



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

suspended in the matrix. The matrix serves as delivery means for the inserts into one or more recessed portions. The inserts comprise a hard material (e.g., ceramic or carbide) and form wear bodies which slow and dissipate kinetic energy of escaping slurry by way of creating paths of resistance. As the suspension matrix erodes over time, a plurality of interstices between the inserts are formed. Escaping slurry slows as it traverses three-dimensional serpentine paths defined by said interstices, thereby reducing its potential to wear surrounding components. Methods for manufacturing an energy diffusion sealing ring and for dissipating the energy of slurry are also disclosed.

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

(19) World Intellectual Property  
Organization  
International Bureau(43) International Publication Date  
21 February 2013 (21.02.2013)(10) International Publication Number  
**WO 2013/025472 A3**(51) International Patent Classification:  
*F02F 5/00* (2006.01)(21) International Application Number:  
PCT/US2012/050275(22) International Filing Date:  
10 August 2012 (10.08.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
61/522,986 12 August 2011 (12.08.2011) US(71) Applicant (for all designated States except US): **FLS-MIDTH A/S** [DK/DK]; 77 Vigerslev Alle, DK-2500 Valby (DK).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **HARWELL, Travis** [US/US]; 2040 Avenue C, Bethlehem, Pennsylvania 18017 (US). **MOORHEAD, Robert, G.** [US/US]; 2040 Avenue C, Bethlehem, Pennsylvania 18017 (US).(74) Agent: **SHARP, Jeffrey, A.**; 2040 Avenue C, Bethlehem, Pennsylvania 18017 (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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, 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, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

**Declarations under Rule 4.17:**

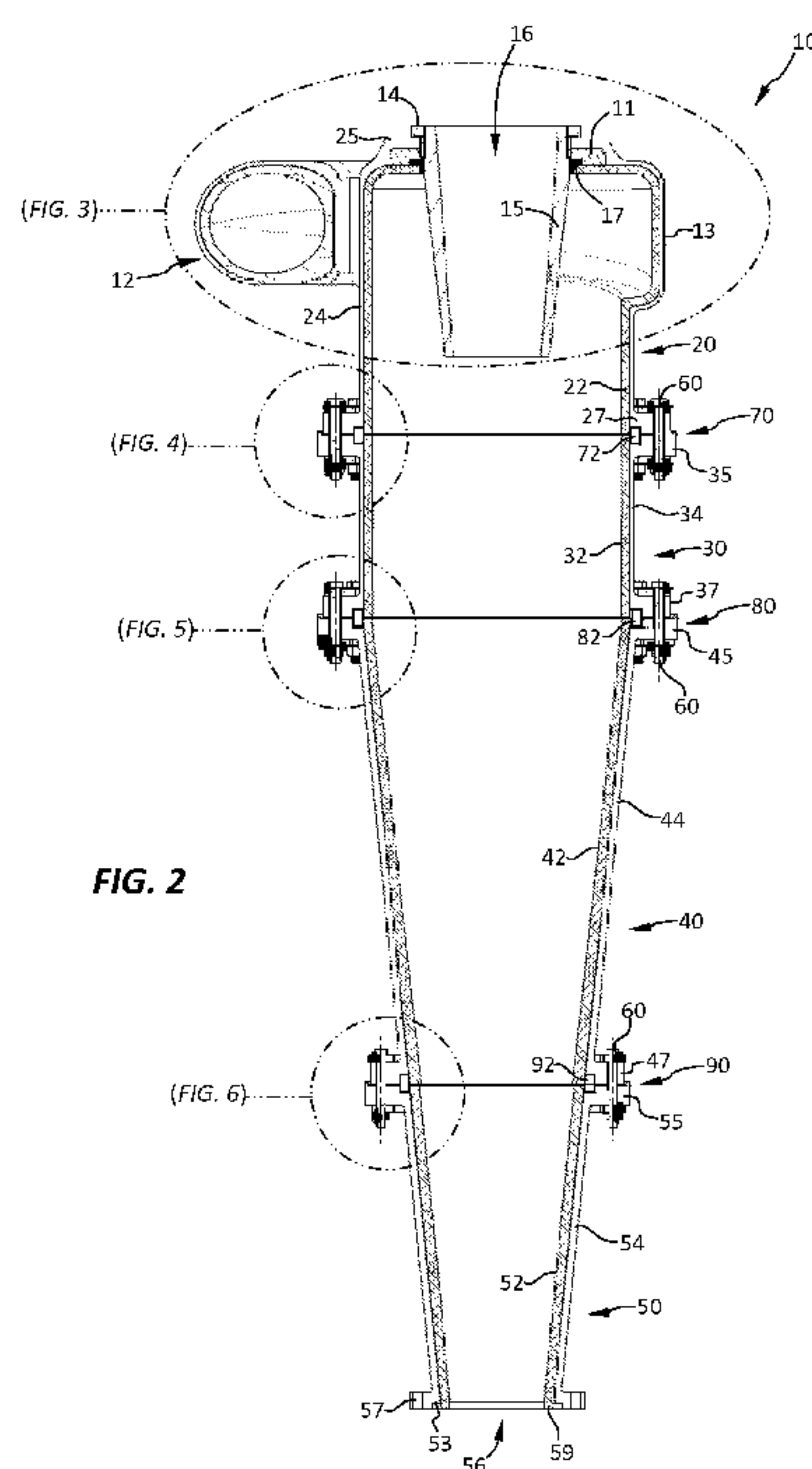
— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

**Published:**

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

[Continued on next page]

(54) Title: ENERGY DIFFUSING WEAR RING AND METHODS THEREOF



(57) Abstract: An energy diffusion sealing ring for use with a hydrocyclone or pump is provided. The energy diffusion sealing ring comprises a sacrificial suspension matrix comprised of a polymer, elastomer, or combination thereof, and a number of packed inserts suspended in the matrix. The matrix serves as delivery means for the inserts into one or more recessed portions. The inserts comprise a hard material (e.g., ceramic or carbide) and form wear bodies which slow and dissipate kinetic energy of escaping slurry by way of creating paths of resistance. As the suspension matrix erodes over time, a plurality of interstices between the inserts are formed. Escaping slurry slows as it traverses three-dimensional serpentine paths defined by said interstices, thereby reducing its potential to wear surrounding components. Methods for manufacturing an energy diffusion sealing ring and for dissipating the energy of slurry are also disclosed.

**WO 2013/025472 A3**



---

**(88) Date of publication of the international search report:**  
6 September 2013

54408-34

**ENERGY DIFFUSING WEAR RING AND METHODS THEREOF****CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims priority to US provisional application no. 61/522,986 filed on August 12, 2011.

**FIELD OF THE INVENTION**

This invention relates to consumable seals for equipment used in industrial, waste, coal, aggregate, and minerals processing technologies, and more particularly to energy-diffusing wear-resistant technologies for hydrocyclones, slurry pumps, and related apparatus.

**BACKGROUND OF THE INVENTION**

The practice of using a hydrocyclone to concentrate and separate coarser-sized particles in a particle-laden aqueous suspension has been practiced for over 100 years; however, the duty of industrial hydrocyclones has been significantly expanded over time. Today, particularly in mineral processing applications, high feed rates of solids and the abrasive nature of these particles requires that hydrocyclones be refined and improved to achieve higher capacities, greater solids recovery, and longer service life.

An important aspect of hydrocyclone operational kinetics which affects service life is the fact that rotating flow inside an operating hydrocyclone obeys the laws of free-vortex rotation. In other words, the rotating velocities (tangential velocities) within an industrial hydrocyclone increase as the radius of the hydrocyclone decreases. Mathematically, this condition of "free

vortex” is expressed by the equation: “ $VR = constant$ ”, wherein “ $V$ ” equals slurry velocity, and “ $R$ ” equals the radius of the hydrocyclone at a given point. Thus, as slurry rotates and descends toward the bottom of a hydrocyclone, it encounters decreasing radius and increasing velocity.

To satisfy the free-vortex equation, slurry must accelerate tangentially in order to maintain a constant result. For example, if slurry enters a 24 inch diameter hydrocyclone fitted with a 4 inch diameter apex orifice with a linear velocity of 25 feet per second, then slurry descending towards the bottom of the hydrocyclone must accelerate to approximately 150 feet per second or increase its tangential velocity approximately 6 times as it encounters a decreasing radius. Since slurry typically contains abrasive particles which can erode interior portions of a hydrocyclone, increased wear is especially prevalent in areas with smaller inner diameters.

To date, hydrocyclone designers have used various approaches including utilizing internal liners constructed of abrasion-resistant materials. In many instances, such an approach requires a multiple-piece hydrocyclone body. FLSmidth Krebs pioneered this concept of “componentized hydrocyclone design” 50 years ago. The concept utilizes multiple sections of wear-resistant liners held together in respective steel-housings. Typically, the liners were comprised of a flexible elastomeric material, and therefore, problems accompanying the sealing of joints between each liner section did not exist.

However, in the mid 1970’s, when “componentized” cyclones were being used in coal processing, elastomeric liners had a short service life because of the abrasiveness of coal particles. Shortly thereafter, FLSmidth Krebs pioneered the use of abrasion-resistant refractory ceramic liners, which, although providing a more abrasion-resistant hydrocyclone, form slight gaps therebetween due to the non-resilient nature of ceramic material. It was discovered that,

unlike elastomeric liners, the gaps at each joint between the rigid ceramic liners permitted some exiting of the rotating slurry suspension within the hydrocyclone, thereby causing premature wear of less abrasion-resistant exterior steel housings.

Since hydrocyclones can be comprised of as many as eight or more sections – with each section having one or more joints, chances are significant that at least one liner joint may succumb to slurry penetration and erosion due to the significant amount of kinetic energy in the rotating slurry.

Through the years, various attempts were made to address slurry erosion in the gaps between ceramic liners. The challenge is that ceramic liners are typically formed by slip casting or isostatic pressing while in a “green” (pre-fired) state, meaning liners need to be sized dimensionally about 15% to 17% larger than the desired final product size (post-firing), depending on material composition. These significant shrinkage rates attributable to kiln-firing lead to non-uniformities which make it extremely difficult to close tight joint gap tolerances between ceramic liners – particularly with oddly sized or shaped liners. Moreover, tightening of tolerances for the casting, pressing, and firing steps would lead to higher manufacturing costs and a non-competitive design in the marketplace.

More recent attempts have incorporated the concept of a labyrinth seal or a half lap-joint type arrangement built-in to each end of the ceramic liners. An example of such a design can be seen in International Patent Application Publication WO10085331. However, independent tests suggest that interfitted ceramic liners incorporating such mechanical interlocks are extremely vulnerable to damage, since ceramic margins generally extend past the respective casing flange. Moreover, such interfaces introduce a level of stress concentration. Thus, the reliance on

traditional labyrinth seals creates a vulnerable ceramic part with a poor resistance to impact. Additionally, higher density abrasive particles have a tendency to orbit in middle and lower sections of a hydrocyclone, further increasing the chance of lap joint failure from orbiting tramp material.

Conventional seals and gaskets commonly used in hydrocyclones are typically made of a solid elastomeric compound such as a urethane or neoprene. The problem with these conventional sealing devices is that they fail to hold up to demanding environments, particularly environments where the sealing devices are subjected to abrasive slurries at high velocities or pressures. Moreover, traditional mechanical interfaces which incorporate seals and gaskets fail to effectively prevent casing blowout as described above. The aforementioned drawbacks are also prevalent in slurry pumps and upper regions of a hydrocyclone, where abrasive slurries under high pressures and/or velocities may escape between components over time. For example, other high wear areas include areas adjacent the vortex finder in a hydrocyclone and areas in slurry pumps adjacent dry glands seals, pump casings, back plates, and hubs.

For example, in a typical hydrocyclone having one or more bolted-together cone sections, a plurality of modular ceramic liner sections protect the inner surfaces of casings which define the outer hydrocyclone housing. Small axial spaces typically exist between the respective mating surfaces of the ceramic liner sections. Slurry passing through these small axial spaces may have large radial velocities and kinetic energy, and can quickly erode both the mating surfaces of the ceramic liners and adjacent portions of the surrounding casings -- including flanged connections and external connectors. Such erosion can lead to spewing, leaks, premature maintenance, and other problems with the hydrocyclone. Since abrasive wear from a particle-

54408-34

laden suspension typically increases at approximately the cube of velocity, it is extremely desirable to slow the velocity of slurry in areas of a hydrocyclone which are not protected with wear surfaces.

### OBJECTS OF THE INVENTION

5                   It is, therefore, an object of some embodiments of the invention to provide an improved wear-resistant sealing junction for hydrocyclones and slurry pump components.

                  It is another object of some embodiments of the invention to provide a method of quickly diffusing high energies and velocities of abrasive slurry to reduce erosion of surrounding components.

10                  Yet another object of some embodiments of the invention is to minimize scheduled and unscheduled maintenance and maximize operation time of equipment at little cost.

                  Another object of some embodiments of the invention is to maximize the safety and performance of hydrocyclones, slurry pumps, and other processing equipment  
15                  requiring robust seals.

                  Another object of some embodiments of the invention is to provide a replaceable sealing wear element which will work to prevent erosion even after a substantial portion of the wear element erodes away.

                  It is another object of some embodiments of the invention to provide a  
20                  replaceable sealing wear element retrofit kit which is compatible with existing conventional hydrocyclone and/or slurry pump units.

                  Another object of some embodiments of the invention is to arrest joint and connection erosion in ceramic-lined hydrocyclones, particularly in areas adjacent to the vortex finder, cone section flanges, and cylinder flanges.

54408-34

Yet another object of some embodiments of the invention is to arrest joint and connection erosion in slurry pumps, particularly in areas adjacent to the dry glands seals, pump casings, back plates, and hubs.

These and other objects of the invention will be apparent from the drawings and description herein. Although every object of the invention is believed to be attained by at least one embodiment of the invention, there is not necessarily any one embodiment of the invention that achieves all of the objects of the invention.

#### SUMMARY OF THE INVENTION

Some embodiments of the present invention utilizes an approach that permits some penetration of abrasive slurry between ceramic liner sections to some extent, so long as the slurry can be quickly arrested by a secondary barrier to protect less wear-resistant housing materials behind it. In some embodiments, a resilient urethane-based casing is directly cast molded to the outside of a preformed refractory/ceramic liner, thereby making an integral single corrosion-resistant housing portion. This process reduces the number of required parts to form a hydrocyclone. Since urethane is more vulnerable to erosion, steel housings may be employed.

An annular energy diffusion sealing ring for a hydrocyclone or slurry pump is disclosed. According to some embodiments, the sealing ring may comprise a resilient suspension matrix comprised of at least one of a polymer or elastomer and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix. In some instances, the inserts are formed of a ceramic or carbide material and the matrix comprises a silicone, urethane, or other form of rubber.

The energy diffusion sealing ring may be received in a complementary shaped annular receiving portion within the hydrocyclone or slurry pump. A kit for refurbishing a hydrocyclone is also disclosed, wherein a first annular energy diffusion sealing ring is configured for sealing an upper side of a hydrocyclone cone section having a larger diameter, and wherein the second annular energy diffusion sealing ring is configured for sealing a lower side of a hydrocyclone cone section having a smaller diameter.

A hydrocyclone comprising an annular energy diffusion sealing ring is also disclosed. The hydrocyclone comprises a first section having a casing, a second section having a casing, and at least one receiving portion which receives the annular energy diffusion sealing ring. The ring comprises a resilient suspension matrix comprised of at least one of a polymer or elastomer and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix.

A slurry pump having a drive shaft, impeller, pump casing, and a back plate or hub further comprises an annular receiving portion which provides seating for the annular energy diffusion sealing ring. The ring comprises a resilient matrix which contains at least one of a polymer or elastomer and a plurality of closely-spaced or closely-packed hard inserts suspended within said resilient matrix.

A method of reducing wear in a hydrocyclone or pump is further disclosed. The method involves providing at least one annular receiving portion in a first component which is adjacent to a second component, providing an annular energy diffusion sealing ring in said at least one annular receiving portion, the annular energy diffusion sealing ring comprising at least one of a polymer or elastomer and a plurality of closely-spaced or closely-packed hard inserts; allowing

54408-34

slurry to wear away portions of the polymer or elastomer thereby forming a plurality of interstices between the inserts; and, diffusing energy of slurry moving between the first and second components via paths of resistance created by said plurality of interstices.

A method of manufacturing a hydrocyclone is also disclosed. The method involves providing a first section and casing; providing a second section and casing; providing at least one receiving portion; inserting an annular energy diffusion sealing ring into said at least one receiving portion, and then assembling the first and second sections together to capture said annular energy diffusion sealing ring in said at least one receiving portion between the first and second section.

Several methods of manufacturing an energy diffusion sealing ring are also provided. For example, energy diffusion sealing rings may be formed by packing inserts tightly together in a ring-shaped mold cavity, and filling the cavity with uncured polymer or elastomer to suspend the inserts. The uncured polymer or elastomer is then cured to capture the inserts in the matrix. In some embodiments, packing of inserts is performed prior to filling, and in other embodiments, filling may be performed before packing. In some embodiments, the ring is formed "in-situ" by applying uncured polymer or elastomer to an annular receiving portion in a hydrocyclone or pump. Yet in other embodiments, inserts may be packed simultaneously with filling, wherein inserts are fed into the ring-shaped mold cavity as the cavity is being filled with uncured polymer or elastomer. Alternatively, the inserts may be pre-mixed with an uncured polymer or elastomer prior to injecting the mix into the ring-shaped mold cavity.

54408-34

According to one aspect of the present invention, there is provided an annular energy diffusion sealing ring for a hydrocyclone or slurry pump, said energy diffusion sealing ring comprising: a resilient suspension matrix comprising at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use; and, a plurality of

5 closely-spaced or closely-packed hard inserts suspended within said matrix; wherein the energy diffusion sealing ring is configured to be received in a complementary-shaped annular receiving portion within the hydrocyclone or slurry pump; and, wherein in use, by virtue of the sacrificial nature of the resilient suspension matrix, the energy diffusion sealing ring is configured to reduce slurry velocities and dissipate kinetic energy of slurry by eroding,

10 forming interstices between said hard inserts, and creating a plurality of high-resistance serpentine paths within the receiving portion for slurry to flow.

According to another aspect of the present invention, there is provided a hydrocyclone comprising: a first section having a first casing and a first liner; a second section having a second casing and a second liner; a receiving portion provided in at least one of said

15 first and second sections, a portion of the receiving portion being defined by a surface of the first or second liner; and, an annular energy diffusion sealing ring situated in said at least one receiving portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended

20 within said matrix; wherein in use, the annular energy diffusion sealing ring is configured to diffuse slurry passing between said first liner and said second liner before it reaches a portion of the first or second casing.

According to still another aspect of the present invention, there is provided a slurry pump comprising: a drive shaft; an impeller; a pump casing; a back plate or hub having

25 an annular receiving portion; and an annular energy diffusion sealing ring situated in said annular receiving portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix; wherein in use, by virtue of the sacrificial nature of the

30 resilient suspension matrix, the energy diffusion sealing ring is configured to reduce slurry

54408-34

velocities and dissipate kinetic energy of slurry by eroding, forming interstices between said hard inserts, and creating a plurality of high-resistance serpentine paths within the receiving portion for slurry to flow.

