

24. A radial filtration system comprising a filter element as recited in claim 1, 6 or 8, the filter element configured as a cylinder.

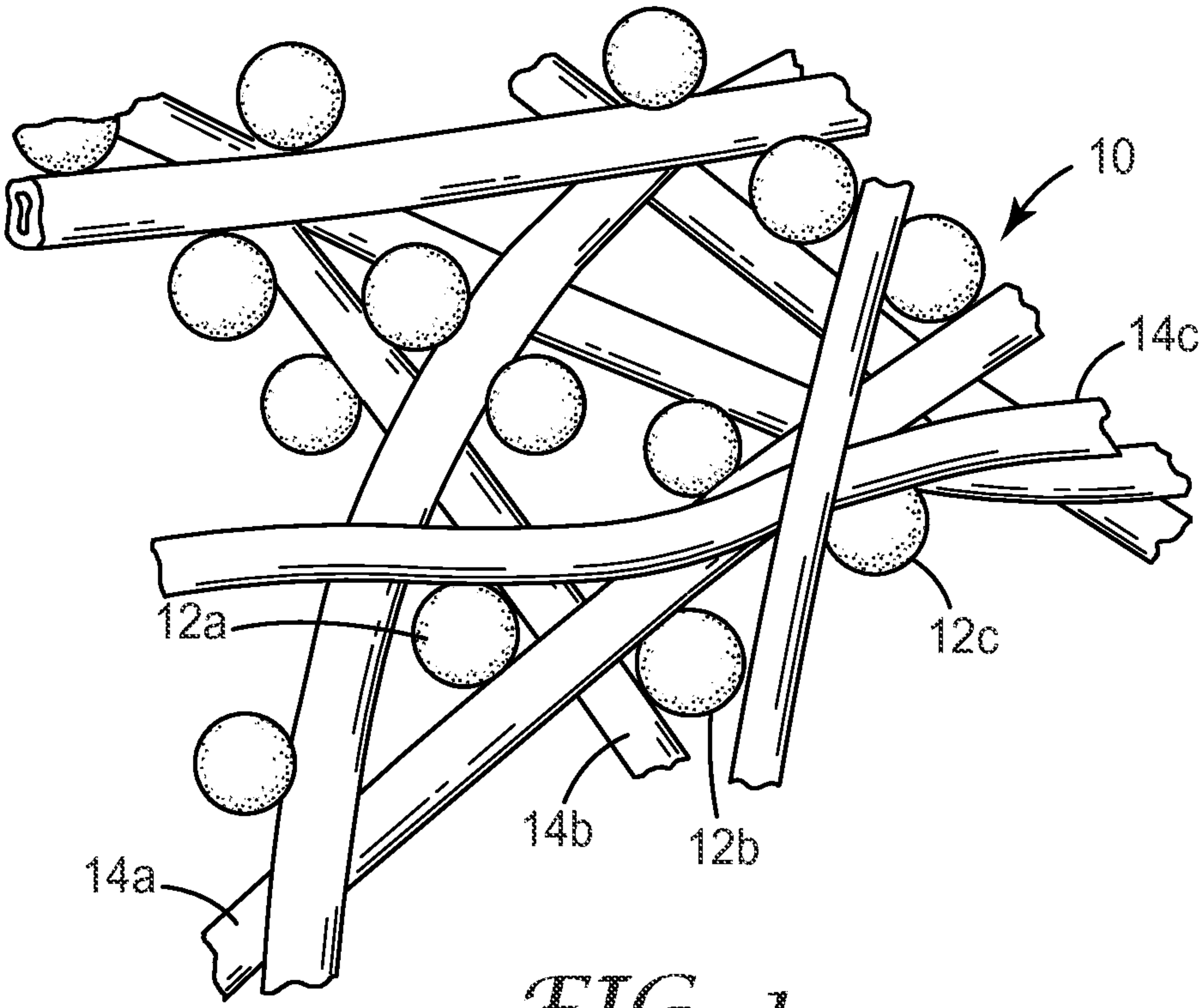
10
14c
12a
12c
14b
12b
14a

FIG. 1

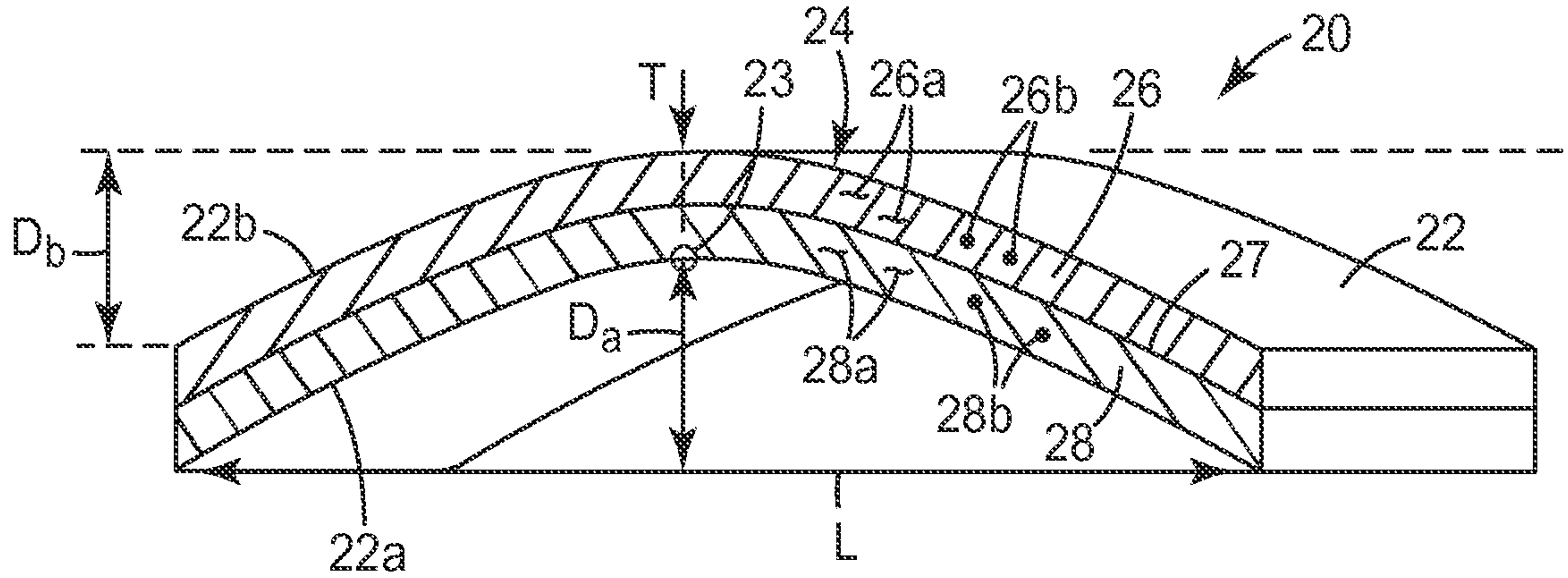
24
20
T
23
26a
26b
26
D_b
22b
22
27
D_a
28a
28b
28
22a
L

