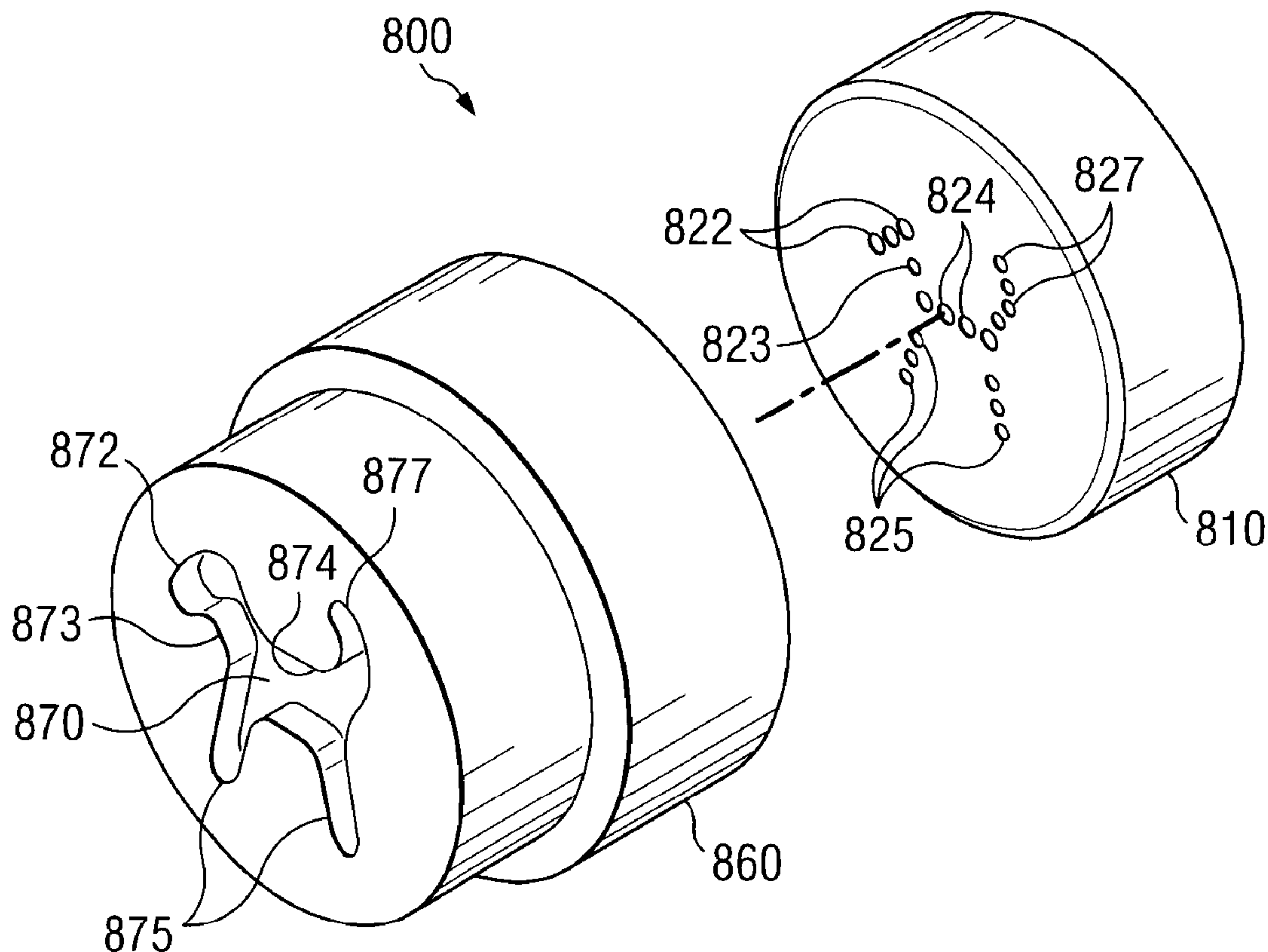




(86) Date de dépôt PCT/PCT Filing Date: 2005/08/29
(87) Date publication PCT/PCT Publication Date: 2006/03/16
(45) Date de délivrance/Issue Date: 2011/06/07
(85) Entrée phase nationale/National Entry: 2007/02/23
(86) N° demande PCT/PCT Application No.: US 2005/030693
(87) N° publication PCT/PCT Publication No.: 2006/028780
(30) Priorité/Priority: 2004/09/01 (US10/932,225)