According to yet another aspect of the present invention, there is provided a  
5 method of reducing wear in a hydrocyclone or pump comprising: providing at least one annular receiving portion in a first component which is adjacent to a second component; providing an annular energy diffusion sealing ring in said at least one annular receiving portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during  
10 use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix; allowing slurry to wear away portions of the suspension matrix thereby forming a plurality of interstices between said inserts; maintaining inserts within the annular receiving portion even after portions of the suspension matrix have been worn away; and, diffusing energy of slurry moving between said first and second components via paths of resistance  
15 created by said plurality of interstices.

According to a further aspect of the present invention, there is provided a kit for refurbishing a hydrocyclone comprising: a first annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-  
20 packed hard inserts suspended within said matrix, the first annular energy diffusion sealing ring comprising a first diameter; a second annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix, the second annular energy diffusion seating ring  
25 comprising a second diameter different than said first diameter; wherein the first annular energy diffusion scaling ring is configured for sealing a first end portion of a hydrocyclone cone section having an inner liner and diffusing slurry after it passes the liner, but before it reaches a portion of the hydrocyclone cone section; wherein the second annular energy diffusion sealing ring is configured for sealing a second end portion of a hydrocyclone cone  
30 section and diffusing slurry after it passes the liner, but before it reaches a portion of the

54408-34

hydrocyclone cone section; and, wherein in use, by virtue of the sacrificial nature of the resilient suspension matrix, the energy diffusion sealing ring is configured to reduce slurry velocities and dissipate kinetic energy of slurry by eroding, forming interstices between said hard inserts, and creating a plurality of high-resistance serpentine paths within the receiving  
5 portion for slurry to flow.

According to yet a further aspect of the present invention, there is provided a method of manufacturing a hydrocyclone comprising: providing a first section having a first casing and a first liner; providing a second section having a second casing and a second liner; providing a receiving portion in at least one of said first and second sections, a portion of the  
10 receiving portion being defined by a surface of the first or second liner; inserting an annular energy diffusion sealing ring into said at least one receiving portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix; assembling said  
15 first section and second section together; and capturing said annular energy diffusion sealing ring in said at least one receiving portion between the first section and second section such that the annular energy diffusion sealing ring is exposed to said surface of the first or second liner.

According to still a further aspect of the present invention, there is provided a  
20 method of manufacturing an energy diffusion sealing ring comprising: packing inserts together in a ring-shaped mold cavity which is complimentary in shape with an annular receiving portion of a hydrocyclone or slurry pump; filling the ring-shaped mold cavity with an uncured polymer or elastomer to suspend the inserts in a resilient suspension matrix which is configured to be sacrificed by erosion during use; and curing the uncured polymer or  
25 elastomer; wherein in use, by virtue of the sacrificial nature of the resilient suspension matrix, the energy diffusion sealing ring is configured to reduce slurry velocities and dissipate kinetic energy of slurry by eroding, forming interstices between said inserts, and creating a plurality of high-resistance serpentine paths within the receiving portion for slurry to flow.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a hydrocyclone according to some embodiments;

FIG. 2 is a longitudinal cross-section of the hydrocyclone shown in FIG. 1;

FIG. 3 is a detailed cross-sectional view showing particulars of FIG. 2;

FIGS. 4-6 are detailed cross-sectional views showing the particulars of first, second, and third connections shown in FIG. 2, respectively;

FIGS. 7A-7D illustrate an energy-diffusion sealing ring according to the embodiment which is shown in FIGS. 2 and 4.

FIGS. 8A-8D illustrate an energy-diffusion sealing ring according to other embodiments.

FIG. 9 is a photograph showing one example of inserts which may be used for an energy-diffusion sealing ring;

FIG. 10 is a photograph showing inserts for an energy-diffusion sealing ring according to other embodiments;

FIG. 11 is a photograph showing an energy-diffusion sealing ring incorporating the inserts shown in FIG. 10;

FIG. 12 is a photograph showing an energy-diffusion sealing ring incorporating inserts according to other embodiments;

FIG. 13 is a photograph showing an energy-diffusion sealing ring incorporating inserts according to FIG. 9;

FIGS. 14A and 14B show an energy-diffusion sealing ring according to some embodiments, incorporating randomized inserts;

FIG. 15 is two side-by-side photographs showing close-ups of an inside portion of the energy-diffusion sealing ring according to FIGS. 14A and 14B;

FIG. 16 shows alternative polygonal-shaped energy-diffusion sealing rings incorporating various thicknesses, sizes, and shape;

FIG. 17 shows an alternative polygonal cross-section arrangement for energy-diffusion sealing rings according to some embodiments;

FIGS. 18A and 18B show an alternative use for energy-diffusion sealing rings according to the invention, particularly in a slurry pump; and,

FIG. 19 shows an energy-diffusion sealing ring and its sacrificial properties in use.

#### DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1-6 depict a hydrocyclone 10 according to some embodiments. The hydrocyclone 10 comprises an inlet 12 for delivery of a slurry feed to be separated. Inlet 12 is part of an inlet head 20 located at an upper region of the hydrocyclone 10. Below the inlet head 20 may be attached one or more cylinders 30 and/or cone sections 40, 50. For example, a first cone section 40 and a second cone section 50 may be provided below a single cylinder 30 as shown. The cone sections 40, 50 may taper down as they approach a lower region of the hydrocyclone 10 as shown.

In use, slurry fines entering the inlet 12 traverse a volute portion 13 and eventually exit an overflow exit port 16 defined by a vortex finder 15. Conversely, heavies and course particles in the slurry feed exit the hydrocyclone 10 through an underflow exit port 56 located in or otherwise defined by a bottommost cone section 50. The underflow exit port 56 may comprise a flange 57 or equivalent structure for connecting to piping, a splash skirt, an underflow launder, or other device. The vortex finder 15 may attach to the inlet head 20 via a vortex finder flange 14.

The flange 14 may be integrally formed (e.g., machined, molded, casted, monolithic) with the vortex finder, or the flange 14 may be formed of a separate material and subsequently joined the vortex finder 15 by pressing, adhesive, or other means known in the art. In a preferred embodiment, the vortex finder 15 may be comprised of a ceramic material, whereas the flange 14 comprises a metallic substrate. A gasket 19 may be provided between an upper flange 25 on the inlet head 20 and said vortex finder flange 14 to prevent leakage. A backing ring 11 may also be provided to provide support and center the vortex finder 15 within the inlet head 20.

In the particular embodiment shown, the backing ring 11 comprises an annular recess in which an energy diffusion sealing ring 17 may be disposed. The sealing ring 17 is wear-resistant and is designed to dissipate energy within high velocity slurries and particles, thereby preventing premature erosion of gasket 19, flange 25, inlet head casing 24, and backing ring 11. In some embodiments, the sealing ring 17 may comprise a polymer, elastomer, or combination thereof and a number of wear-resistant inserts. For example, sealing ring 17 may include a urethane, rubber, or neoprene impregnated with or co-molded with a dense packing of ceramic inserts contained therein. As shown, the sealing ring 17 may comprise a depending lower lip portion which fits concentrically between an upper surface 28 of an inlet head liner 22 and the vortex finder 15. Though not expressly shown, it will be appreciated by those of ordinary skill in the art that other cross-sectional geometries and centering features may be employed by sealing ring 17.

Since insertion areas surrounding the vortex finder 15 generally require clearances with respect to the inlet head liner 22 in order to permit the removal and installation of differently-sized vortex finders used for different processes, particles (particularly coal particles) orbiting in close proximity to the vortex finder 15 may exit the hydrocyclone 10 via said clearances in the

insertion areas surrounding the vortex finder 15. This phenomenon can result in premature wearing of flange 25 and other portions of the casing 24 in upper regions of the cyclone 10, particularly between the inlet head liner 22 and vortex finder 15. The adaptability and compressibility of the flexible energy-diffusion sealing ring 17 provides an improved manner in which to seal vortex finder insertion areas without necessarily requiring permanent cementation of the vortex finder 15 in the hydrocyclone 10.

The inlet head liner 22 serves to protect the softer inlet head casing 24 from abrasive slurries within the hydrocyclone 10. A bottom portion of the inlet head casing 24 comprises an inlet head lower flange 27 configured to assemble with a cylinder 30 or cone section 40, 50. The inlet head lower flange 27 comprises a receiving portion 23 configured to receive an upper portion of a complementary-shaped first connection energy diffusion sealing ring 72.

In the particular embodiment shown in FIGS. 1-6, a cylinder 30 is mounted to the inlet head 20 via a first connection 70 which comprises a cylinder upper flange 35 and the inlet head lower flange 27. As best seen in FIG. 4, the upper flange 35 comprises a receiving portion 31 which is configured to receive a lower portion of a complementary-shaped first connection energy diffusion sealing ring 72. The sealing ring 72 serves to diffuse energy in slurry escaping between a lower surface 29 of the inlet head liner 22 and an upper surface 38 of a cylinder liner 32 at high radial velocities and centrifugal forces.

A first connection gasket 78 such as a neoprene gasket may be placed between the inlet head lower flange 27 and the cylinder upper flange 35 in order to further seal the inlet head 20 to the cylinder 30. The first connection gasket 78 is protected from slurry escaping between surfaces 29 and 38 by the energy diffusion sealing ring 72. An upper backing plate 74 and a

lower backing plate 76 are provided on opposing sides of the inlet head lower flange 27 and cylinder upper flange 35, respectively, in order to maintain clamping forces between the cylinder 30 and the inlet head 20. A number of fasteners 60 apply the clamping forces to the backing plates 74, 76 thereby pressing the flanges 27, 35 together and compressing the gasket 78.

According to FIG. 5, cylinder 30 is mounted to a first cone section 40 via a second connection 80. The second connection 80 comprises a cylinder lower flange 37 and a first cone section upper flange 45. The cylinder lower flange 37 comprises a lower receiving portion 33 which is configured to receive an upper portion of a complementary-shaped second connection energy diffusion sealing ring 82. The first cone section upper flange 45 comprises a first cone section upper receiving portion 41 which is configured to receive a lower portion of a complementary-shaped second connection energy diffusion sealing ring 82. The sealing ring 82 serves to diffuse energy in slurry escaping between a lower surface 39 of the cylinder liner 32 and an upper surface 48 of a first cone section liner 42 at high radial velocities and centrifugal forces. The cylinder liner 32 serves to protect a cylinder casing 34 from abrasive slurries within the hydrocyclone 10 and the first cone section liner 42 serves to protect the first cone section casing 44 from abrasive slurries within the hydrocyclone 10.

A second connection gasket 88 (for example, a neoprene gasket) may be placed between the cylinder lower flange 37 and the first cone section upper flange 45 to seal the first cone section 40 to the cylinder 30. The second connection gasket 88 is protected from slurry escaping between surfaces 39 and 48 by the second connection energy diffusion sealing ring 82. An upper backing plate 84 and a lower backing plate 86 are similarly provided on opposing sides of the cylinder lower flange 37 and first cone section upper flange 45. A plurality of fasteners 60 apply

clamping forces to the backing plates 84, 86 thereby pressing the flanges 37, 45 together and compressing the gasket 88.

According to FIG. 6, a second cone section 50 is mounted to the first cone section 40 via a third connection 90. The third connection 90 comprises a first cone section lower flange 47 and a second cone section upper flange 55. The first cone section lower flange 47 comprises a lower receiving portion 43 which is configured to receive an upper portion of a complementary-shaped third connection energy diffusion sealing ring 92. The second cone section upper flange 55 comprises an upper receiving portion 51 which is configured to receive a lower portion of a complementary-shaped third connection energy diffusion sealing ring 92. The sealing ring 92 serves to diffuse energy in slurry escaping between a lower surface 49 of the first cone section liner 42 and an upper surface 58 of a second cone section liner 52 at high radial velocities and centrifugal forces. The second cone section liner 52 serves to protect a second cone section casing 54 made of a softer material from abrasive incoming slurries.

A third connection gasket 98 is placed between the first cone section lower flange 47 and the second cone section upper flange 55 (for example, a neoprene gasket), to seal the second cone section 50 to the first cone section 40. The second connection gasket 98 is protected from slurry escaping between surfaces 49 and 58 by the third connection energy diffusion sealing ring 92. An upper backing plate 94 and a lower backing plate 96 are provided on opposing sides of the first cone section lower flange 47 and second cone section upper flange 55, respectively. A lower receiving portion 53 may be provided to the second cone section 50 adjacent a second cone section liner lower surface 59, in order to accommodate a fourth energy diffusion sealing

ring (not shown) or conventional seal or gasket to improve the connection between the hydrocyclone 10 and another device such as a splash skirt, under flow launder, or pipe/tube.

FIGS. 7A-7D illustrate an energy-diffusion sealing ring 72 according to the embodiment shown in FIGS. 2 and 4. The sealing ring 72 comprises a polymeric or elastomeric suspension matrix 72A and a number of inserts 72B. The inserts 72B are formed of a wear-resistant material such as a ceramic, ceramic composite, carbide (tungsten carbide, high carbon steel), or other material. Though the inserts 72B shown in FIGS. 7A-7D comprise smooth round spheres (e.g., ceramic ball bearings), it should be noted that in some embodiments, inserts 72B may comprise one or more surface textures including ridges, bands, dimples, protuberances, or grooves, and may be provided as, cubes, pyramids, prisms, packing or non-packing polyhedrons (e.g., dodecahedrons), etc. For example, FIG. 9 shows a photograph of inserts 372B having an equatorial band portion.

To form the energy-diffusion sealing ring 372, the inserts 372B are packed together tightly in a ring-shaped mold cavity and then the mold cavity is filled with a urethane or equivalent polymer or elastomer to suspend the inserts 372B in a flexible annular matrix 372A. Alternatively, the inserts 372B are injected into a ring-shaped mold cavity simultaneously with said urethane or equivalent polymer or elastomer to suspend the inserts 372B in a flexible annular matrix 372A. While not shown, the ring 72 may be formed “in-situ” within the receiving portions 23, 31 by filling the receiving portions with a sealant such as RTV silicone pre-mixed with said inserts. Alternatively, the receiving portions 23, 31 may be filled with a sealant and then subsequently, inserts added to the wet sealant prior to hydrocyclone assembly.

The combination of round ceramic inserts 72B with the flexible properties of a softer elastomeric or polymeric matrix 72A provides an erosion resistant sealing ring 72 that can adapt to the dimensional variations of refractory/ceramic liners 24, 34. This insures a tight seal between the sealing ring 72 and the liners 24, 34 – thereby ensuring that any slurry exiting the surfaces 29, 38 between liners 24, 34 cannot short-circuit the sealing ring 72. In addition, such a composite ring is capable of diffusing the energy associated with slurry escaping from lined inner portions of the cyclone 10.

FIGS. 8A-8D illustrate an energy-diffusion sealing ring 172 according to alternative embodiments. The sealing ring 172 comprises a polymeric or elastomeric suspension matrix 172A and a number of tiled inserts 172B which may or may not be integrally provided with a screen or web backing member 172C. The inserts 172B are formed of a wear-resistant material such as a ceramic, ceramic composite, carbide (tungsten carbide, high carbon steel), or other material. FIG. 10 shows a photograph of inserts 172B according to some embodiments. Though the inserts 172B are shown to comprise one or more surface textures including sharp edges, depressions, grooves, and ridges, they may also be provided as smooth round spheres, circular tiles, cubes, 3-dimensionally packing or non-packing polyhedrons, etc. To manufacture the ring 172, the inserts 172B may be tightly pre-packed or otherwise arranged together in a ring-shaped mold cavity prior to filling the mold cavity with a urethane or equivalent polymer or elastomer to suspend the inserts 172B in an annular flexible matrix 172A.

As shown in FIG. 19, after molding (or otherwise curing in-situ), an energy diffusion sealing ring 872 may be installed in one or more recessed portions 833, 841, prior to assembling a hydrocyclone. During installation, the suspension matrix 872A serves as a means for

delivering the inserts 872B into said recessed portions 833, 841. During use, abrasive slurry 850 having a high radial/tangential velocity and escaping between surfaces 848, 839 of liners 832, 842 may erode all or some portions of the suspension matrix 872A away over time, leaving a tight dense packing of hard, wear-resistant inserts 872B in said recessed portions 833, 841 provided in flanges 837, 845. Without the (eroded) suspension matrix 872A, the inserts 872B form small interstices 872C between themselves, thereby creating a plurality of high-resistance three-dimensional serpentine paths where the suspension matrix 872A previously existed. It is these interstices 872C and the geometries resulting from the dimensionally-packed inserts 872B that quickly reduce the radial velocity and dissipate kinetic energy contained within slurry 852. Over time, the inserts 872B may slowly wear away as sacrificial items do, at which time the hydrocyclone can be dismantled and refurbished by sucking out the used inserts 872B and introducing a new replacement ring 872.

FIG. 11 is a photograph of an energy diffusion sealing ring 172 graphically shown in FIG. 8A-8D, incorporating one or more of the hexagonal prismatic honeycomb inserts 172B shown in FIG. 10. The inserts 172B are arranged orderly in series circumferentially around the ring 172. FIG. 12 is a photograph showing an energy-diffusion sealing ring 272 incorporating small cylindrical inserts 272B which are randomly configured and dispersed within a matrix suspension 272A. FIG. 13 is a photograph showing an energy-diffusion sealing ring 372 incorporating inserts 373B shown in FIG. 9.

FIG. 14A is a graphical depiction of an energy-diffusion sealing ring 472 incorporating a randomized distribution of hard wear inserts 472B suspended in a resilient elastomeric or polymeric matrix 472B. FIG. 14B is a cross-section of the ring 472 shown in FIG. 14A. As

shown in FIG. 14B, by randomizing a size and/or shape distribution of inserts 472B, it is possible to form a tighter packing of inserts 472B which is better configured to slow radial velocities of slurry and therefore, diffuse high kinetic energies. FIG. 15 shows actual photos of a cross-section of an energy-diffusion sealing ring 472 according to some embodiments.

FIG. 16 illustrates two embodiments of an energy-diffusion sealing ring 572, 672 -- each having different perimeters and cross-sectional areas. Both rings 572, 672 comprise a number of hard (i.e., ceramic) inserts 572B, 672B suspended in an elastomeric or polymeric matrix 572A, 672A. In the particular embodiments shown, the energy-diffusion sealing rings 572, 672 comprise a rectangularly-shaped annular ring as compared to the circularly-shaped annular ring shown in FIG. 14A. Such embodiments may be particularly useful for rectangular duct joints.

FIG. 17 depicts an energy-diffusion sealing ring 782 according to further embodiments, wherein a cross-section of the sealing ring 782 comprises a polygon resembling an irregular pentagon. It should be understood that other cross-sectional shapes such as triangles, parallelograms, trapezoids may be utilized. According to FIG. 17, cylinder 730 is mounted to a cone section 740 via a connection 780. The connection 780 comprises a cylinder lower flange 737 and a cone section upper flange 745. The cylinder lower flange 737 comprises a lower receiving portion 733 which is configured to receive an upper portion of a complementary-shaped connection energy diffusion sealing ring 782. The cone section upper flange 745 comprises a cone section upper receiving portion 741 which is configured to receive a lower portion of a complementary-shaped connection energy diffusion sealing ring 782. The sealing ring 782 serves to diffuse energy in slurry escaping between a lower surface 739 of the cylinder liner 732 and an upper surface 748 of a cone section liner 742 at high radial velocities and

centrifugal forces. The cylinder liner 732 serves to protect a cylinder casing 734 from abrasive slurries within the hydrocyclone 710. The cone section liner 742 serves to protect the cone section casing 744 from abrasive slurries within the hydrocyclone 710.