FIG. 2

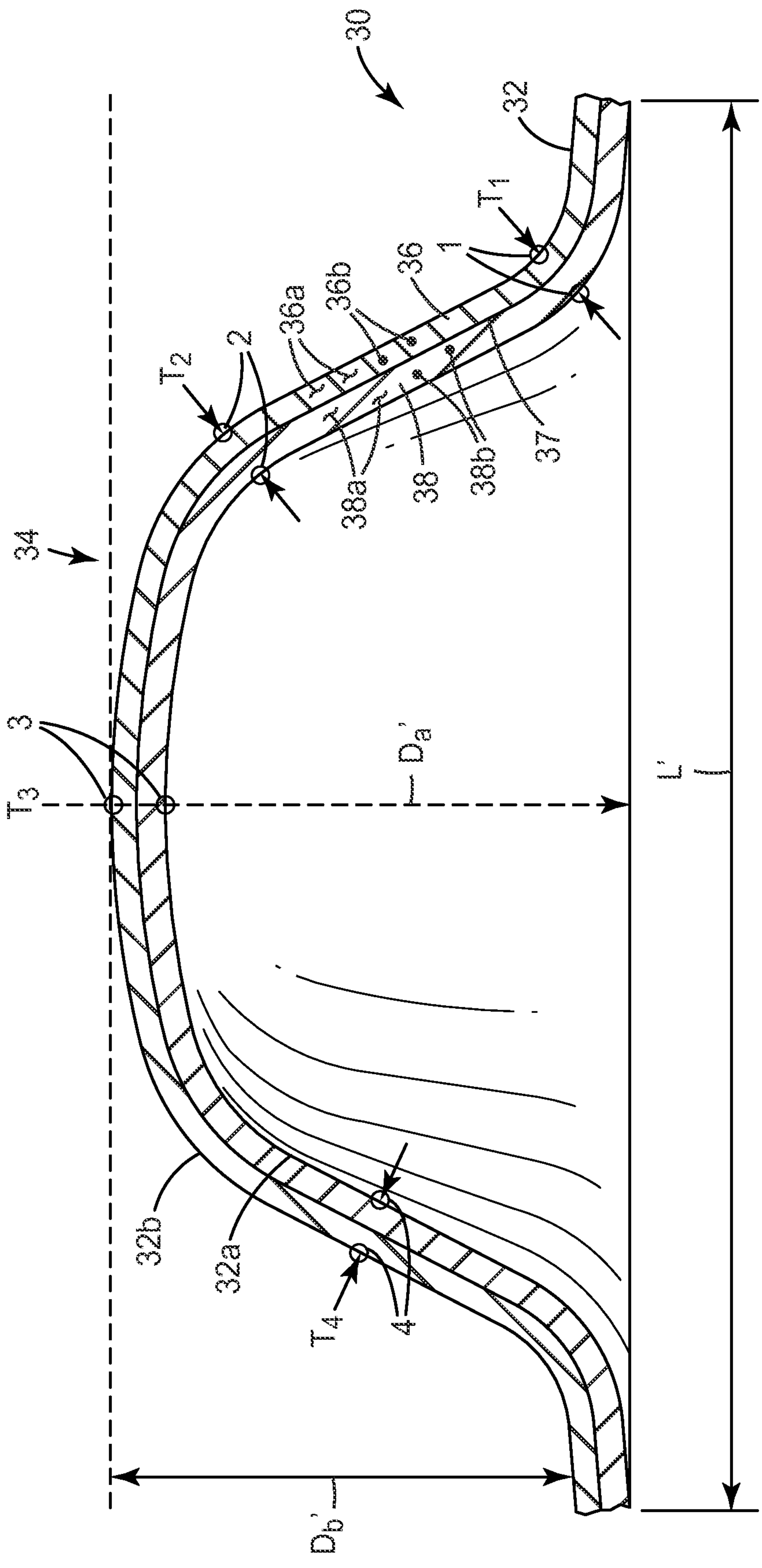

FIG. 3

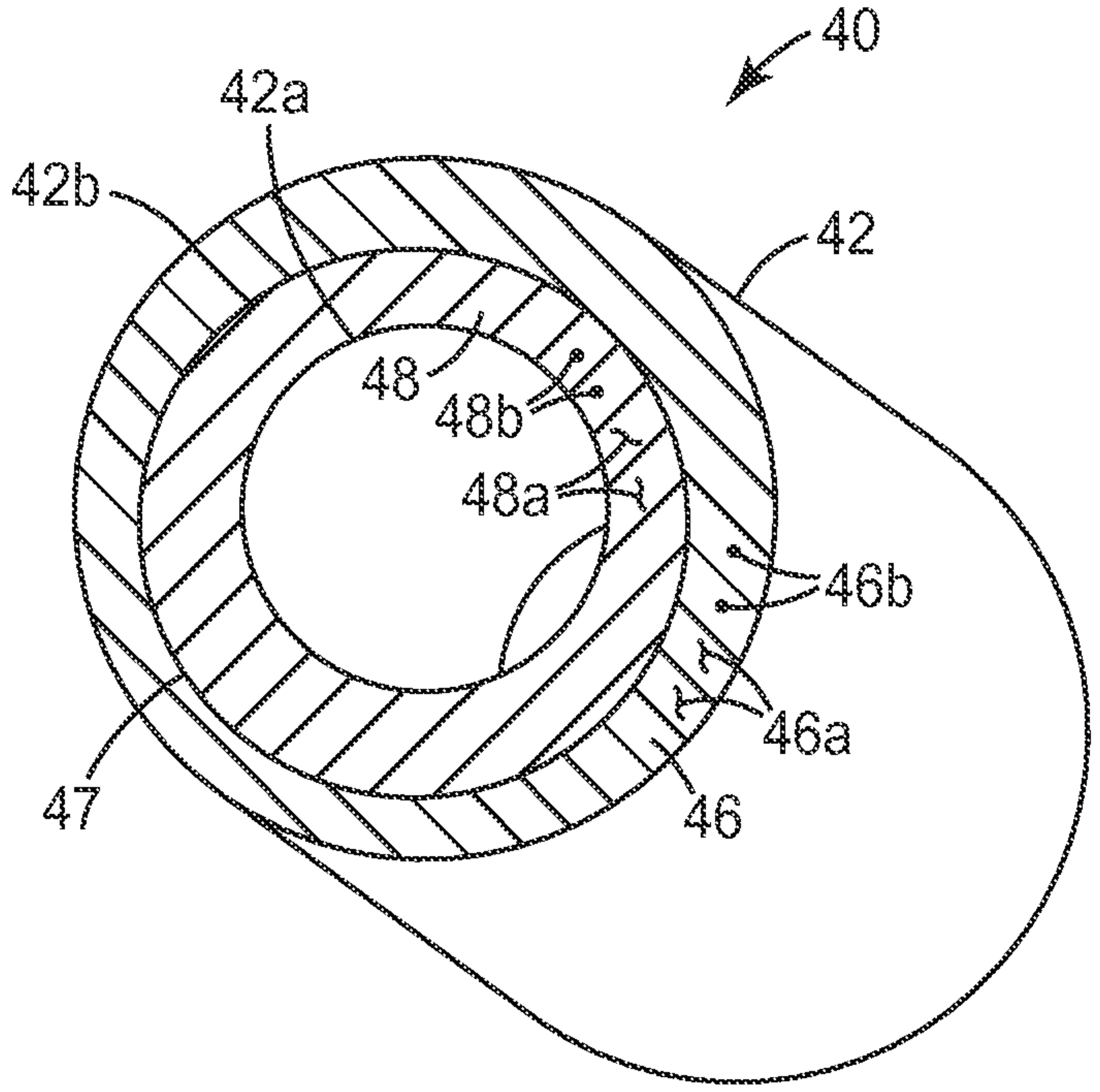