(51) Cl.Int./Int.Cl. *A23L 1/00* (2006.01),
A23P 1/00 (2006.01)
(72) Inventeurs/Inventors:
MOORE, GARY STEVEN, US;
MORALES-ALVAREZ, JORGE C., US
(73) Propriétaire/Owner:
FRITO-LAY NORTH AMERICA, INC., US
(74) Agent: DEETH WILLIAMS WALL LLP

(54) Titre : APPAREIL ET PROCEDE PERMETTANT D'AMELIORER LA QUALITE DIMENSIONNELLE DE PRODUITS ALIMENTAIRES EXTRUDES A FORMES COMPLEXES
(54) Title: APPARATUS AND METHOD FOR IMPROVING THE DIMENSIONAL QUALITY OF EXTRUDED FOOD PRODUCTS HAVING COMPLEX SHAPES



(57) Abrégé/Abstract:

The present invention comprises an improved extruder die assembly (800) and method for using same to improve the quality of dimensional design aspects of extruded, complexly shaped, direct expanded food products. The improved system includes an

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

improved die assembly (800) comprising a first die (810) and a second die (860) having at least one orifice. A majority of the total pressure drop occurs in the first die (810) to pre-expand the dough prior to the dough entering the second die (860). The orifices in the first die (810) can be individually configured to obtain differing dough flow speeds resulting in a desired flow pattern. A plurality of extruded dough ropes formed at each orifice exit of the first die (810) can meld together in the bore and exit the second die. Color or flavor can be added at the first die (810) to enhance the food product.

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

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
16 March 2006 (16.03.2006)

PCT

(10) International Publication Number
WO 2006/028780 A3

(51) International Patent Classification:

A23L 1/00 (2006.01) A23P 1/00 (2006.01)

(21) International Application Number:

PCT/US2005/030693

(22) International Filing Date: 29 August 2005 (29.08.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

10/932,225 1 September 2004 (01.09.2004) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:

US 10/623,048 (CIP)
Filed on 18 July 2003 (18.07.2003)

(71) Applicant (for all designated States except US):
FRITO-LAY NORTH AMERICA, INC. [US/US];
7701 Legacy Drive, Plano, TX 75024-4099 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **MOORE, Gary, Steven** [US/US]; 5308 Autumn Way, Mchenry, IL 60050 (US). **MORALES-ALVAREZ, Jorge, C.** [GT/US]; 8025 Elliot Drive, Plano, TX 75024 (US).

(74) Agent: **CAHOON, Colin, P.**; Carstens & Chaoon, LLP,
P.O. Box 802334, Dallas, TX 75380 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US (patent), UZ, VC, VN, YU, 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, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