A connection gasket 788 (for example, a neoprene gasket) may be placed between the cylinder lower flange 737 and the cone section upper flange 745 to seal the cone section 740 to the cylinder 730. The connection gasket 788 is protected from slurry escaping between surfaces 739 and 748 by the connection energy diffusion sealing ring 782. An upper backing plate 784 and a lower backing plate 786 are similarly provided on opposing sides of the cylinder lower flange 737 and cone section upper flange 745. A plurality of fasteners 760 applies clamping forces to the backing plates 784, 786 thereby pressing the flanges 737, 745 together and compressing the gasket 788.

According to some embodiments, an energy diffusion sealing ring 1072, 1074 may advantageously find use in a slurry pump 1000 - for example, in a slurry pump 1000 having a drive shaft 1010, centrifugal dry glands seal 1020, impeller 1030, pump casing 1040, back plate 1050, hub 1052, and one or more connectors 1060 holding the back plate 1050 and hub 1052 to the centrifugal dry glands seal 1020 and pump casing 1040. Slurry under high pressure and/or radial velocity (i.e., high kinetic energy) finding its way past the dry glands seal 1020 is slowed and diffused by energy diffusion sealing rings 1072, 1074.

The advantage of the flexible suspension matrix 72A, 172A, 272A, 372A, 472A, 572A, 672A is that it permits dimensional adaptation which is not possible with a solid ceramic ring, as well as provides some initial sealing benefits. Dimensional adaptation is generally required due to the tight manufacturing tolerances of refractory ceramic parts. The polymer or elastomeric

suspension matrix 72A, 172A, 272A, 372A, 472A, 572A, 672A is able to deform and provide some “play” in taking up small differences in dimensions. The matrix may be modified to fit a receiving portion 23, 31, 33, 41, 43, 51, 53, 733, 741 after manufacturing (e.g. by cutting, heating, expanding, shrinking, deforming, or otherwise altering its shape). The matrix essentially serves as a temporary sacrificial “carrier” which enables and facilitates precise depositing of the inserts 72B, 172B, 272B, 372B, 472B, 572B, 672B snugly into the recessed portion(s) 31, 41, 51, 741; 23, 33, 43, 53, 733 during assembly. Once an energy diffusion sealing ring 72, 82, 92, 172, 272, 372, 472, 572, 672, 782, 1072, 1074 is assembled with its respective component of a hydrocyclone 10 or slurry pump 1000, the matrix 72A, 172A, 272A, 372A, 472A, 572A, 672A, can essentially be sacrificed, because the wear media is captured in said respective component. By utilizing a wear-resistant media such as ceramic for the material choice of inserts 72B, 172B, 272B, 372B, 472B, 572B, 672B, it is ensured that interstitial geometry is maintained longer, and thus energy-diffusing potential is preserved.

A contractor or other entity may provide an energy-diffusion sealing ring system or install an energy-diffusion sealing ring according to a process in whole, or in part, as shown and described. For instance, the contractor may receive a bid request for a project related to designing an energy-diffusion sealing ring, or the contractor may offer to design or provide such an apparatus for a client (e.g., a hydrocyclone or pump comprising one or more of the energy-diffusion sealing rings described, or a repair kit having multiple energy-diffusion sealing rings). The contractor may then provide, for example, any one or more of the devices or features thereof shown and/or described in the embodiments discussed above. The contractor may provide such devices by selling those devices or by offering to sell those devices. The contractor may provide

54408-34

various embodiments that are sized, shaped, and/or otherwise configured to meet the design criteria of a particular client or customer. The contractor may subcontract the fabrication, delivery, sale, or installation of a component or whole of the devices disclosed, or of other devices used to provide said devices. The contractor may also survey a site and design or designate one or more storage areas for stacking the material used to manufacture the devices. The contractor may also maintain, modify, replace, or upgrade the provided devices. The contractor may provide such maintenance or modifications by subcontracting such services or by directly providing those services or components needed for said maintenance or modifications, and in some cases, the contractor may modify an existing hydrocyclone or pump with a "retrofit kit" to arrive at a modified hydrocyclone or pump system comprising one or more method steps, devices, or features of the sealing/energy-diffusion technologies discussed herein.

Although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without exceeding the scope of the claimed invention. For example, it is envisaged that features of the invention may be employed in applications where there exists a cavity in a component (e.g., an O-ring groove or gasket channel) capable of accepting an elastomeric seal, wherein the elastomeric seal can potentially fail due to an abrasive substance which penetrates the interface between two assembled parts.

Accordingly, it is to be understood that the drawings and descriptions herein are proffered by way of example to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

Reference numeral identifiers

|     |                                                |
|-----|------------------------------------------------|
| 10  | Hydrocyclone                                   |
| 11  | Backing ring                                   |
| 12  | Inlet                                          |
| 13  | Volute portion                                 |
| 14  | Vortex finder flange                           |
| 15  | Vortex finder                                  |
| 16  | Overflow exit port                             |
| 17  | Vortex finder energy diffusion sealing ring    |
| 19  | Vortex finder flange gasket                    |
| 20  | Inlet head                                     |
| 22  | Inlet head liner                               |
| 23  | Inlet head lower receiving portion             |
| 24  | Inlet head casing                              |
| 25  | Inlet head upper flange                        |
| 27  | Inlet head lower flange                        |
| 28  | Inlet head liner upper surface                 |
| 29  | Inlet head liner lower surface                 |
| 30  | Cylinder                                       |
| 31  | Cylinder upper receiving portion               |
| 32  | Cylinder liner                                 |
| 33  | Cylinder lower receiving portion               |
| 34  | Cylinder casing                                |
| 35  | Cylinder upper flange                          |
| 37  | Cylinder lower flange                          |
| 38  | Cylinder liner upper surface                   |
| 39  | Cylinder liner lower surface                   |
| 40  | First cone section                             |
| 41  | First cone section upper receiving portion     |
| 42  | First cone section liner                       |
| 43  | First cone section lower receiving portion     |
| 44  | First cone section casing                      |
| 45  | First cone section upper flange                |
| 47  | First cone section lower flange                |
| 48  | First cone section liner upper surface         |
| 49  | First cone section liner lower surface         |
| 50  | Second cone section                            |
| 51  | Second cone section upper receiving portion    |
| 52  | Second cone section liner                      |
| 53  | Second cone section lower receiving portion    |
| 54  | Second cone section casing                     |
| 55  | Second cone section upper flange               |
| 56  | Underflow exit port                            |
| 57  | Second cone section lower flange               |
| 58  | Second cone section liner upper surface        |
| 59  | Second cone section liner lower surface        |
| 60  | Fastener                                       |
| 70  | First connection                               |
| 72  | First connection energy diffusion sealing ring |
| 72A | Suspension matrix                              |
| 72B | Inserts                                        |
| 74  | First connection upper backing plate           |
| 76  | First connection lower backing plate           |
| 78  | First connection gasket                        |
| 80  | Second connection                              |

|                                                    |                                                  |
|----------------------------------------------------|--------------------------------------------------|
| 82                                                 | Second connection energy diffusion sealing ring  |
| 84                                                 | Second connection upper backing plate            |
| 86                                                 | Second connection lower backing plate            |
| 88                                                 | Second connection gasket                         |
| 90                                                 | Third connection                                 |
| 92                                                 | Third connection energy diffusion sealing ring   |
| 94                                                 | Third connection upper backing plate             |
| 96                                                 | Third connection lower backing plate             |
| 98                                                 | Third connection gasket                          |
| 172, 272, 372, 472, 572, 672, 782, 872, 1072, 1074 | Energy diffusion sealing ring                    |
| 172A, 272A, 372A, 472A, 572A, 672A                 | Suspension matrix                                |
| 172B, 272B, 372B, 472B, 572B, 672B                 | Inserts                                          |
| 172C                                               | Screen or web backing member                     |
| 710                                                | Hydrocyclone                                     |
| 730                                                | Cylinder                                         |
| 732                                                | Cylinder liner                                   |
| 733                                                | Cylinder lower flange receiving portion          |
| 734                                                | Cylinder casing                                  |
| 737                                                | Cylinder lower flange                            |
| 739                                                | Cylinder liner lower surface                     |
| 740                                                | Cone section                                     |
| 741                                                | Cone section upper receiving portion             |
| 742                                                | Cone section liner                               |
| 744                                                | Cone section casing                              |
| 745                                                | Cone section upper flange                        |
| 748                                                | Cone section liner upper surface                 |
| 739                                                | Cone section liner lower surface                 |
| 780                                                | Connection                                       |
| 782                                                | Energy diffusion sealing ring                    |
| 784                                                | Upper backing plate                              |
| 786                                                | Lower backing plate                              |
| 788                                                | A connection gasket                              |
| 872A                                               | Suspension matrix                                |
| 872B                                               | Hard, wear-resistant insert                      |
| 833, 841                                           | Recessed portion.                                |
| 850                                                | Slurry w/ high radial velocity/kinetic energy    |
| 832, 842                                           | Liner                                            |
| 848                                                | Liner upper surface                              |
| 839                                                | Liner lower surface                              |
| 872A                                               | Suspension matrix                                |
| 837, 845                                           | Flange                                           |
| 872C                                               | Interstices                                      |
| 852                                                | Slurry w/ reduced radial velocity/kinetic energy |
| 1000                                               | Pump                                             |
| 1010                                               | Drive shaft                                      |
| 1020                                               | Centrifugal dry glands seal                      |
| 1030                                               | Impeller                                         |
| 1040                                               | Pump casing                                      |
| 1050                                               | Back plate                                       |
| 1051                                               | Back plate receiving portion                     |
| 1052                                               | Hub                                              |
| 1053                                               | Hub receiving portion                            |
| 1060                                               | Connector(s)                                     |

54408-34

CLAIMS:

1. An annular energy diffusion sealing ring for a hydrocyclone or slurry pump, said energy diffusion sealing ring comprising:

5 a resilient suspension matrix comprising at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use; and,

a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix;

10 wherein the energy diffusion sealing ring is configured to be received in a complementary-shaped annular receiving portion within the hydrocyclone or slurry pump; and,

wherein in use, by virtue of the sacrificial nature of the resilient suspension matrix, the energy diffusion sealing ring is configured to reduce slurry velocities and dissipate kinetic energy of slurry by eroding, forming interstices between said hard inserts, and creating a plurality of high-resistance serpentine paths within the receiving portion for slurry to flow.

15 2. The annular energy diffusion sealing ring according to claim 1, wherein a configuration or distribution of the hard inserts is randomized to allow tighter packing of inserts and more tortuous high-resistance serpentine paths within the receiving portion for slurry to flow.

20 3. The annular energy diffusion sealing ring according to claim 1, wherein said hard inserts comprise one or more of the following: prismatic shapes, cylindrical shapes, surface textures, sharp edges, depressions, grooves, ridges, smooth round spheres, circular tiles, cubes, 3-dimensionally packing polyhedrons, 3-dimensionally non-packing polyhedrons, hexagonal shapes, honeycomb shapes.

4. A hydrocyclone comprising:  
25 a first section having a first casing and a first liner;

54408-34

a second section having a second casing and a second liner;

a receiving portion provided in at least one of said first and second sections, a portion of the receiving portion being defined by a surface of the first or second liner; and,

an annular energy diffusion sealing ring situated in said at least one receiving  
 5 portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix;

wherein in use, the annular energy diffusion sealing ring is configured to  
 10 diffuse slurry passing between said first liner and said second liner before it reaches a portion of the first or second casing.

5. A slurry pump comprising:

a drive shaft;

an impeller;

15 a pump casing;

a back plate or hub having an annular receiving portion; and

an annular energy diffusion sealing ring situated in said annular receiving  
 portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of  
 at least one of a polymer or elastomer which is configured to be sacrificed by erosion during  
 20 use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix;

wherein in use, by virtue of the sacrificial nature of the resilient suspension  
 matrix, the energy diffusion sealing ring is configured to reduce slurry velocities and dissipate  
 kinetic energy of slurry by eroding, forming interstices between said hard inserts, and creating  
 25 a plurality of high-resistance serpentine paths within the receiving portion for slurry to flow.

54408-34

6. A method of reducing wear in a hydrocyclone or pump comprising:

providing at least one annular receiving portion in a first component which is adjacent to a second component;

5 providing an annular energy diffusion sealing ring in said at least one annular receiving portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix;

10 allowing slurry to wear away portions of the suspension matrix thereby forming a plurality of interstices between said inserts;

maintaining inserts within the annular receiving portion even after portions of the suspension matrix have been worn away; and,

diffusing energy of slurry moving between said first and second components via paths of resistance created by said plurality of interstices.

15 7. A kit for refurbishing a hydrocyclone comprising:

a first annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix, the first annular energy diffusion sealing ring comprising a first diameter;

20 a second annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix, the second annular energy diffusion seating ring comprising a second diameter different than said first diameter;

54408-34

wherein the first annular energy diffusion sealing ring is configured for sealing a first end portion of a hydrocyclone cone section having an inner liner and diffusing slurry after it passes the liner, but before it reaches a portion of the hydrocyclone cone section;

5 wherein the second annular energy diffusion sealing ring is configured for sealing a second end portion of a hydrocyclone cone section and diffusing slurry after it passes the liner, but before it reaches a portion of the hydrocyclone cone section; and,

10 wherein in use, by virtue of the sacrificial nature of the resilient suspension matrix, the energy diffusion sealing ring is configured to reduce slurry velocities and dissipate kinetic energy of slurry by eroding, forming interstices between said hard inserts, and creating a plurality of high-resistance serpentine paths within the receiving portion for slurry to flow.

8. A method of manufacturing a hydrocyclone comprising:

providing a first section having a first casing and a first liner;

providing a second section having a second casing and a second liner;

15 providing a receiving portion in at least one of said first and second sections, a portion of the receiving portion being defined by a surface of the first or second liner;

20 inserting an annular energy diffusion sealing ring into said at least one receiving portion, the annular energy diffusion sealing ring comprising a resilient suspension matrix of at least one of a polymer or elastomer which is configured to be sacrificed by erosion during use, and a plurality of closely-spaced or closely-packed hard inserts suspended within said matrix;

assembling said first section and second section together; and

capturing said annular energy diffusion sealing ring in said at least one receiving portion between the first section and second section such that the annular energy diffusion sealing ring is exposed to said surface of the first or second liner.

25 9. A method of manufacturing an energy diffusion sealing ring comprising:

54408-34

packing inserts together in a ring-shaped mold cavity which is complimentary in shape with an annular receiving portion of a hydrocyclone or slurry pump;

filling the ring-shaped mold cavity with an uncured polymer or elastomer to suspend the inserts in a resilient suspension matrix which is configured to be sacrificed by  
5 erosion during use; and

curing the uncured polymer or elastomer;

wherein in use, by virtue of the sacrificial nature of the resilient suspension matrix, the energy diffusion sealing ring is configured to reduce slurry velocities and dissipate kinetic energy of slurry by eroding, forming interstices between said inserts, and creating a  
10 plurality of high-resistance serpentine paths within the receiving portion for slurry to flow.

10. The method according to claim 9, wherein the step of packing inserts is performed prior to filling.

11. The method according to claim 9, wherein the step of packing inserts is performed after filling.

15 12. The method according to claim 9, wherein the ring-shaped mold cavity comprises said annular receiving portion of a hydrocyclone or pump, and the energy diffusion sealing ring is formed within the hydrocyclone or pump in-situ.

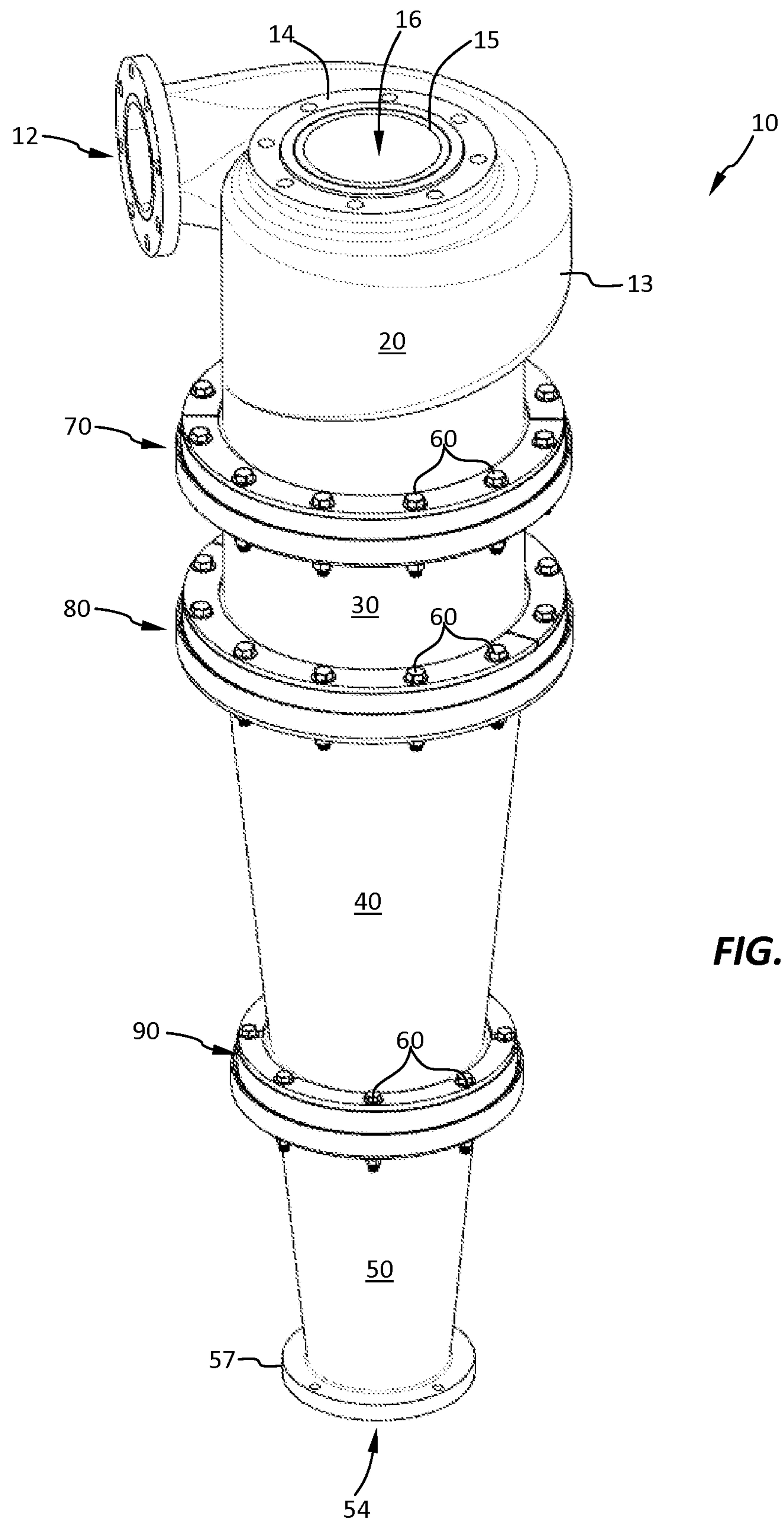
13. The method according to claim 9, wherein the step of packing inserts is performed simultaneously with filling, whereby inserts are densely injected into the ring-  
20 shaped mold cavity while the cavity is being filled with the uncured polymer or elastomer to suspend the inserts in said resilient suspension matrix.