40
42a
42b
42
48
48b
48a
46b
46a
47
46

FIG. 4

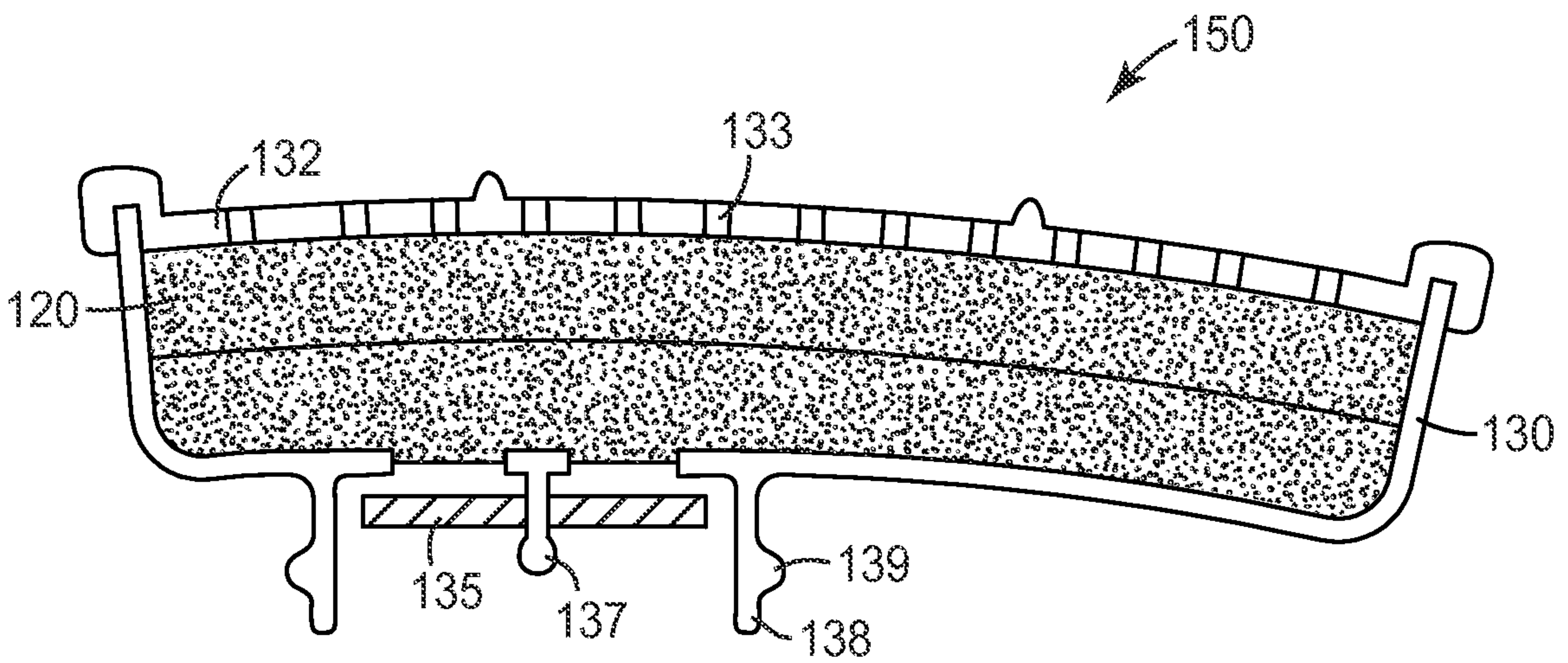