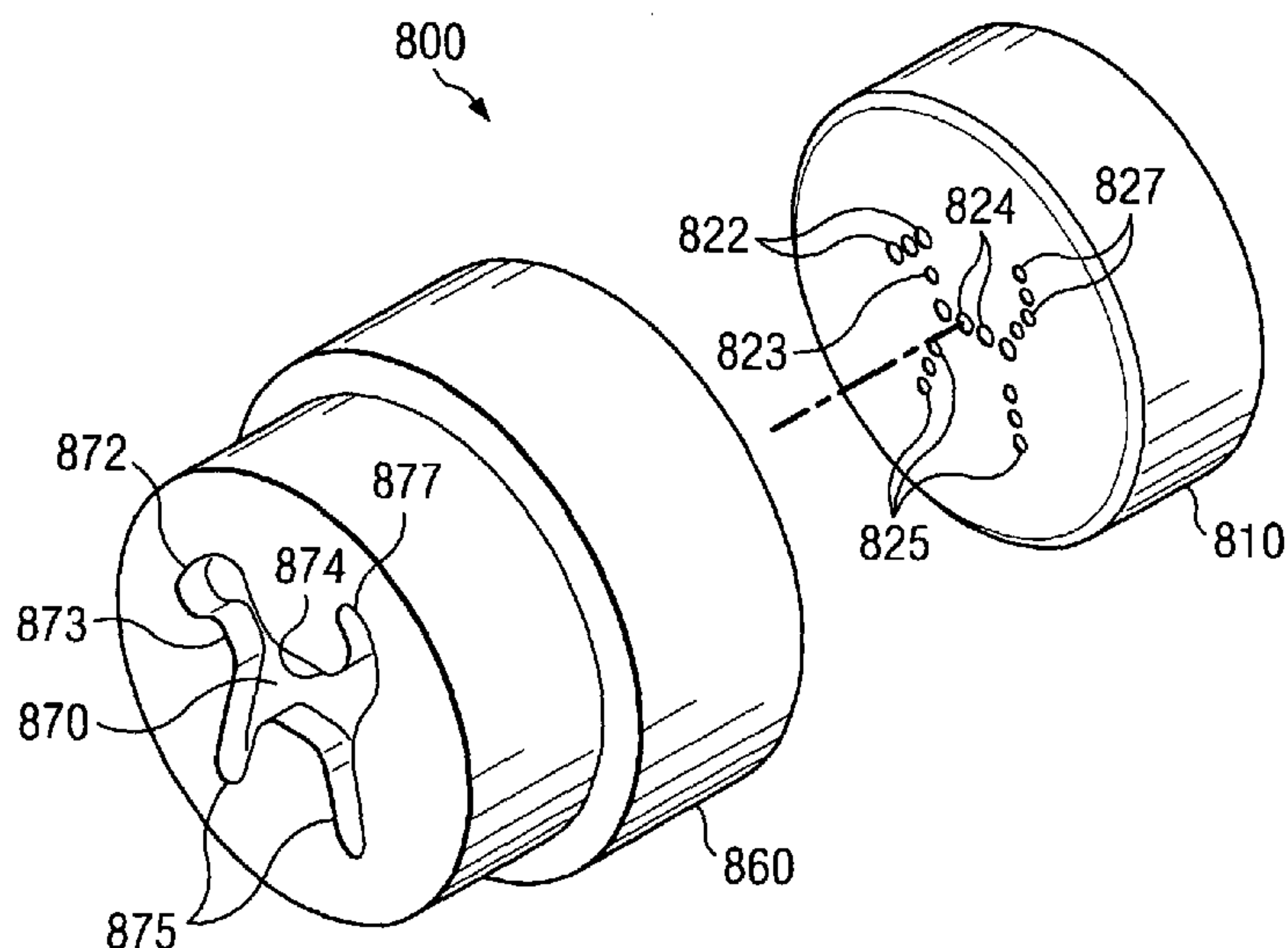
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
- of inventorship (Rule 4.17(iv))

Published:

- with international search report

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR IMPROVING THE DIMENSIONAL QUALITY OF EXTRUDED FOOD PRODUCTS HAVING COMPLEX SHAPES



(57) Abstract: The present invention comprises an improved extruder die assembly (800) and method for using same to improve the quality of dimensional design aspects of extruded, complexly shaped, direct expanded food products. The improved system includes an improved die assembly (800) comprising a first die (810) and a second die (860) having at least one orifice. A majority of the total pressure drop occurs in the first die (810) to pre-expand the dough prior to the dough entering the second die (860). The orifices in the first die (810) can be individually configured to obtain differing dough flow speeds resulting in a desired flow pattern. A plurality of extruded dough ropes formed at each orifice exit of the first die (810) can meld together in the bore and exit the second die. Color or flavor can be added at the first die (810) to enhance the food product.