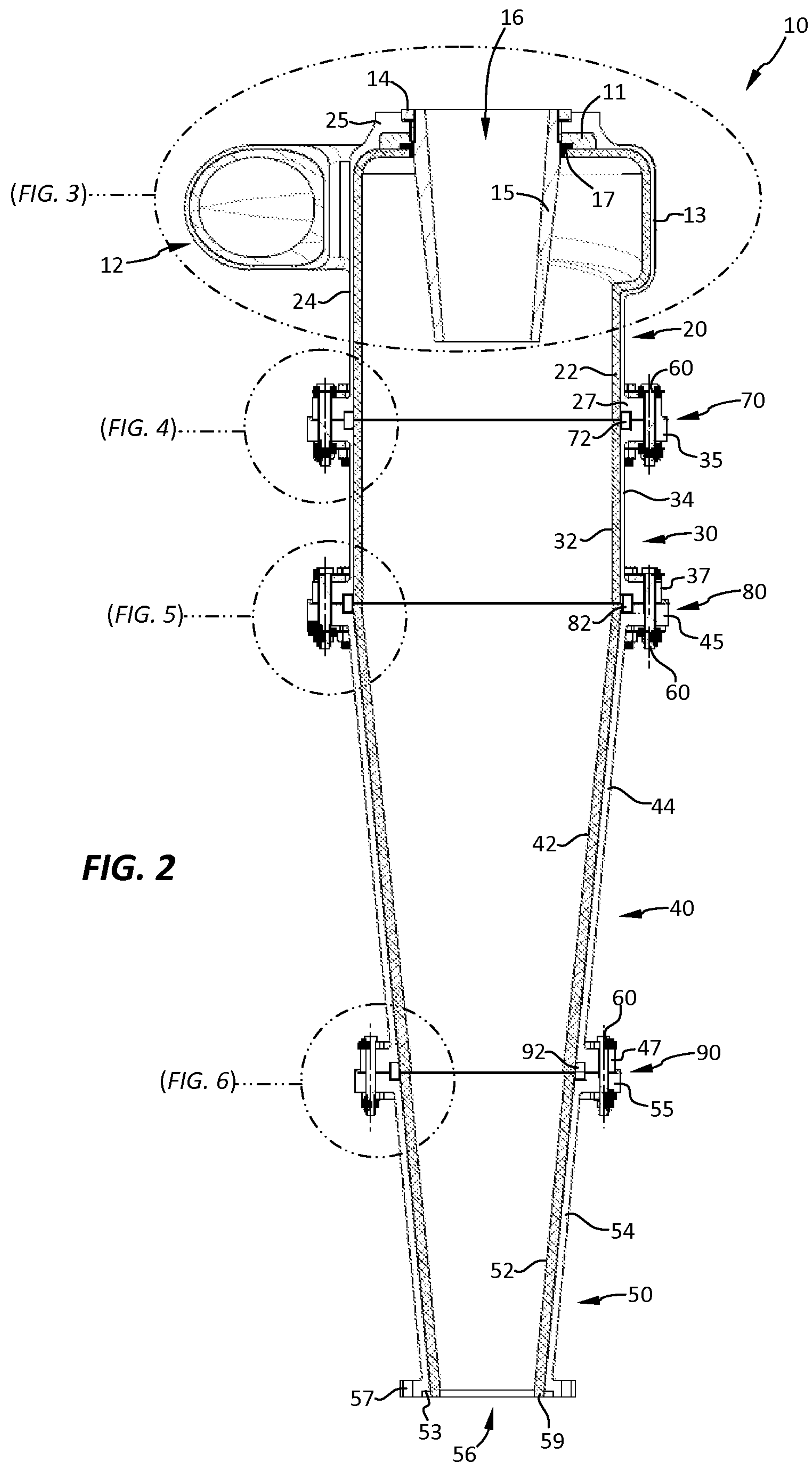
14. The method according to claim 13, wherein the inserts are pre-mixed with the uncured polymer or elastomer prior to injecting into the ring-shaped mold cavity.

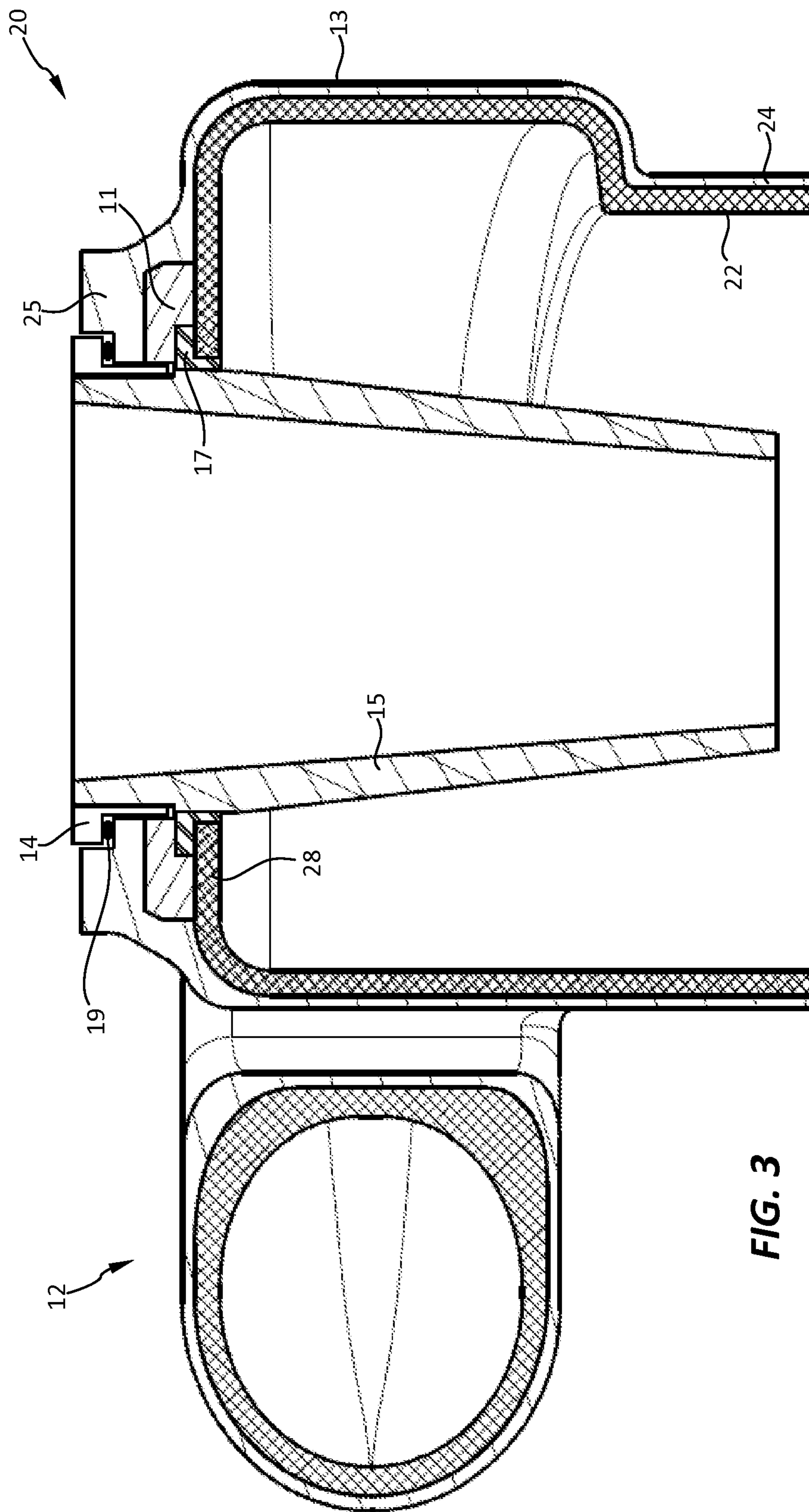
15. The method according to claim 9, wherein the inserts are formed of a ceramic  
25 or carbide material.

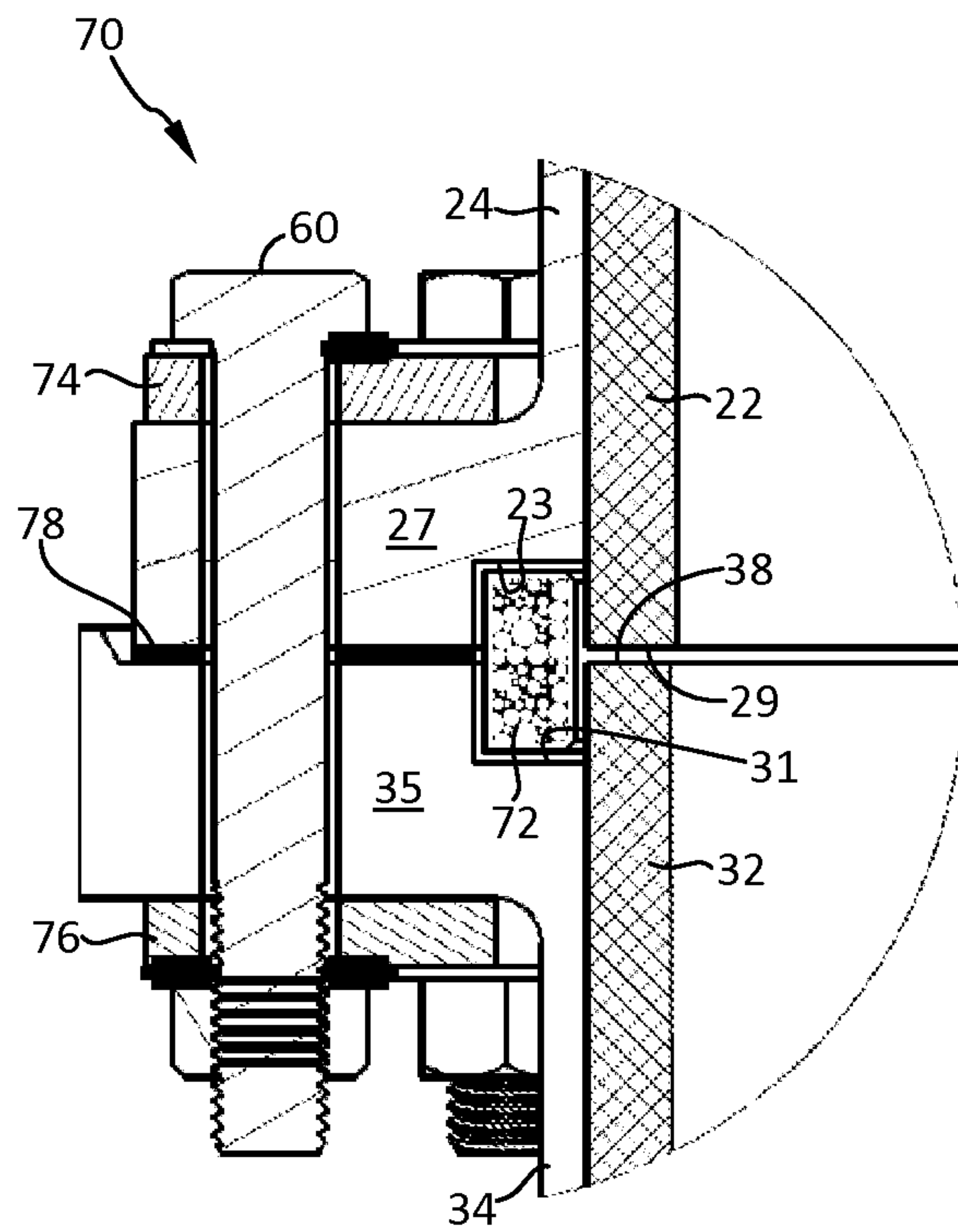
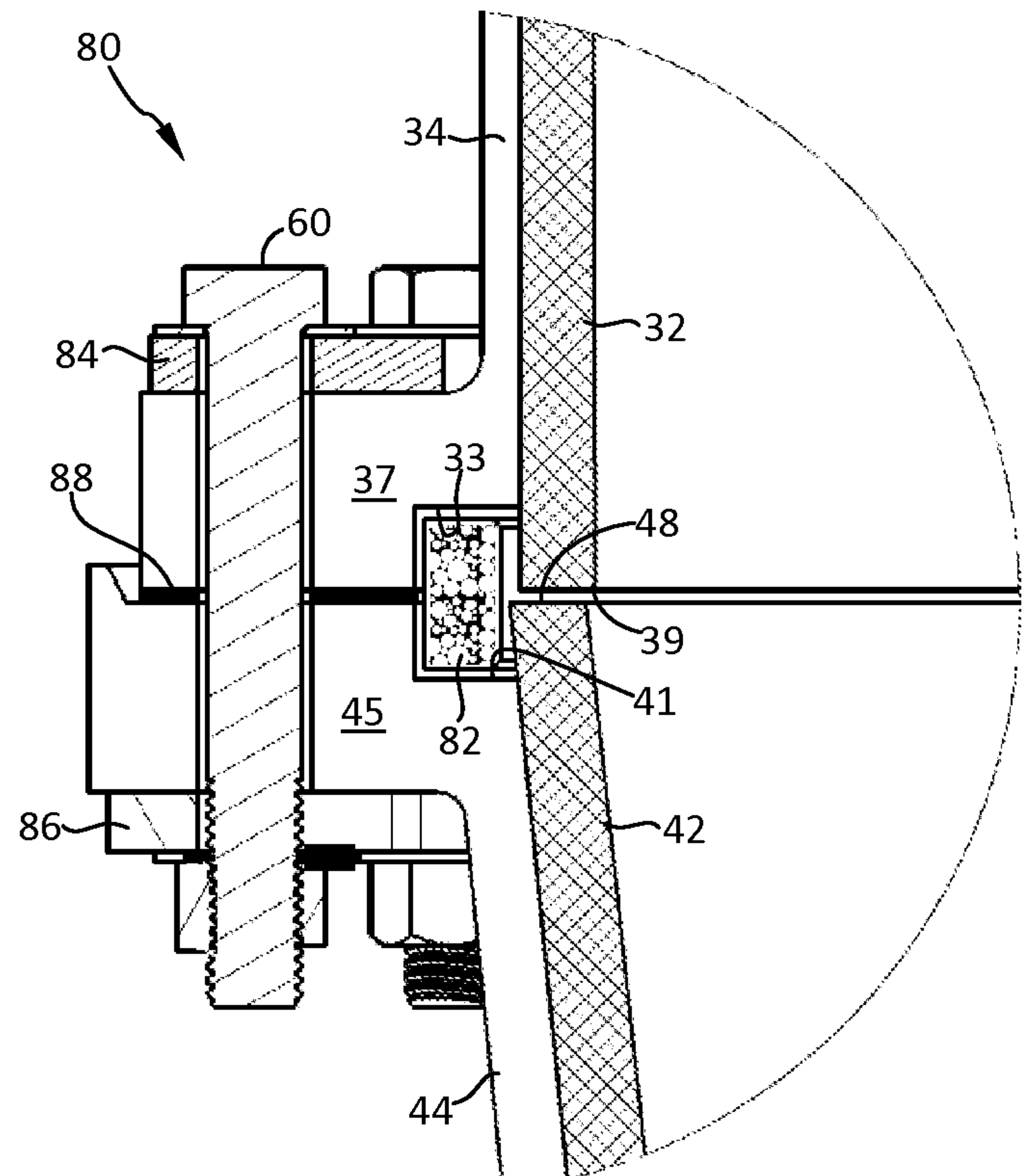
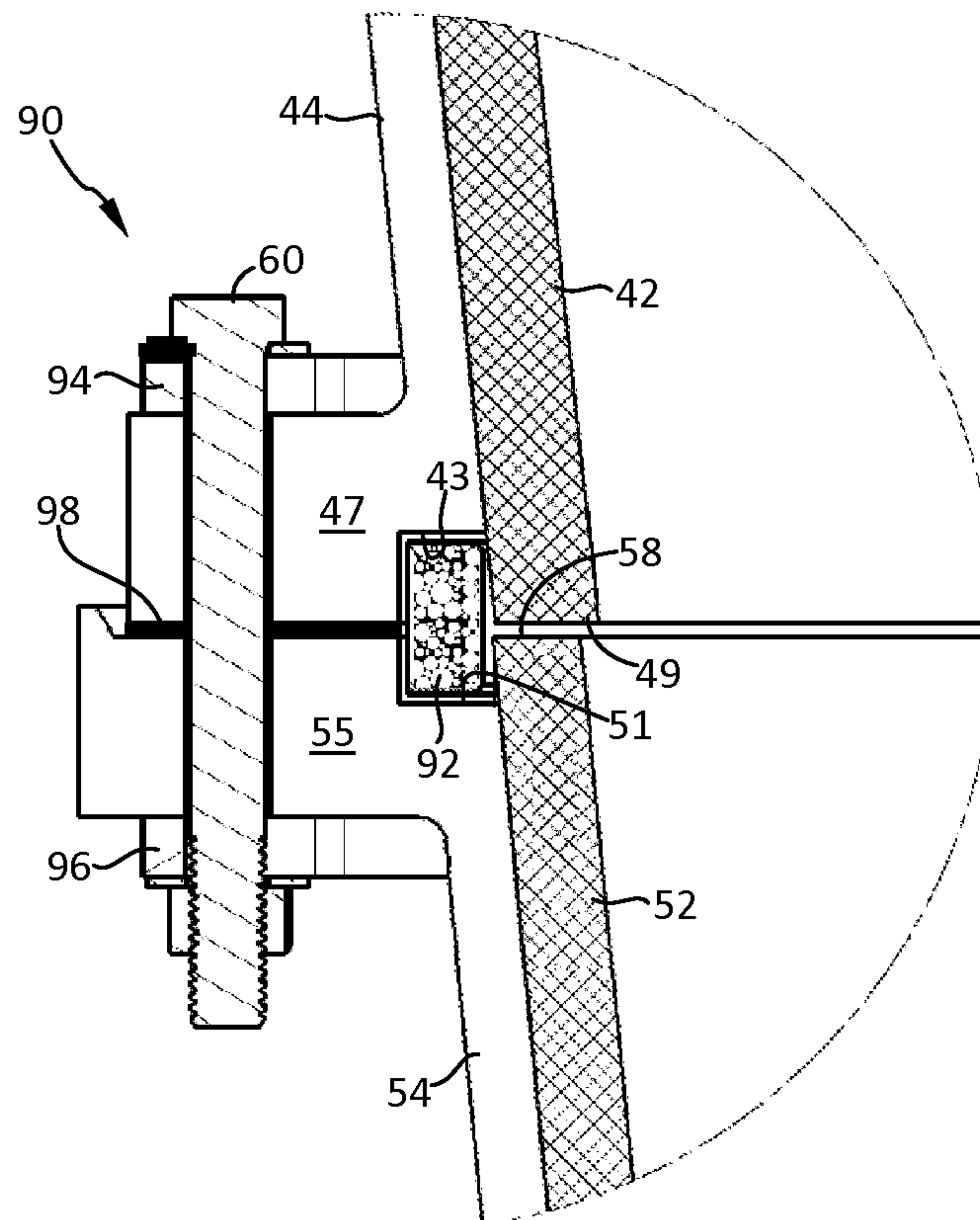
54408-34