150
132
133
120
130
135
137
139
138

FIG. 6

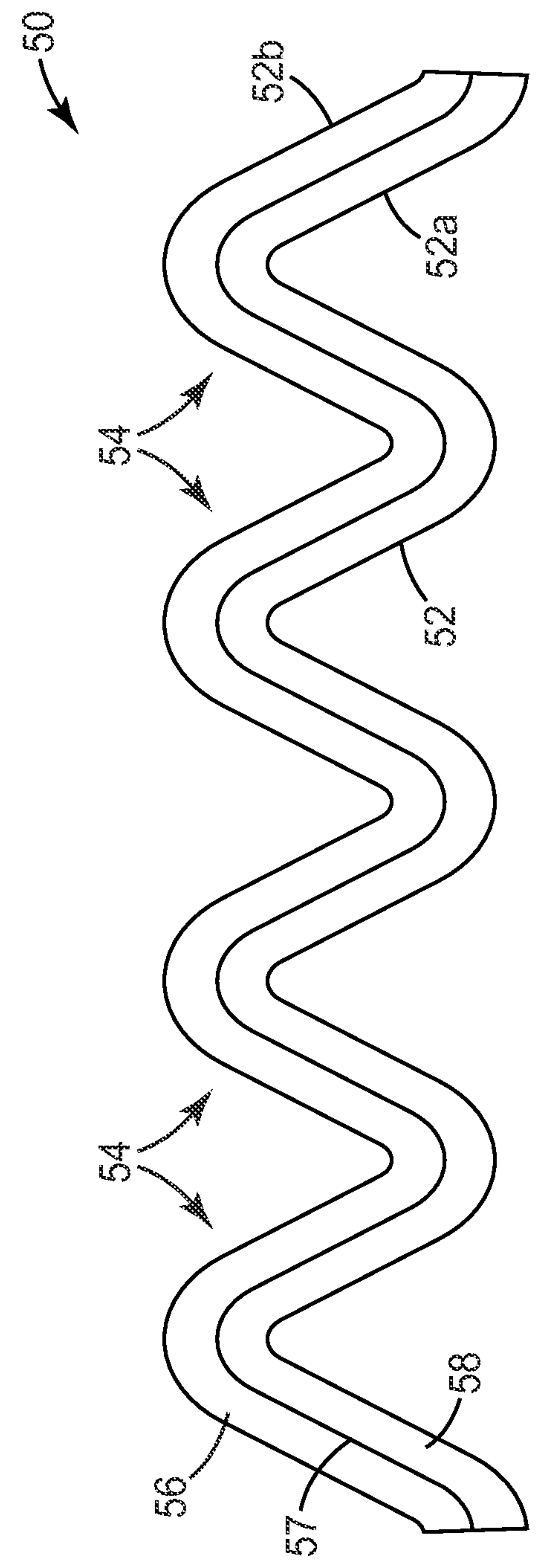