WO 2006/028780 A3

WO 2006/028780 A3



(88) Date of publication of the international search report:
30 November 2006

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

**APPARATUS AND METHOD FOR IMPROVING
THE DIMENSIONAL QUALITY OF EXTRUDED FOOD PRODUCTS
HAVING COMPLEX SHAPES**

BACKGROUND OF THE INVENTION

Technical Field

5 The present invention generally relates to an apparatus and method for improving the dimensional quality of extruded food products. More specifically, the present invention relates to an apparatus and method that utilizes pre-expansion for improving the dimensional quality of extruded food products having complex shapes. In one aspect, the present invention relates to a method and apparatus to impart a distinct colored and/or
10 flavored pattern into an extruded food product having superior dimensional aspects.

Description of the Related Art

 The use of extrusion devices in the preparation of direct expanded food products is long practiced. Utilized to produce a variety of products such as ready-to-eat (R-T-E) cereals, snack foods and confections, extrusion remains prominent among food processes
15 because of its versatility and efficiency.

 Food processes utilizing extrusion devices typically include an edible substance such as dough which is introduced into a device and conveyed via a screw pump to an inlet where the substance is forced through an extruder die assembly. The extruder die assembly may perform a variety of functions: it may form or shape the extrudate; it may
20 divide the extrudate into multiple extrudates; it may inject an additive substance into the extrudate; and it may compress and reduce the cross-sectional area of the extrudate.

Examples of devices used for extrusion of food products are illustrated in U.S. Patents Nos. 2,858,217; 3,314,381; and 5,639,485. While extrusion dies have evolved over the years, the method by which an additive substance is supplied and injected into the extrudate has remained essentially unchanged.

5 For Example, in U.S. Patent No. 2,858,217 to Benson, the introduction of coloring matter, such as a colored liquid dye, is accomplished via a series of apertures **40, 42, 44** disposed in the bridging strips **32, 34, 36** and supplied by horizontal passages **52, 54, 55** which are in fluid communication with the dye reservoir **46**. The supplying of the liquid dye from the dye reservoir **46** to series of apertures **40, 42, 46** is by means of gravitational force. According to the Benson
10 '217 device, dough material **18** is extruded through a divider block **22** which forces the dough material **18** to divide or spread around the bridging strips **32, 34, 36** so that voids **38** are formed into which the coloring matter is introduced via the series of apertures **40, 42, 44**.

Similarly, in U.S. Patent No. 3,314,381 to Fries *et al.*, the fluid injection assembly is comprised of a hollow tubular injection member **29** in a helical spiral configuration, which
15 includes a bore **37** through which pressurized injection fluid is supplied from a source **25** to a plurality of longitudinally spaced bores **39** into a distributing channel **38**. The fluid along the length of channel **38** is injected into the passing dough as a substantially longitudinally continuous spiral band extending from substantially the central axis of the dough to either the outer face of the dough or a point short thereof. However, the Fries *et al.* '381 device is primarily
20 adapted to relatively low pressure comestible extrusions.

U.S. Patent 5,639,485 to Weinstein *et al.* and its related patents, disclose a method and apparatus for adding additives in flowing dough to make complexly patterned multicolored extrudates. The Weinstein *et al.* '485 invention and its progeny all disclose a high pressure extrusion device comprising an extruder die insert **20** which includes means for imparting at least
25 one interstitial gap in the flowing dough by means of a plurality of dividing passageways (*e.g.*, **44, 45, 46**) formed by die dividing members **47**. An additive (*e.g.*, a food color or a second