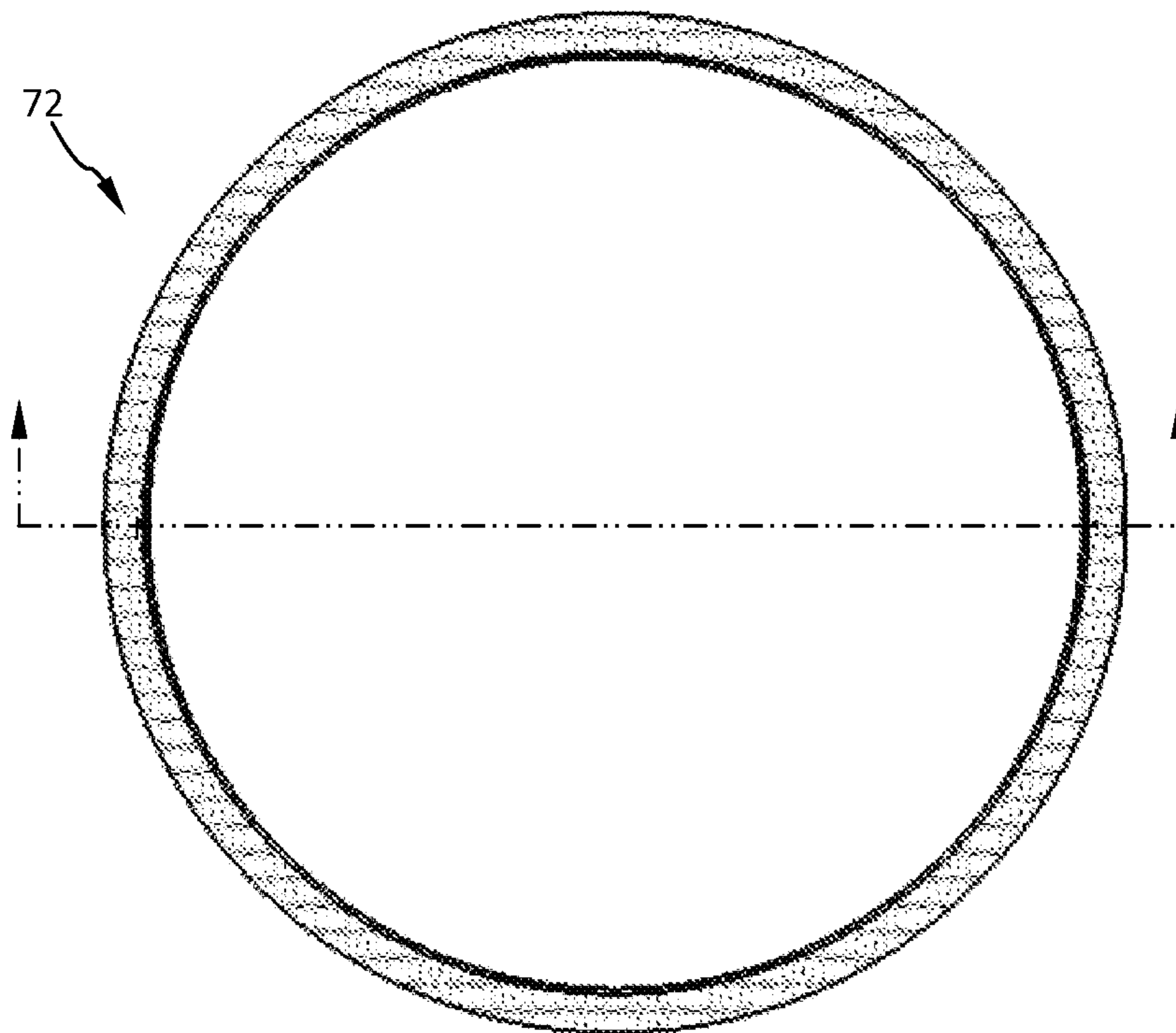
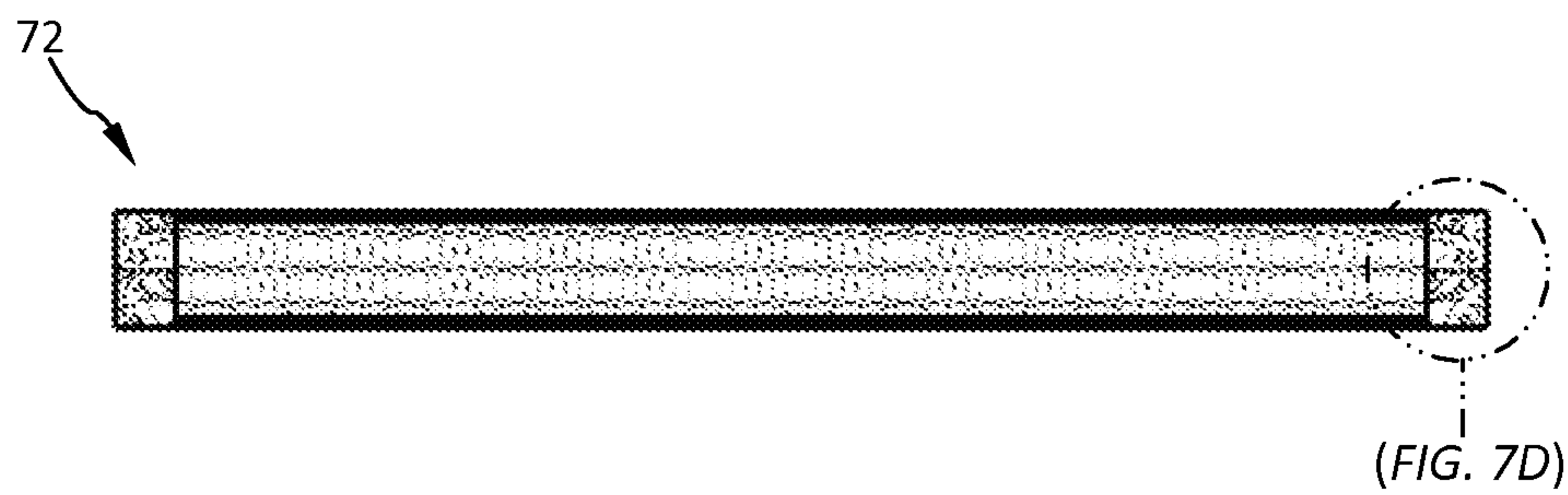
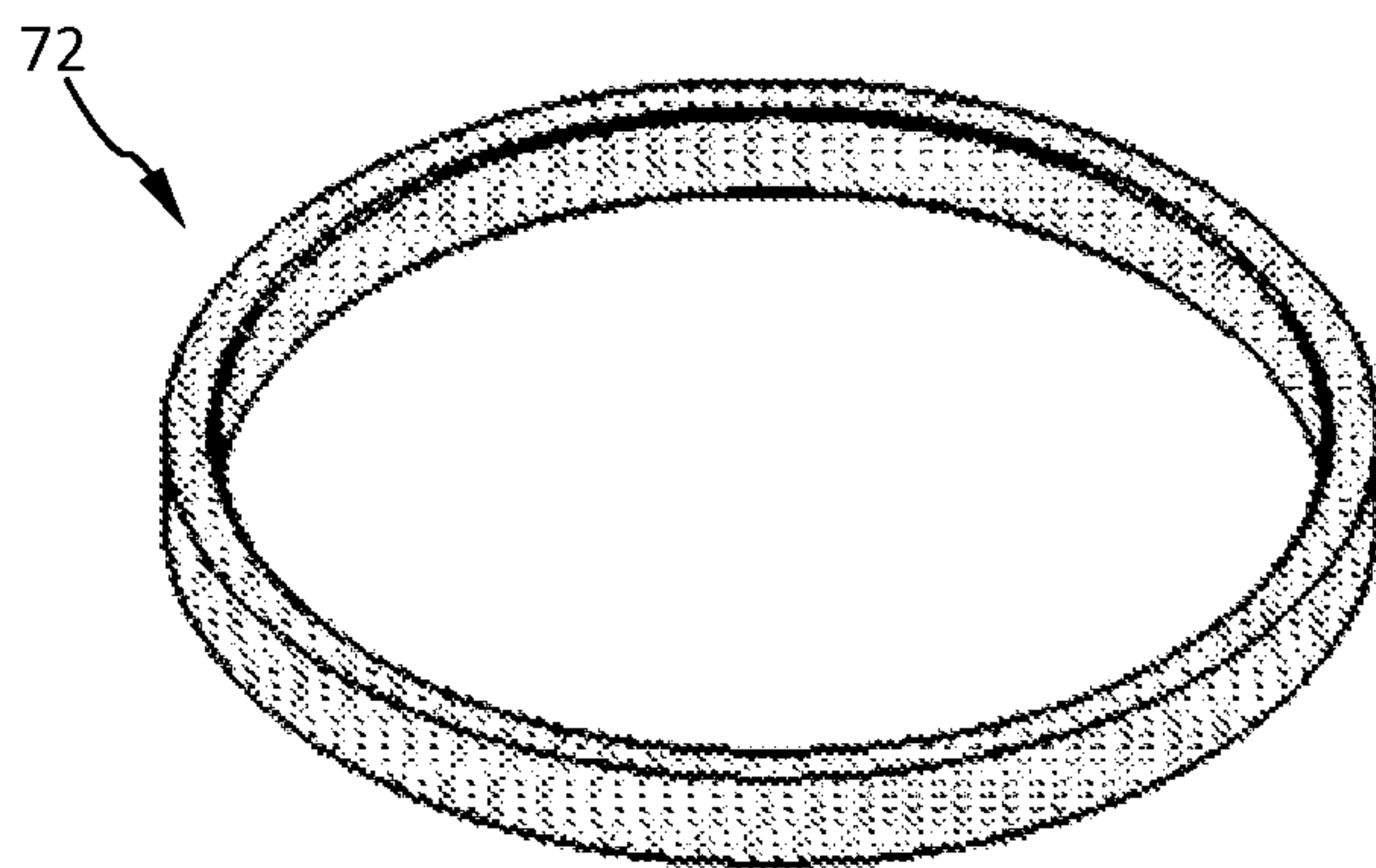
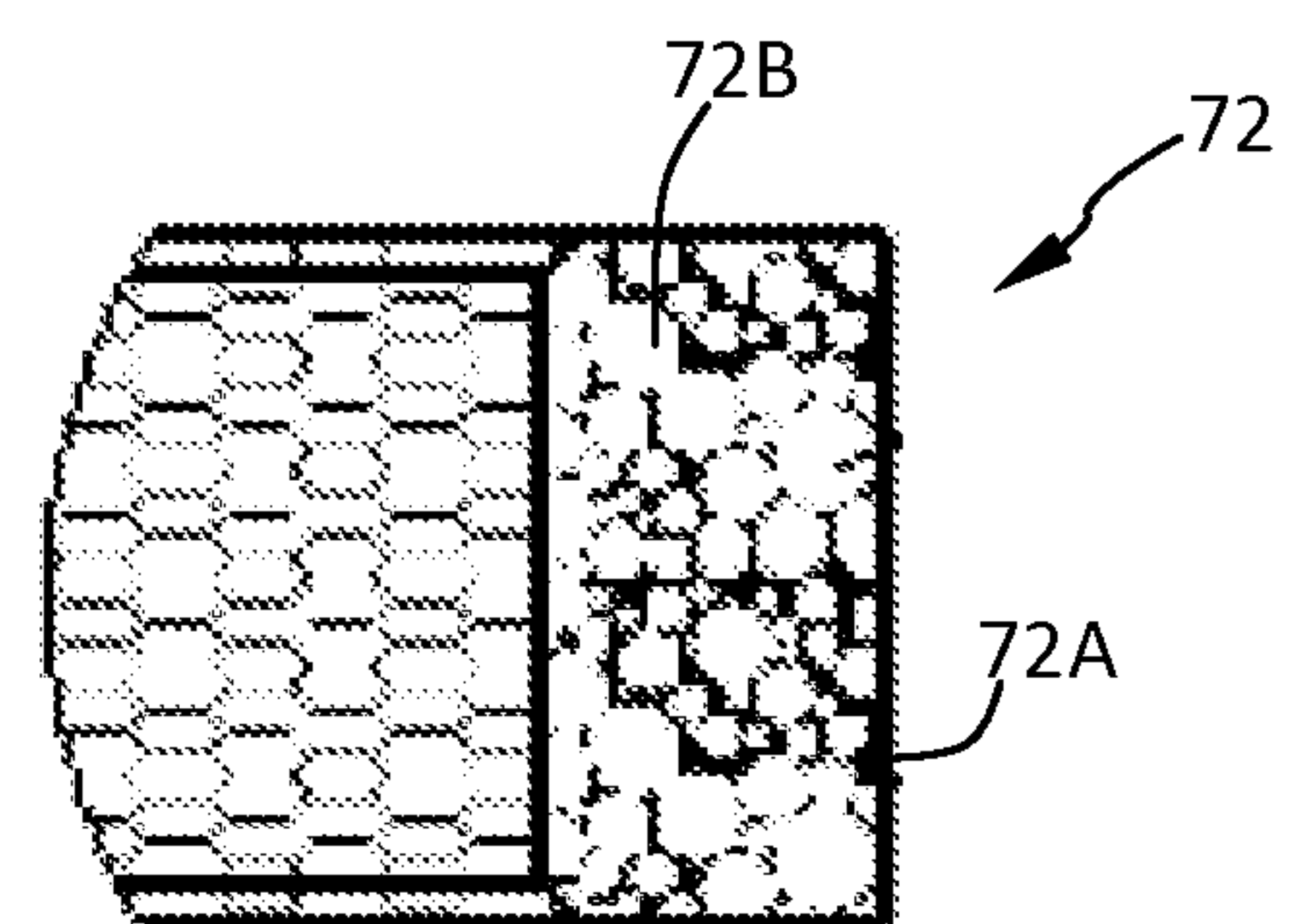
16. The method according to claim 9, wherein the resilient suspension matrix comprises one or more of a silicone, a silicone rubber, fluorosilicone rubber, a urethane, a polyurethane, ethylene propylene copolymer, a polybutadiene rubber, a butyl rubber, a nitrile rubber, a natural rubber, an isoprene rubber, a fluoroelastomer, polychloroprene,
- 5 tetrafluoroethylene, tetrafluoropropylene, an acrylic or acrylic rubber, styrene butadiene rubber, or soft rubber.