FIG. 5

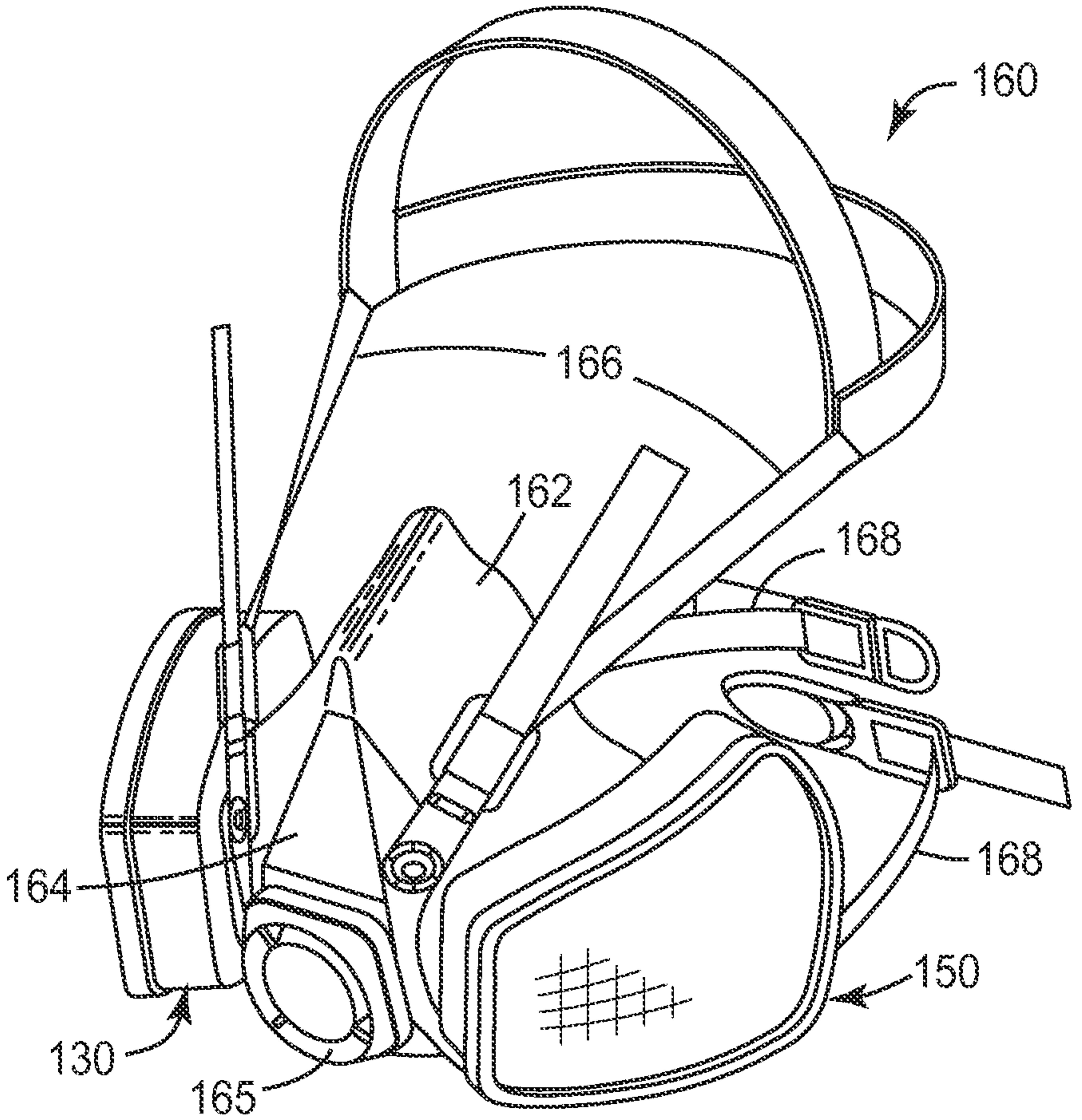
160
166
162
168
164
168
150
130
165