colored dough) may be injected via a plurality or array of evenly spaced food color injection ports 48 formed on the downstream side of die dividing member 47. The injection ports 48 are in fluid communication with a pressurized color supply 18 by means of supply ports 52, 54, 56 and supply passageway 50. The color fluid tends to fill the interstitial gaps in the flowing dough
5 between passageways (*e.g.*, 44, 45, 46) formed by and behind the die dividing members 47 to create a line in the shape of dividing members 47 in the extruded dough. The die insert 20 also includes notches 57 which are used to isolate the color fluid injected into the interstitial gap from spreading to the interior surface wall of die insert 20 thereby reducing if not eliminating the leakage of color fluid onto the outside of the extruded dough. Additionally, the die insert 20 can
10 further include a means for sealing (*e.g.*, “O” rings 60 and 62 as depicted) the color fluid supply reservoir 58 against premature admixture with dough.

The utilization of notches 57, sealing means 60, 62, and multiple enclosed injection ports 48 further complicates the design of the die insert making it harder to clean and maintain. Finally, injecting color fluid at discrete locations into downstream voids or interstitial gaps to
15 disperse the fluid in a generally uniform manner requires precise control of flow rates, internal pressures, and viscosity of the extrudate and various additives. Furthermore, the design of each die insert 20 is limited to the physical constraints imposed by the previously mentioned design elements.

APV Baker, Inc., in an article presented at several Food Extrusion conferences in 1988,
20 and partially authored by one of the inventors of the present application, discloses a technique for filling an extruded food product outside of a “double die” or in post extrudate operations. In the “double die” system, product expands out of one die opening into another die cavity where it is molded into a particular shape while it is still flexible. **Figure 6a** is a perspective view of an embodiment of the prior art die assembly discussed in the APV Baker article. **Figure 6b** is a side
25 view of the prior art die assembly depicted in **Figure 6a**. Referring to **Figure 6b**, when the first die 605 is attached to the second die 665, the cylinder 615 fills a portion of the second die bore

665 and orifice 675 and extends out past the exit of the orifice 675. The orifice 675 and cylinder 615 form an annular open area at the exit of the orifice 675. As the individual ropes from the first die orifices 625 expand due to vapor flashing, the converging bore 665 of the second die restrains radial expansion and creates a hollow tube made up of multiple ropes as illustrated in

5 **Figure 6c.** A hollow cylinder 615 can be used to inject an additive substance into the hollow portion 682 of the tube. However, because the technique relates to an internal filling, it fails to disclose a way to impart a visibly distinct colored and/or flavored pattern into an extrudable food mass during extrusion. The APV Baker die assembly works best for co-extrusion of a cereal tube with a viscous creme or fruit filling. With co-extrusion, the nozzle 615 protrudes past the die
10 face 675 so that the filling is being pumped into a low-pressure area 617. If the injection nozzle 615 stops short of the die face 675, then the filling injection has to overcome the higher pressure within the die cavity 665. Further, because the cylinder 615 extends out past the exit of the orifice 675, a rotating die face cutter cannot be used with the disclosed die assembly. Rather, a guillotine type cutter must be used, somewhere downstream of the cylinder 615 after the
15 extruded food piece 680 has cooled and further solidified. Use of a guillotine type cutter following further solidification of an extruded food product results in a less clean, more fractured cut. What is needed is an extruder die assembly capable of mixing an additive substance at a variety of operating pressures which has improved seal characteristics and is simpler and easier to maintain.

20 Extruder die assemblies have also been used to apply a shape to a food product. **Figure 7a** shows the exit face 752 of a potential forming die 750 used in a prior art extruder die assembly. Included within the periphery of the exit face 752 is a complexly shaped exit port 754. Upon exiting an extruder die assembly, the extruded mass is directly expanded (*e.g.*, via flash puffing), both outwardly (transversely) in a radial direction, and longitudinally (axially) in the direction of
25 flow. The flashed vapor is typically not captured and is thus vented to ambient air once the extruded mass has exited the die assembly. The extruded mass can then be cut into individual

pieces using a rotating blade mechanism. The resulting individual pieces typically have a uniform, puffed shape with a cross-sectional shape that generally corresponds to the expanded outline of the die exit port. While the characteristics of the resulting individual pieces are satisfactory for simple geometric shapes (*e.g.*, spheres, ovoids, and crescents), the design details
5 of more complex shapes tend to be obscured or eliminated.