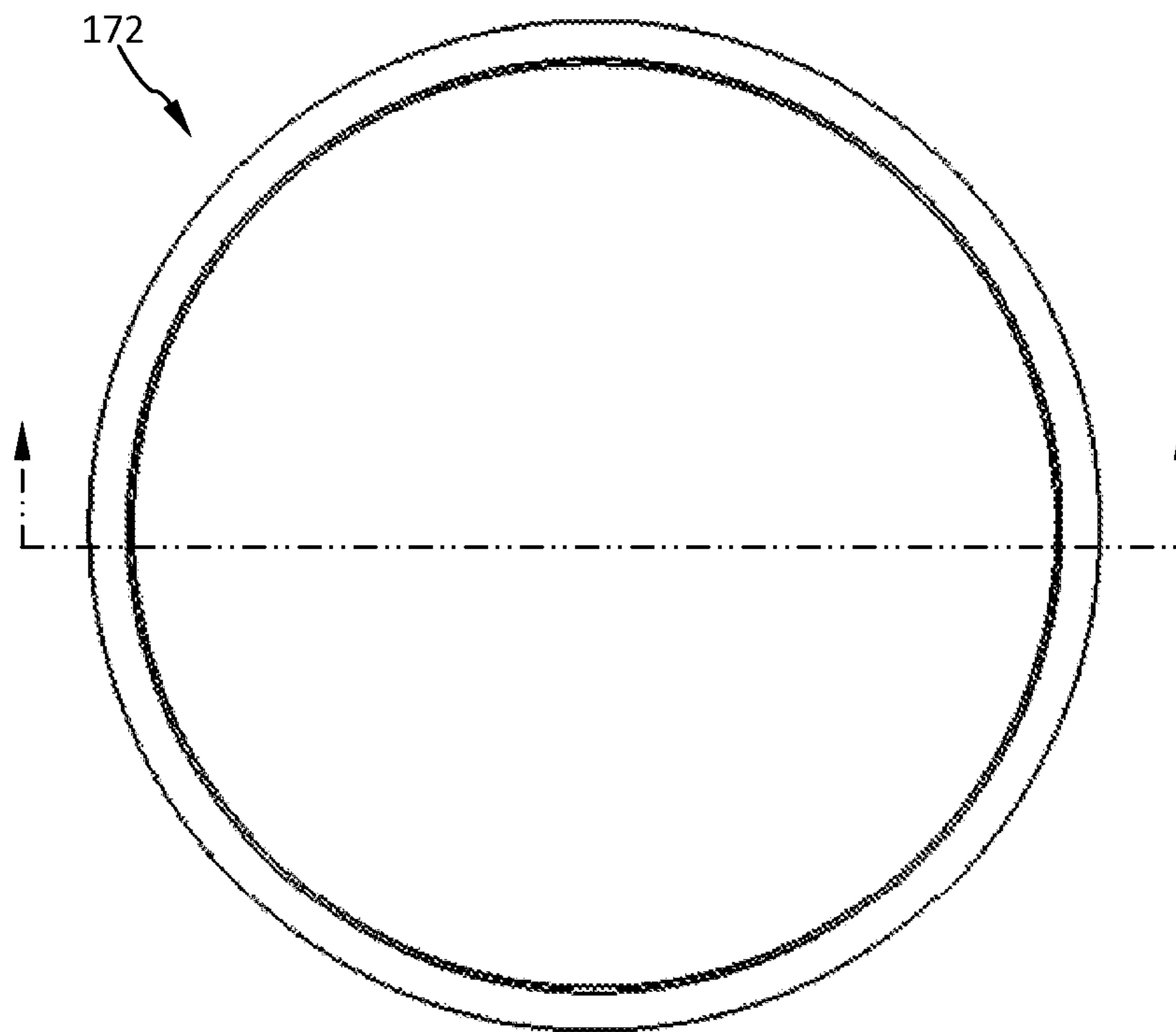
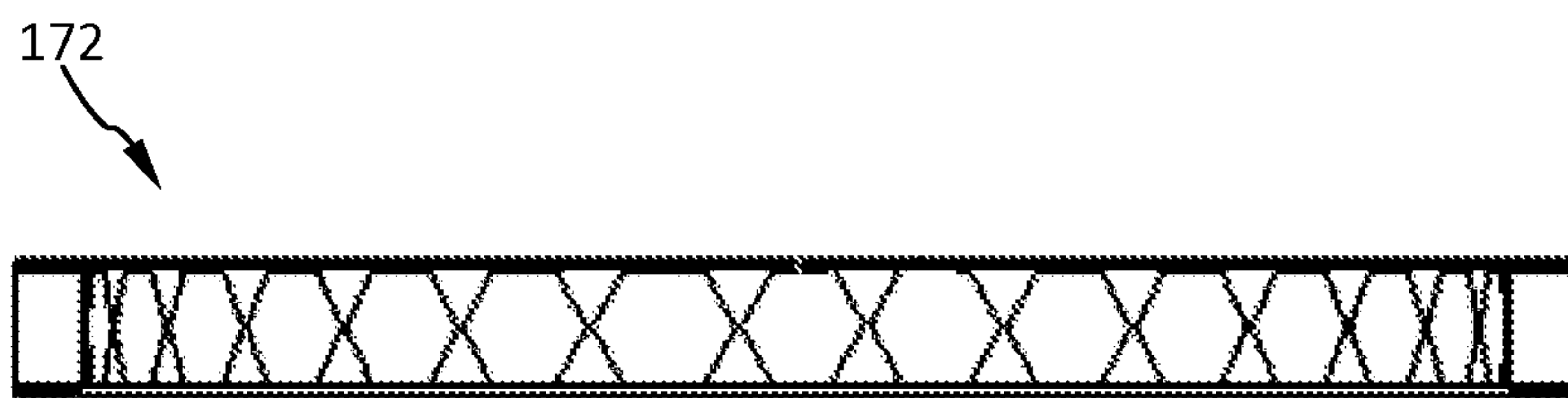
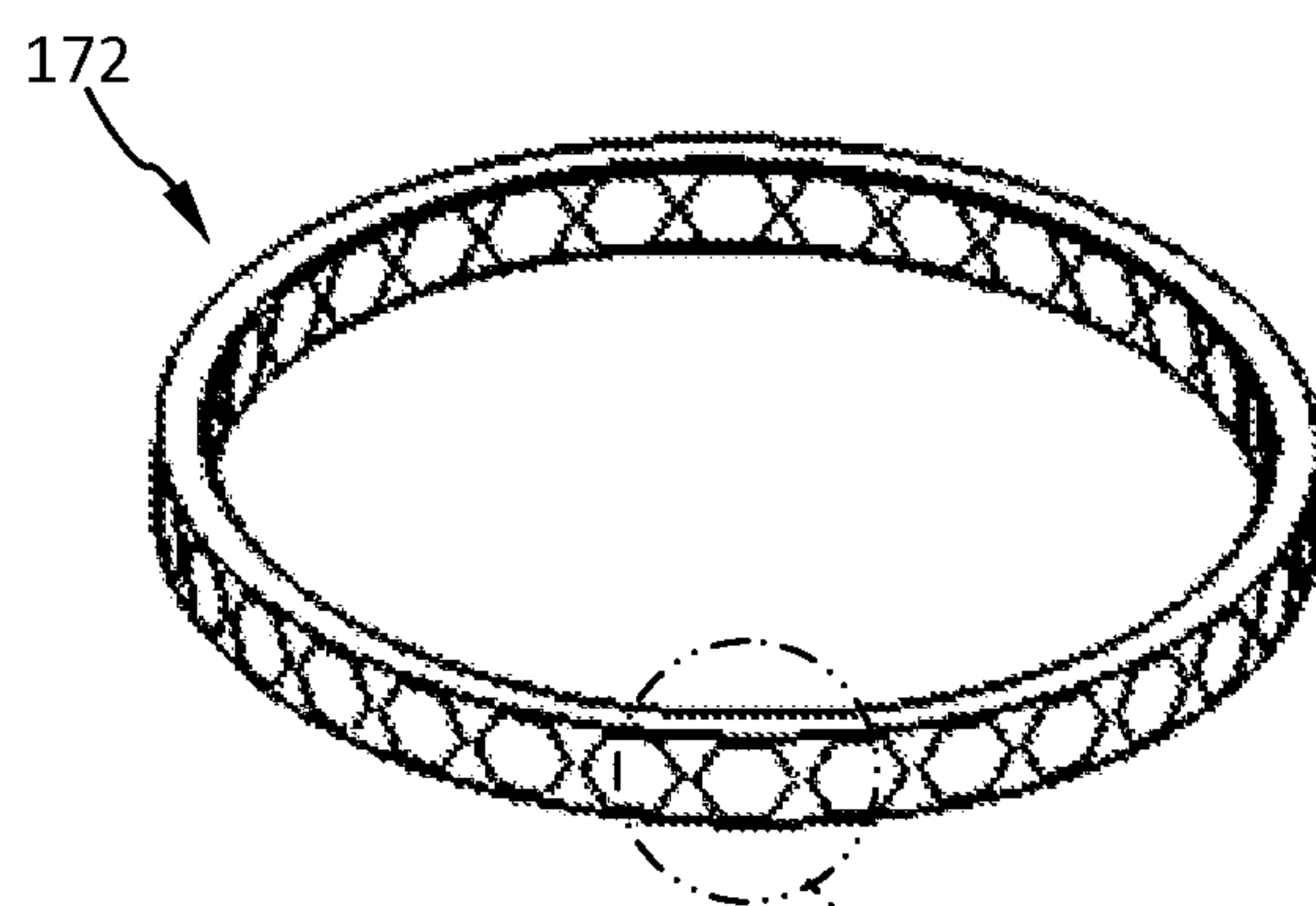




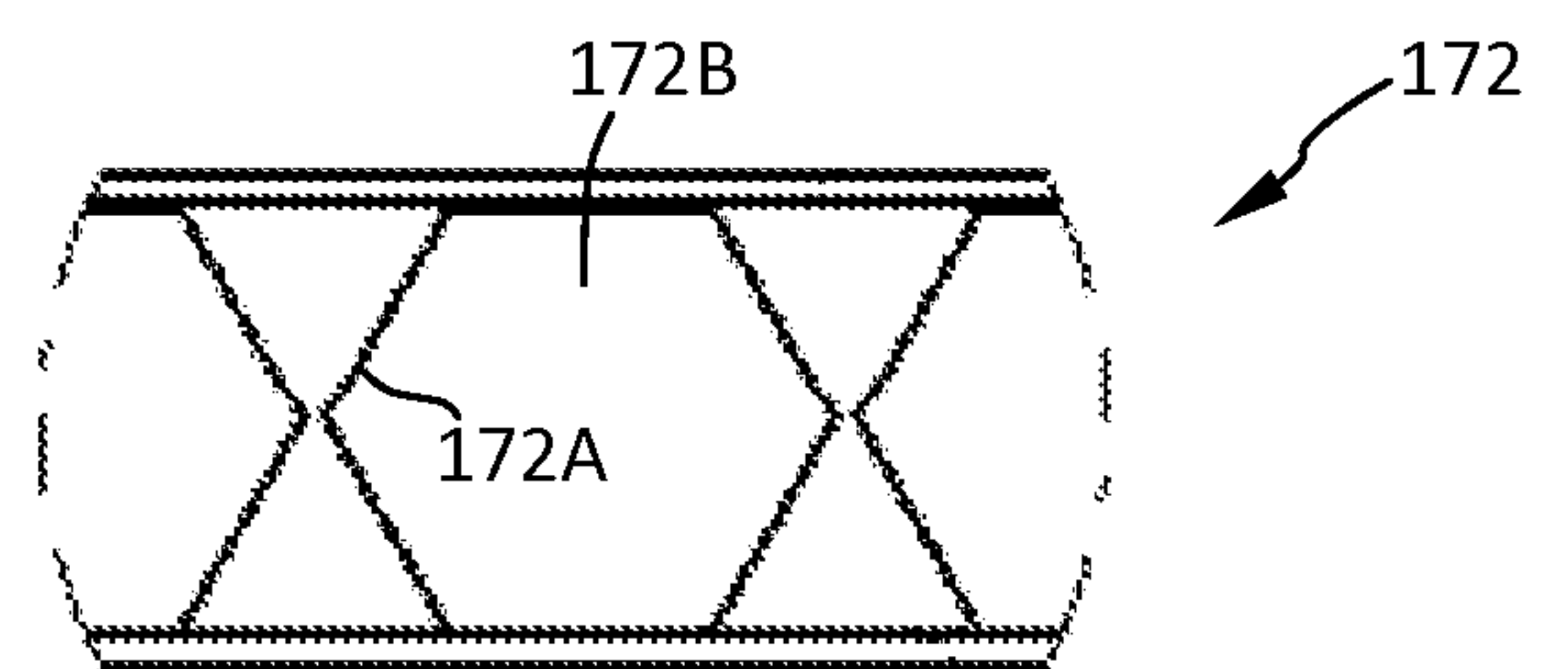
**FIG. 3**

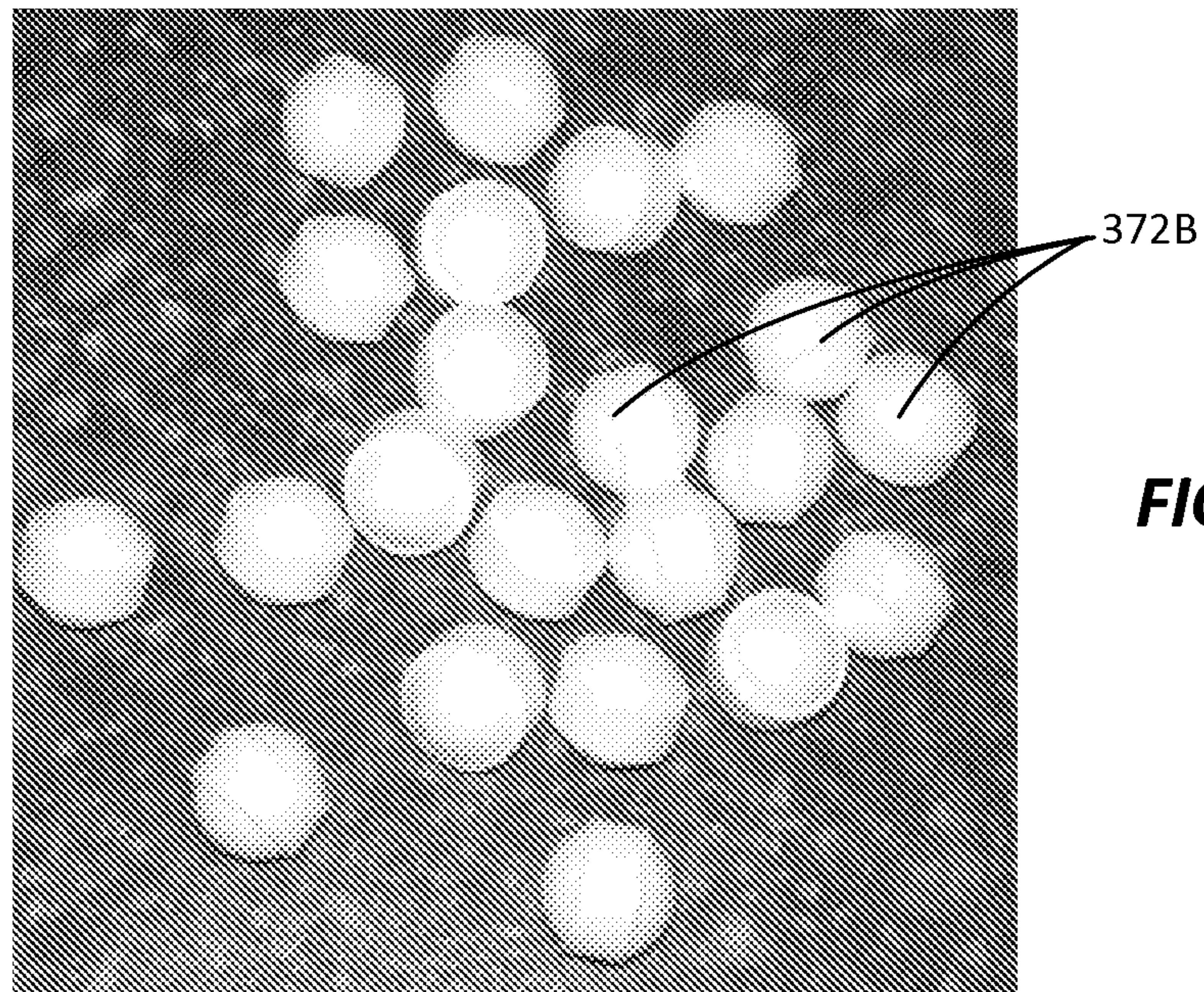
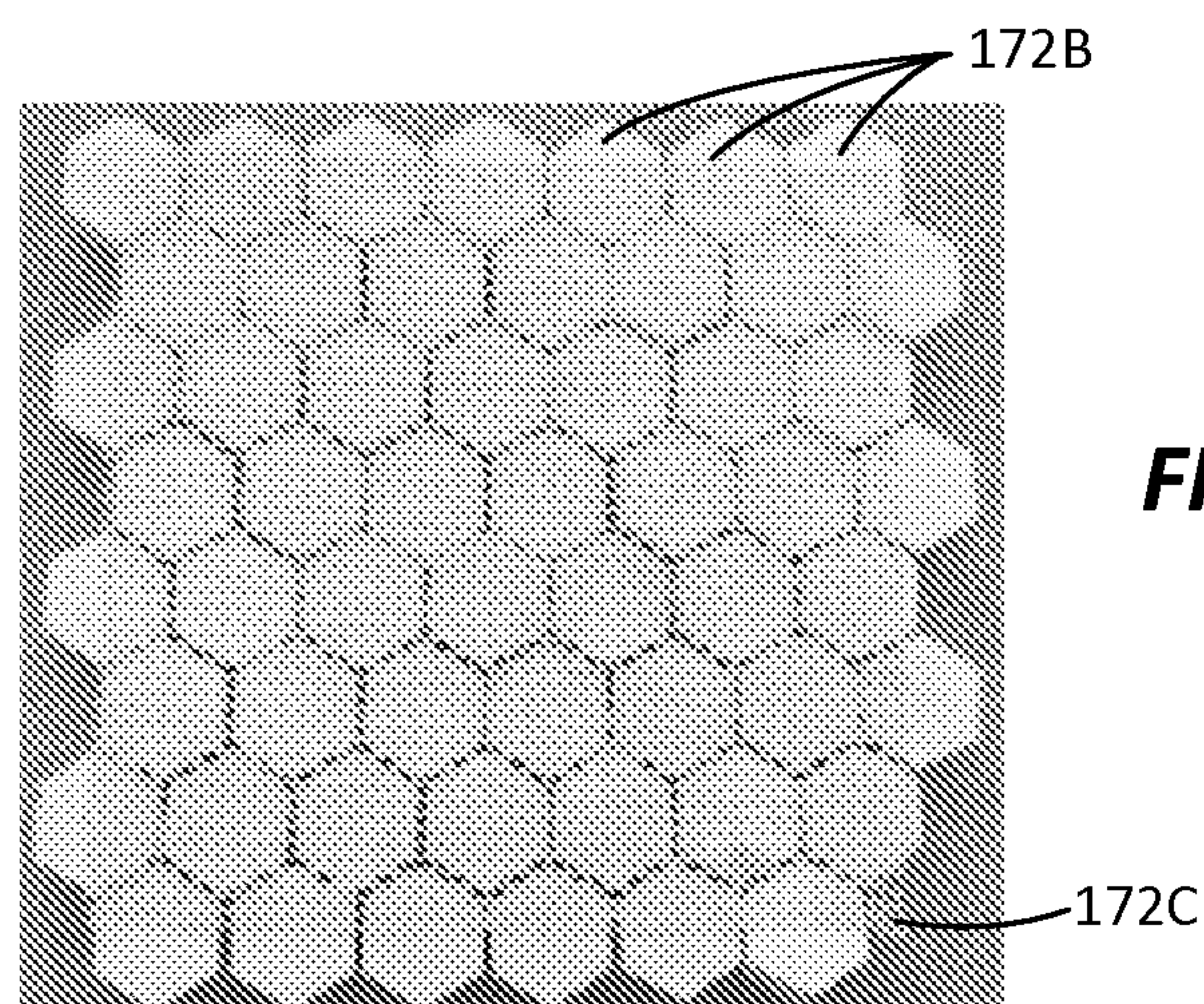
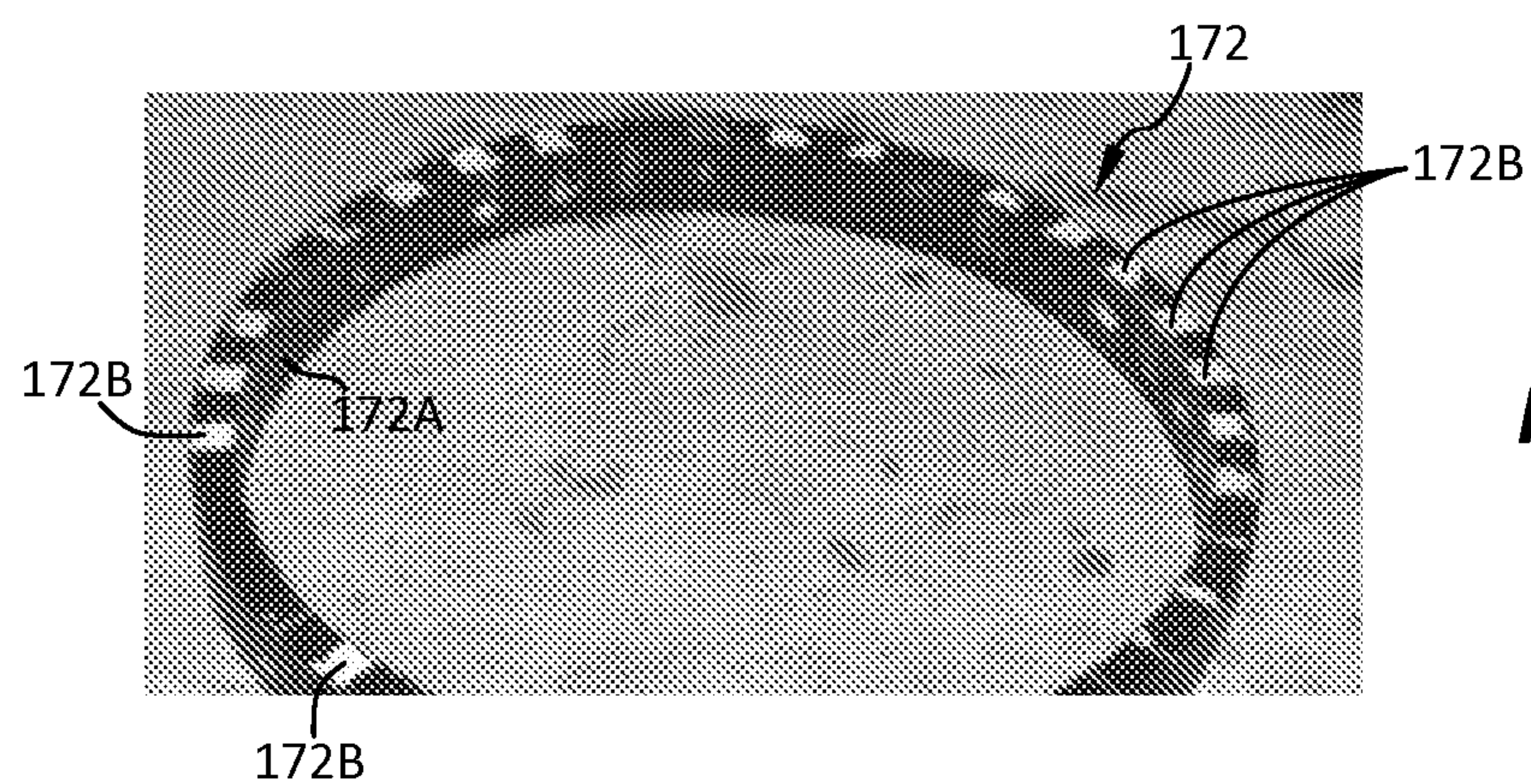
**FIG. 4****FIG. 5****FIG. 6**