FIG. 7

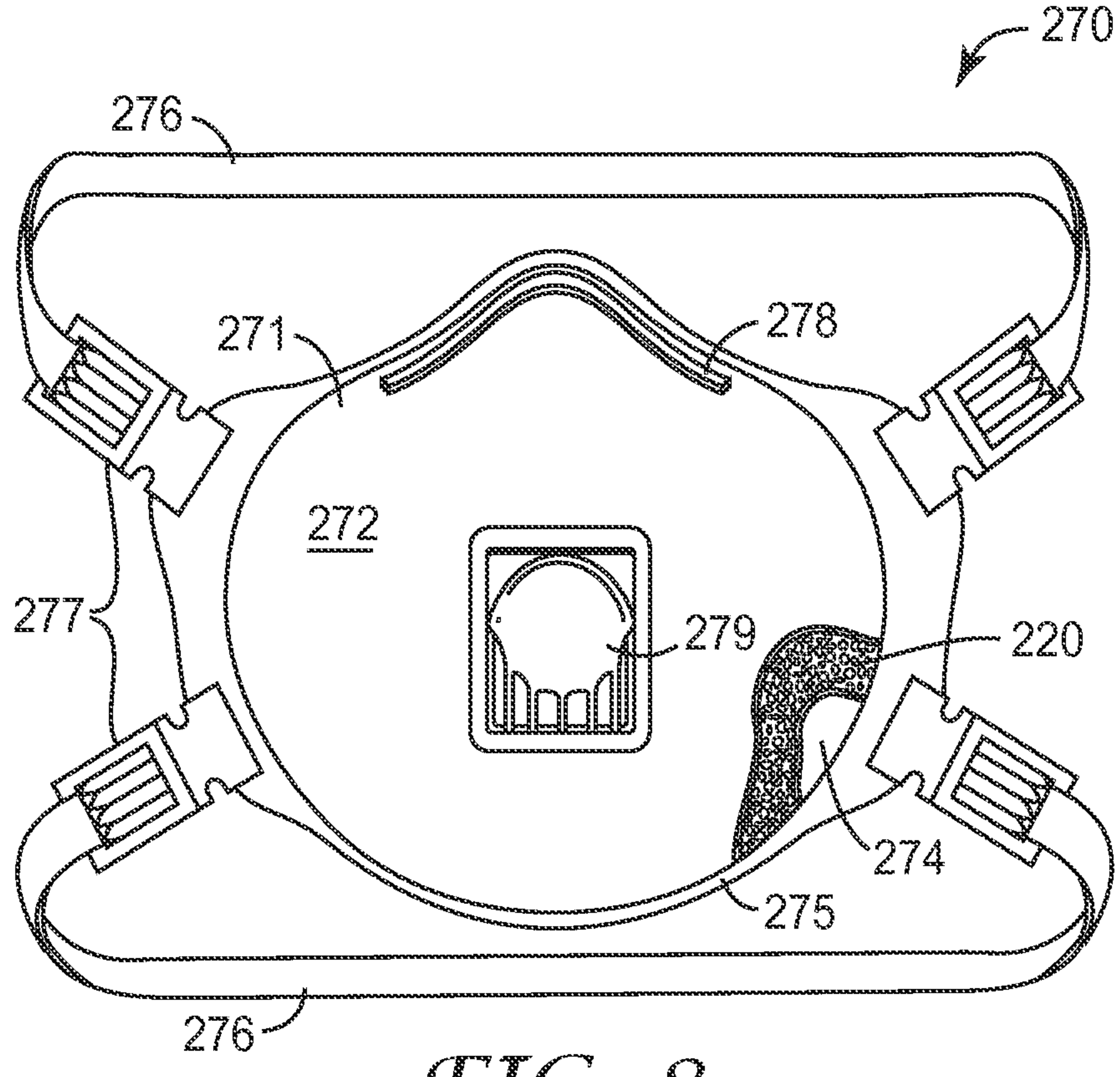
270
276
271
278
272
277
279
220
274
275
276

FIG. 8

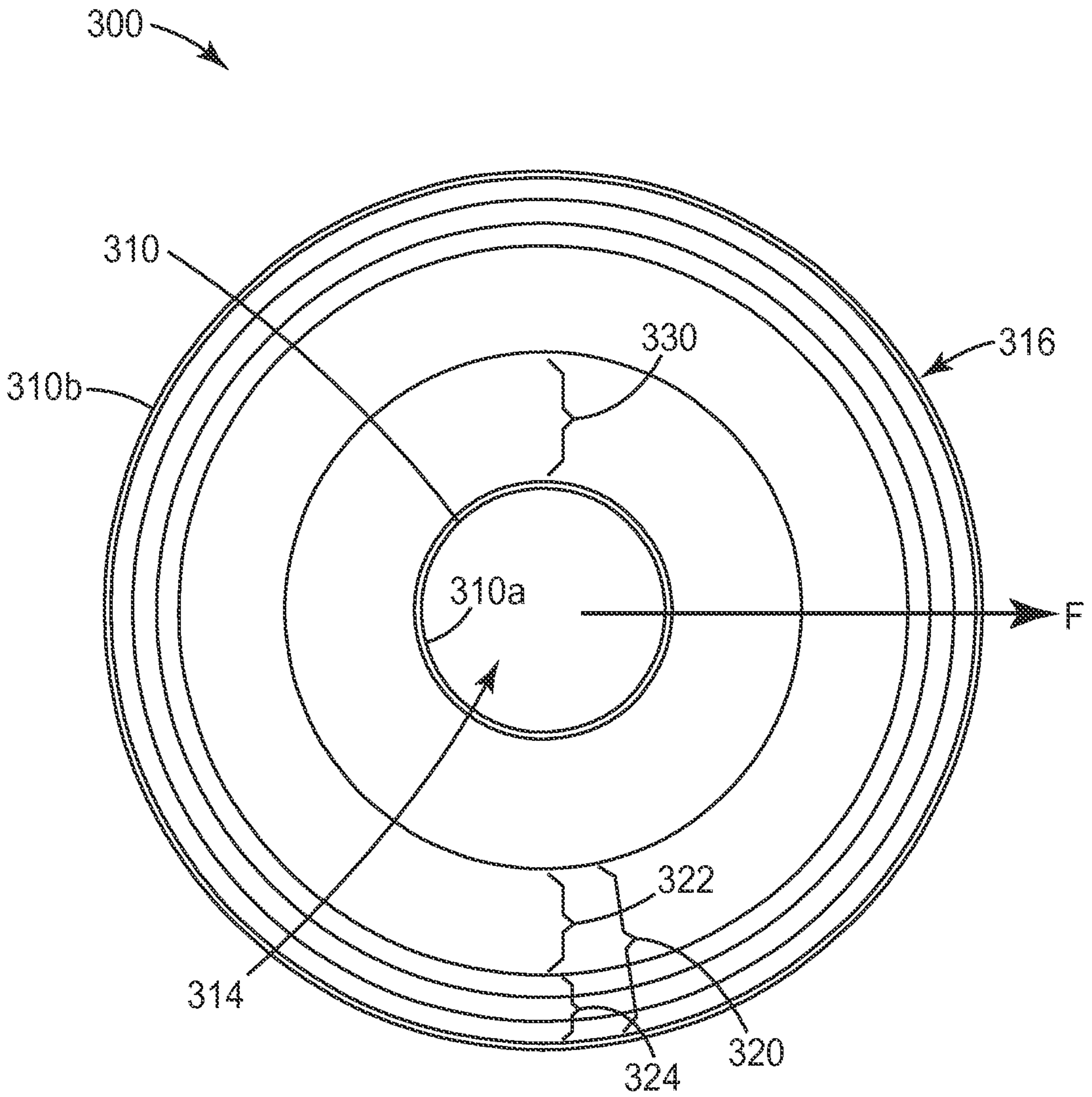

FIG. 9