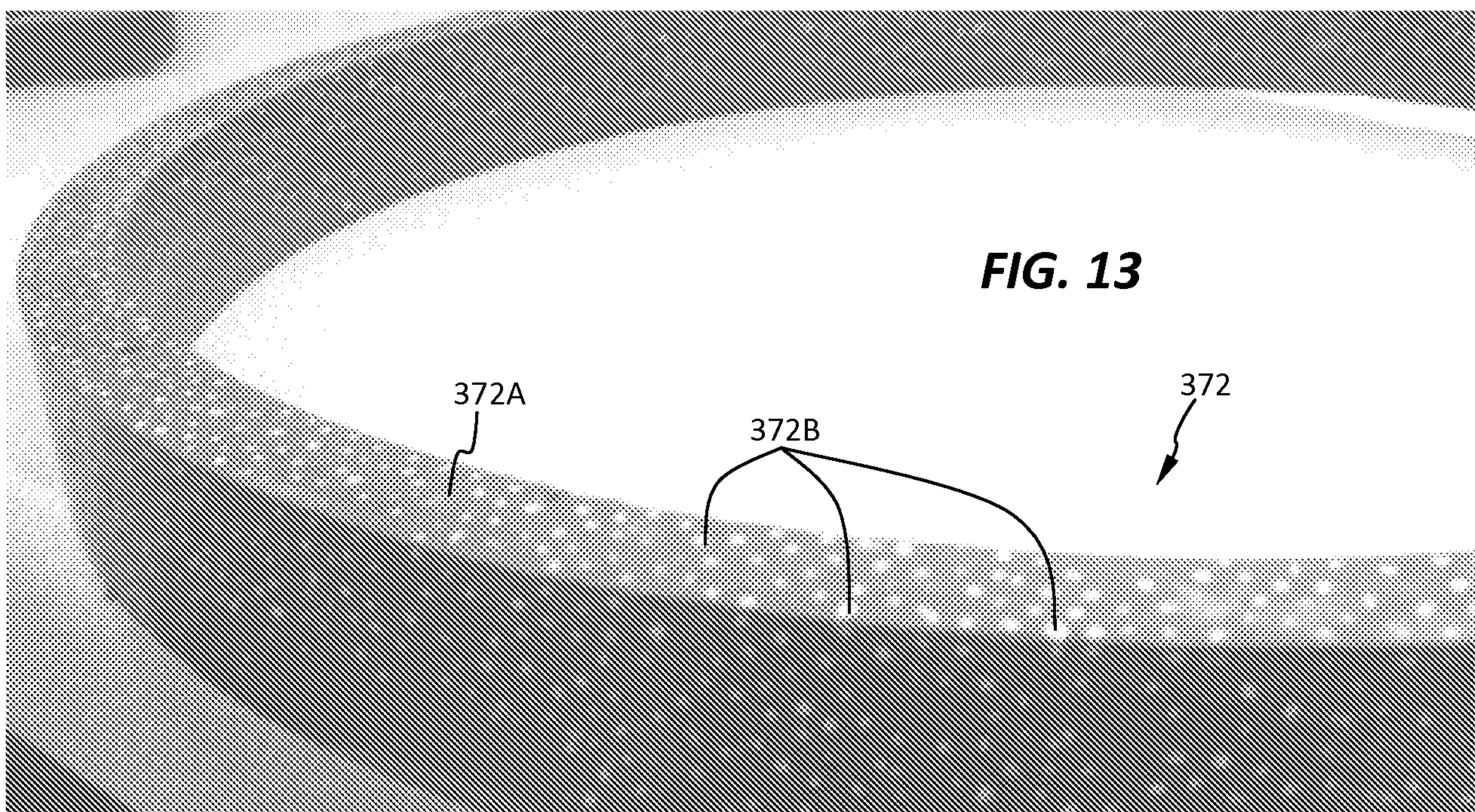
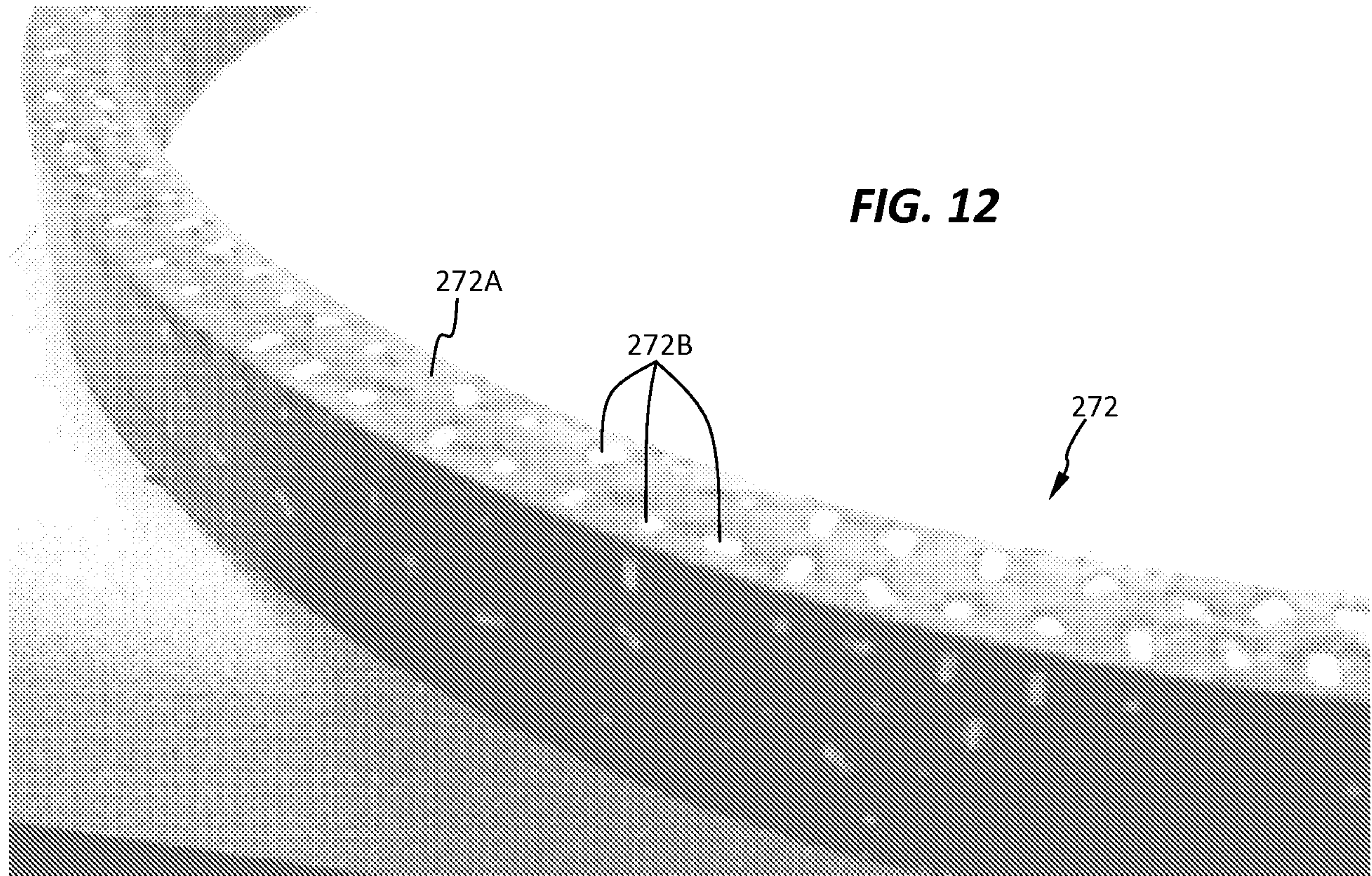
**FIG. 7A****FIG. 7B****FIG. 7C****FIG. 7D**

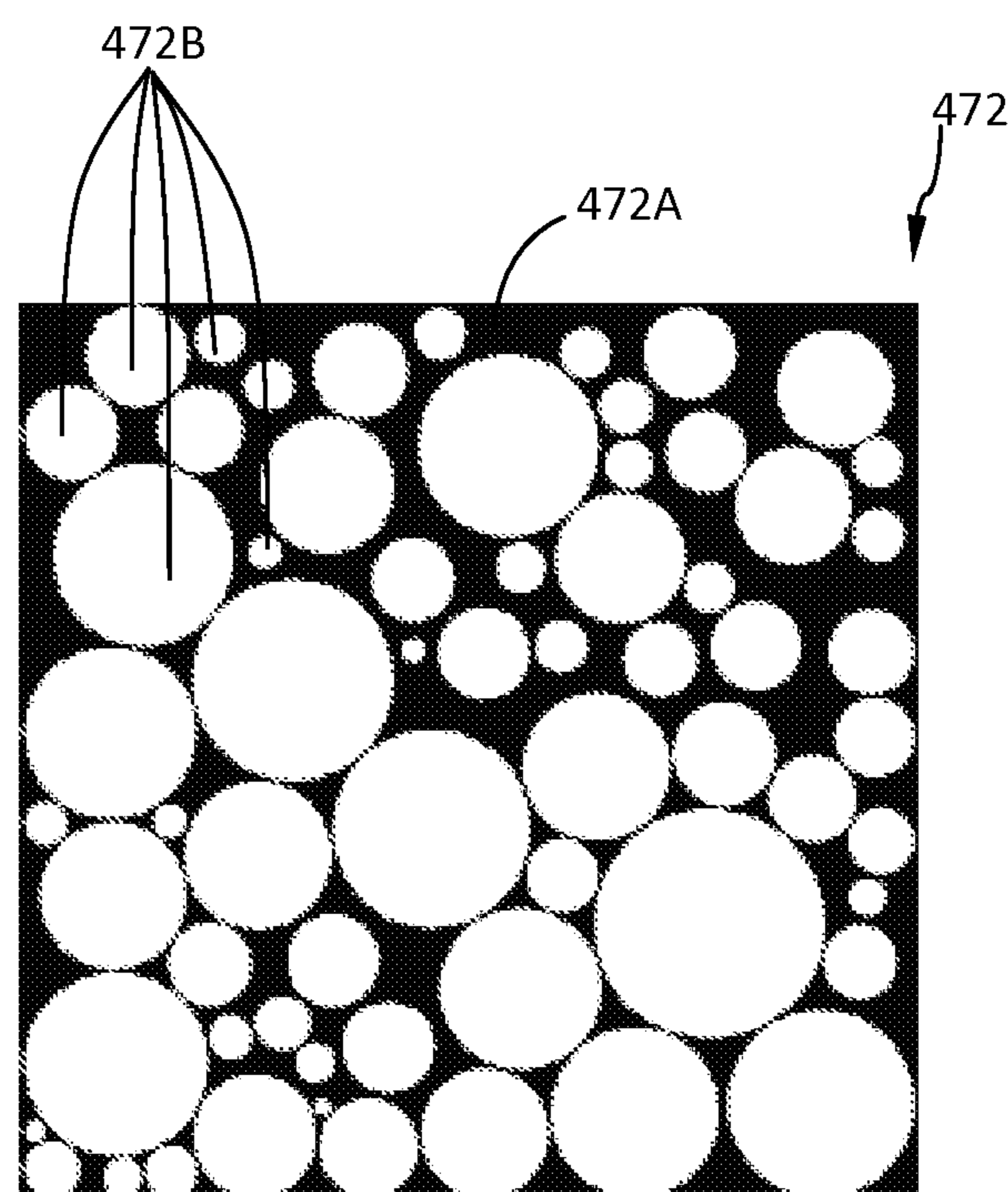
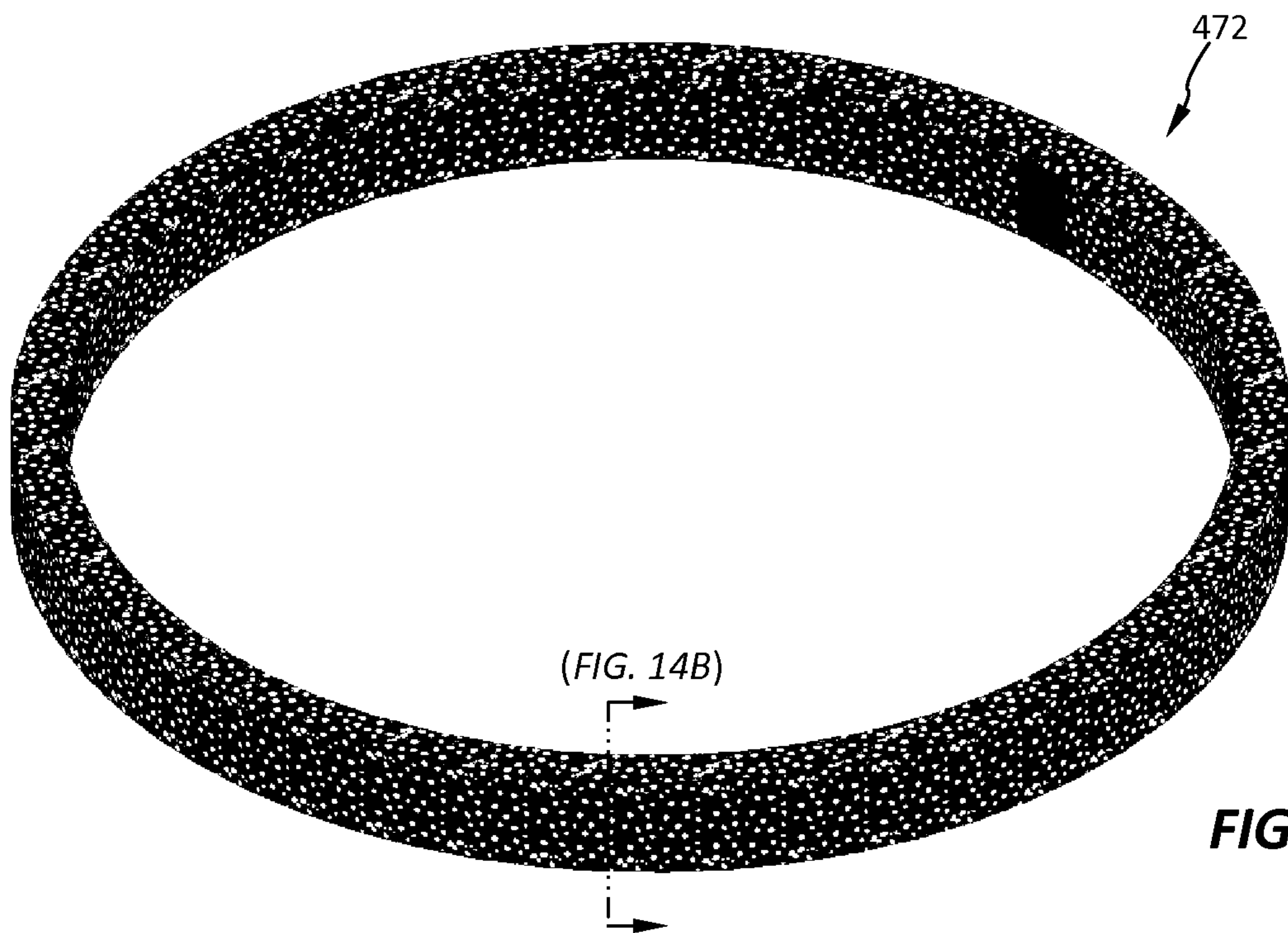
**FIG. 8A****FIG. 8B****FIG. 8C**