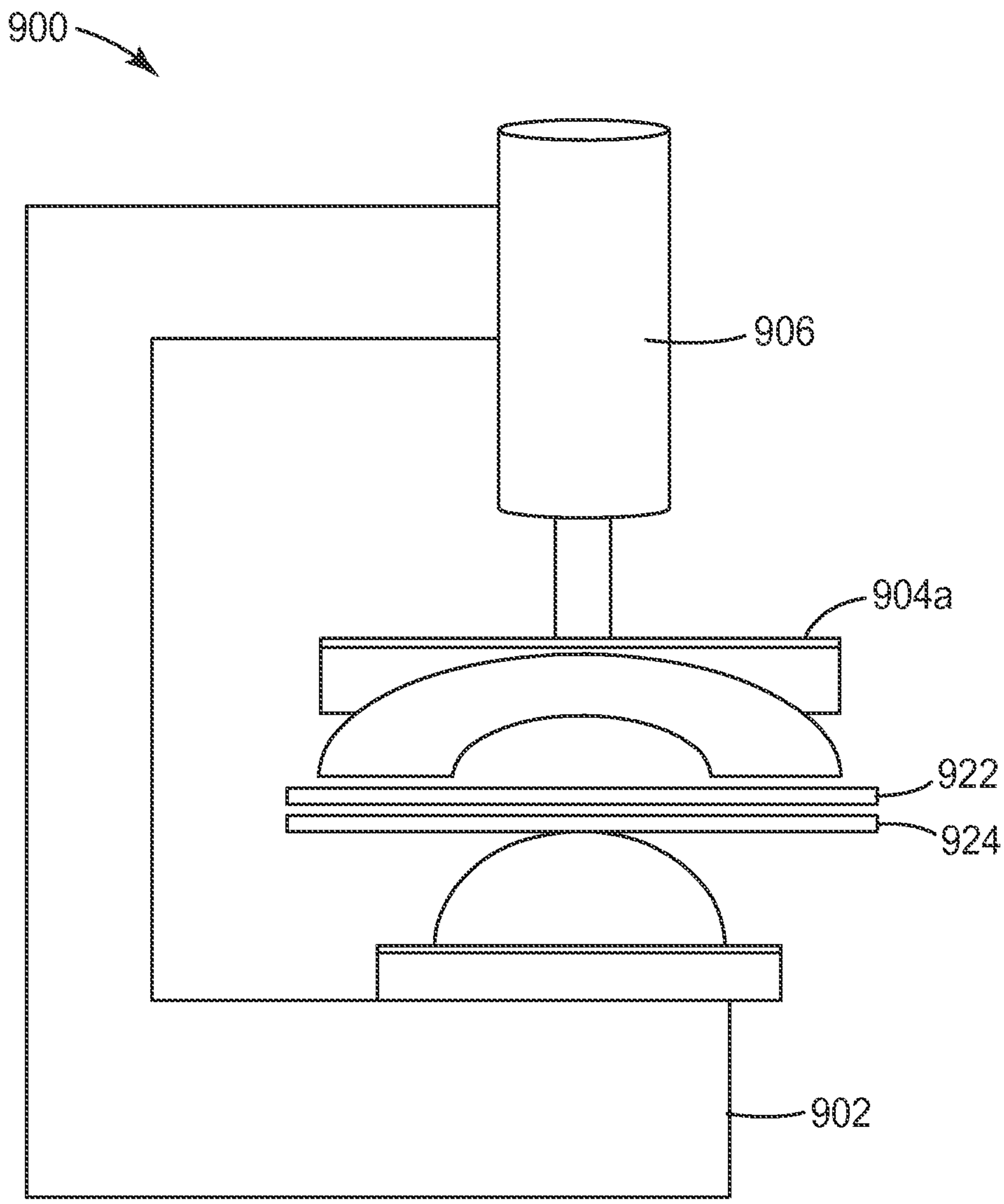

FIG. 10

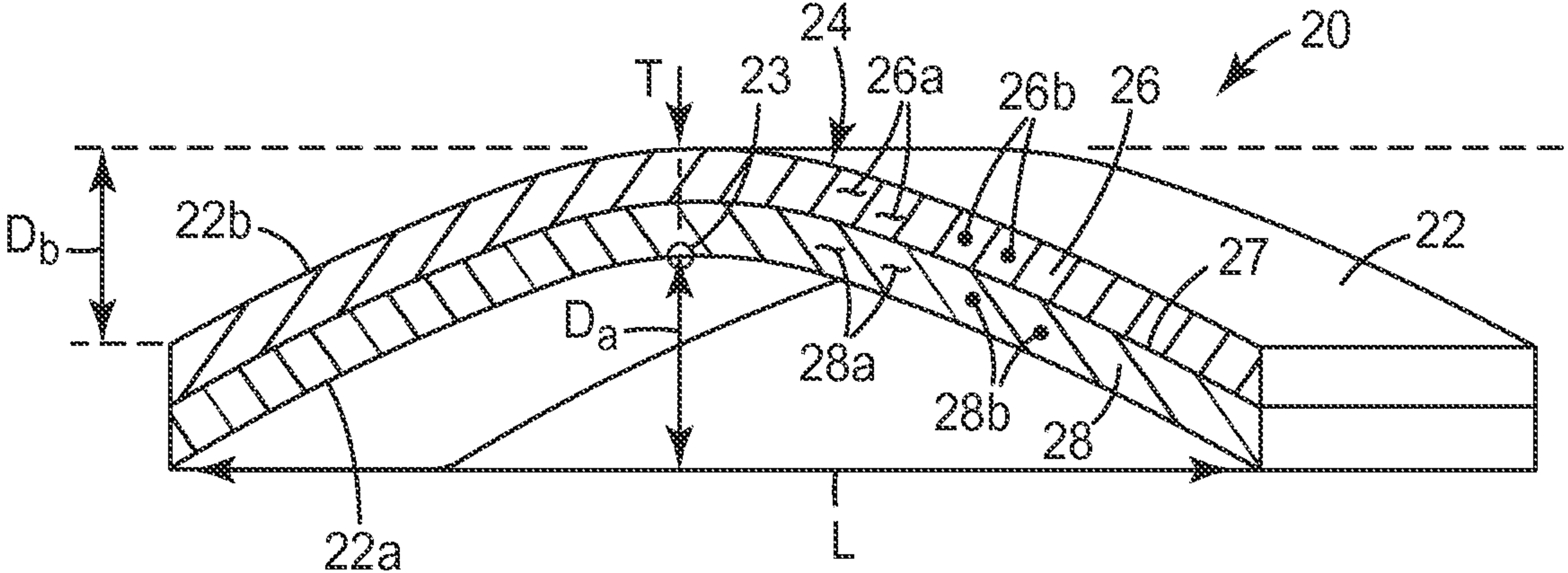

FIG. 2