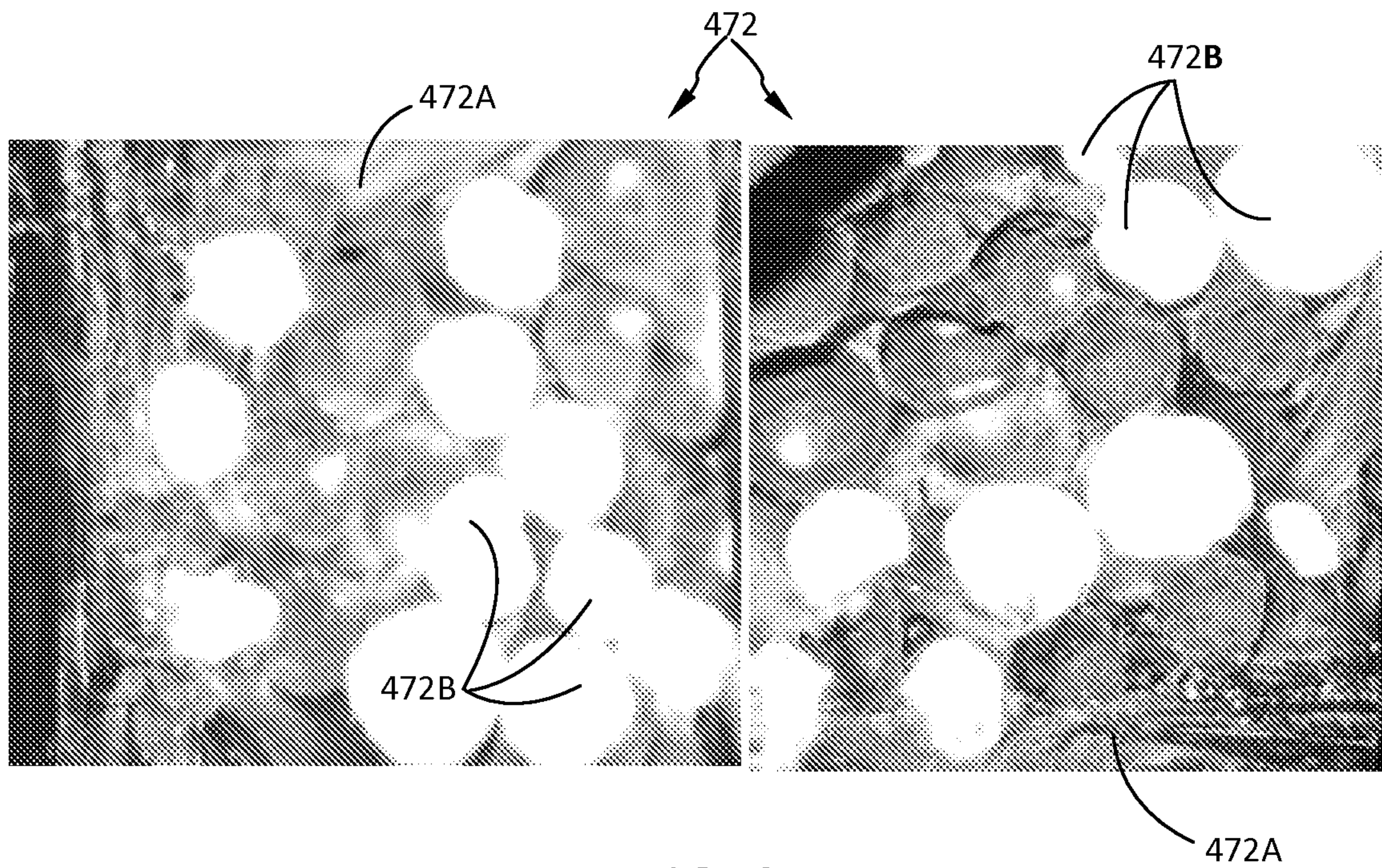
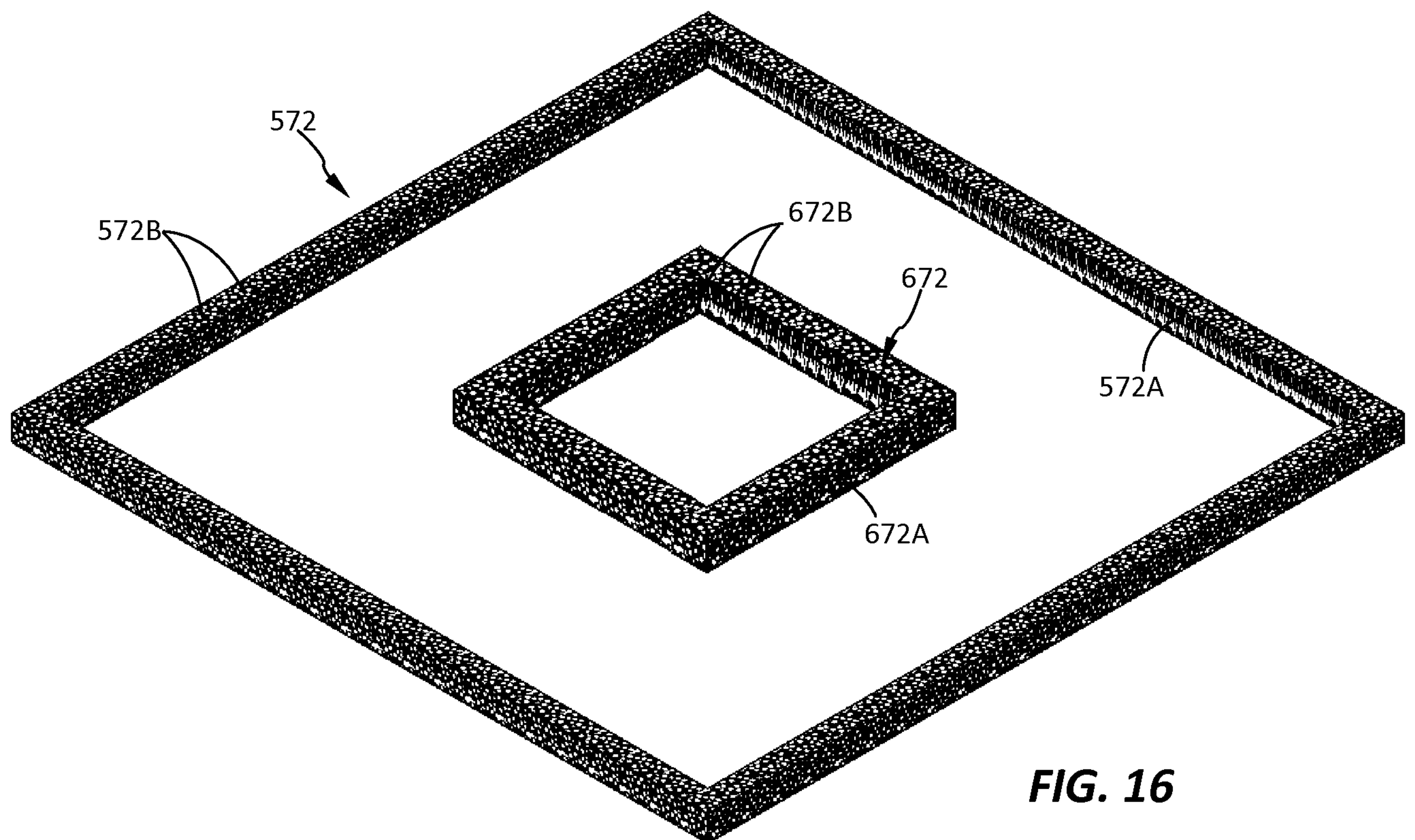
(FIG. 8D)

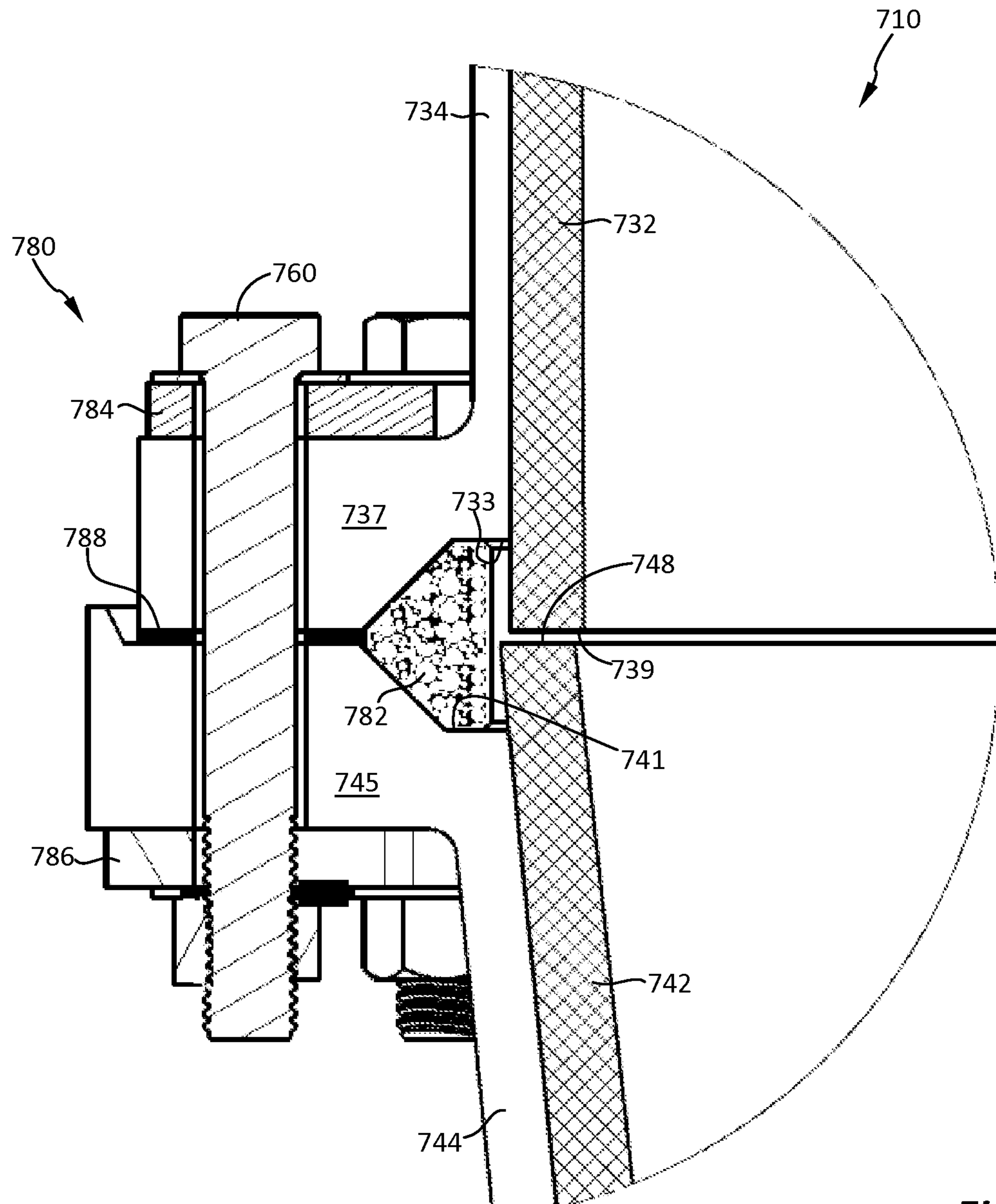
**FIG. 8D**

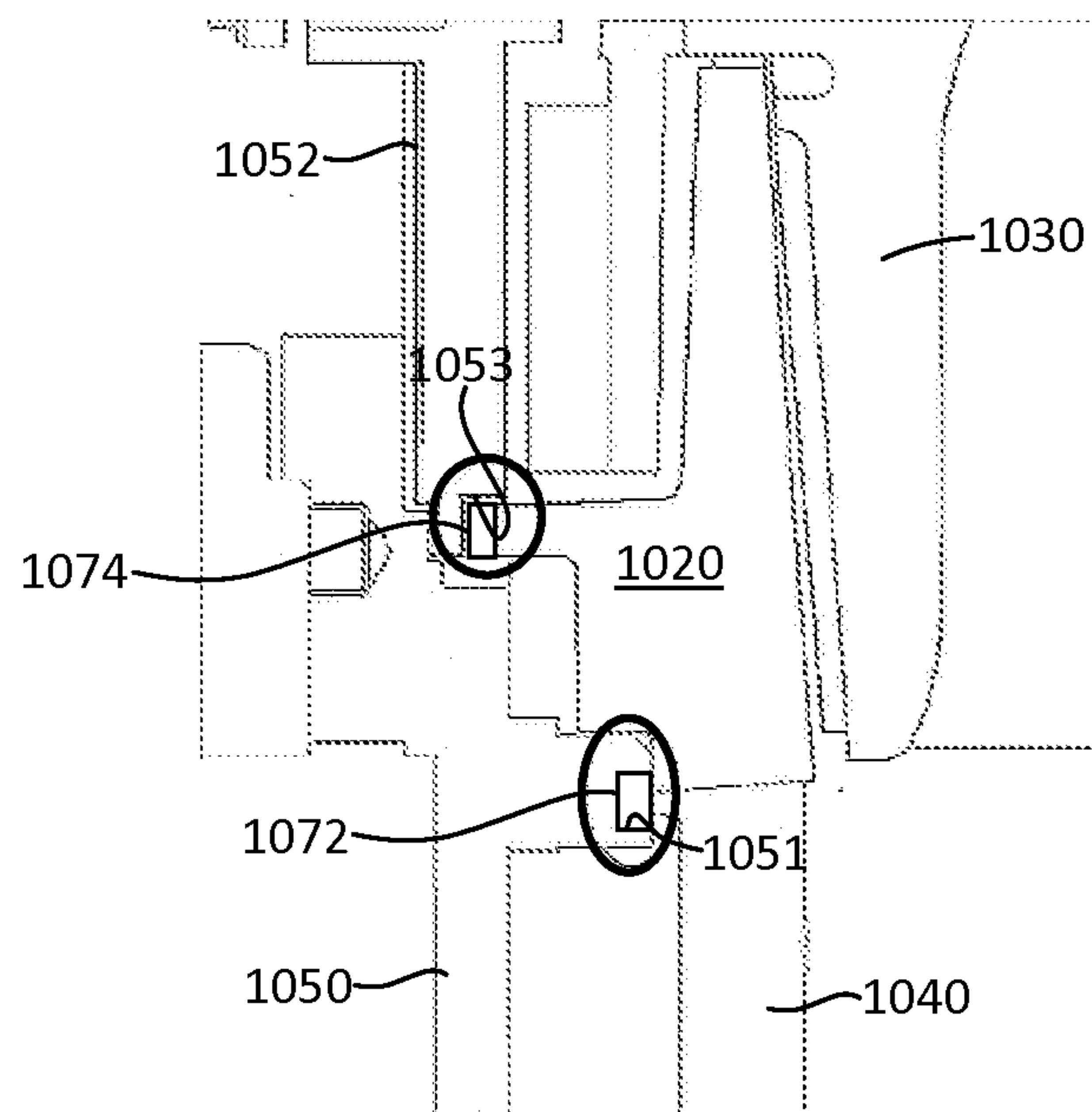
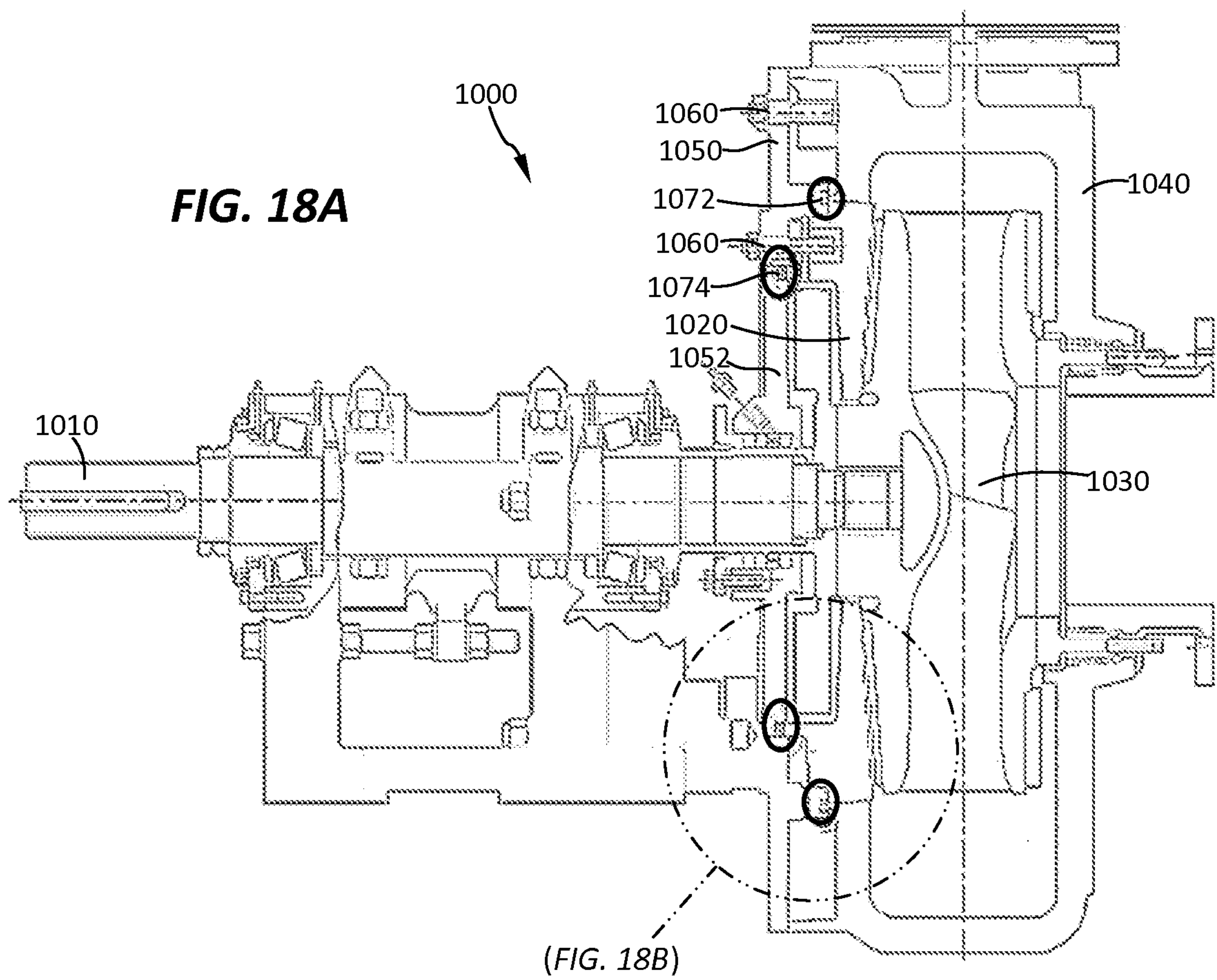
**FIG. 9****FIG. 10****FIG. 11**

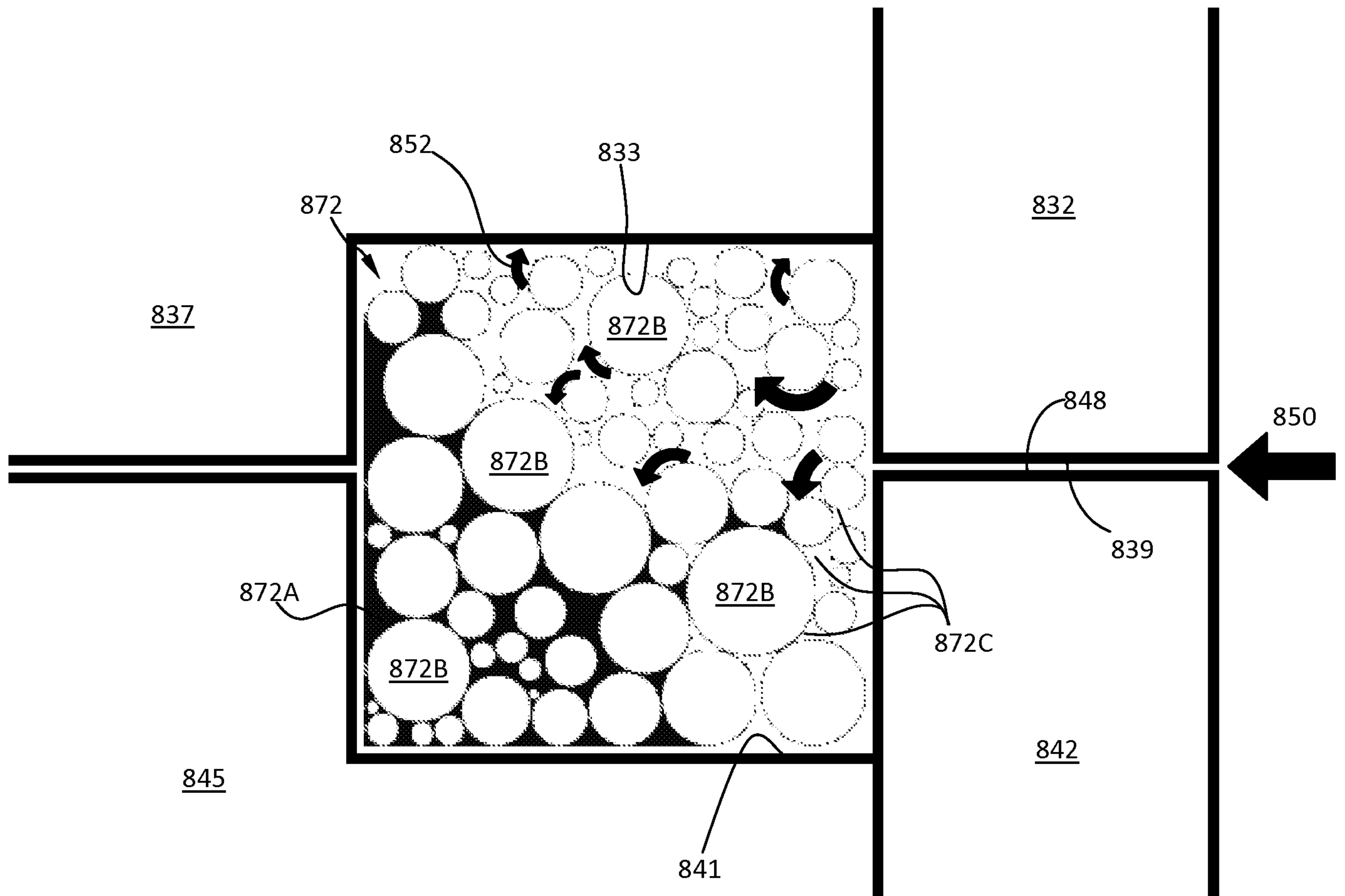




**FIG. 15****FIG. 16**

**FIG. 17**

**FIG. 18B**



**FIG. 19**