For example, the outline **756** of exit port **754** is designed to resemble a dog with two distinct legs, a neck, a body, a head, and a tail. When the forming die **750** is utilized in conjunction with a conventional direct expanded food process, the resulting product is a uniformly puffed food piece **780** as shown in **Figure 7b**. While the shape of the outline **756** of
10 exit port **754** is somewhat discernable in food piece **780**, the design details of the two distinct legs, neck, and tail are generally diminished and obscured. The individual dimensional aspects of the two legs, neck, and tail are simply absorbed by the dimensional aspects of the body areas of the outline **756** of exit port **754** because, in part, of the radial expansion that occurs as the dough exits the die assembly.

15 One solution used to try to solve this problem was to simply further narrow the areas of the exit port where narrower aspects are desired in the food piece **780** in an effort to compensate the radial expansion. For example, the outline **756** of the exit port **754** could be further narrowed in the areas depicting the neck, leg, and tail. This option fails, however, because the driving force required through the narrow areas is much larger than the driving force required to force
20 dough through the main body area. As a result, the extruded mass flows through the path of least resistance, which in **Figure 7a** is the main body area of the dog. Substantially less extruded mass flows through the narrow areas.

One approach of imparting illustrations upon a food product is disclosed by U.S. Pat. No. 5,620,713 assigned to Pillsbury. The Pillsbury patent discloses a die set having an inner die and
25 an outer die. The inner die is formed in a desired shape such as an animal or toy and the outer die has an annular opening surrounding the inner die. However, the outer shape of the food

product is still determined by the outer die. The resultant dough dog must be sliced to observe the internal cross-sectional shaped animal or toy. In addition, at least two different doughs must be used. Further this technology requires cookie dough formulations, operates in a region of lower pressure and temperatures, and generates no flash-off expansion as the dough exits the die.

5 Similarly, U.S. Pat. No. 6,296,465, assigned to Nestec, discloses an extrusion die that produces a three-dimensional shape, having the general shape of a core surrounded by a ring. The core is extruded through a central outlet orifice and is surrounded by the ring extruded through an annular outlet orifice that surrounds the central outlet orifice. Prior to exiting the orifices, the extrudate first enters a convergent wall feed diaphragm, then it enters a divergent
10 wall distribution chamber where it splits into two streams. From the divergent wall distribution chamber, the first stream enters the central duct by means of a circular central pre-expansion diaphragm. The second stream enters the conical convergent coaxial tubular extrusion duct by means of an annular pre-expansion member. The first stream eventually exits the central outlet orifice and the second stream eventually exits the annular outlet orifice. The resultant extruded
15 product has the general shape of a core, surrounded by a ring, best illustrated by Figures 6a-6f of the Nestec Patent. The Nestec Patent, however, fails to disclose a method that provides desired outer narrow feature design details for extruded, complexly shaped food products. The Nestec Patent also does not utilize steam flash-off from the extrudate while contained within the walls of the second die, but rather relies upon steam vaporization and dough expansion that occurs at the
20 exit of die nozzle 90. "Pre-expansion" as defined in the patent appears to refer to controlling the flow rate of dough prior to expansion.

Other prior art solutions, as disclosed in U.S. Pat. No. 5,304,055, issued to Nabisco (Nabisco I) and U.S. Pat. No. 5,435,714 also issued to Nabisco (Nabisco II) disclose an apparatus that utilizes a first cutting means to partially cut across the die orifice so that the extrudate rope is
25 partially cut at an angle transverse to the direction of flow and then utilizes a second cutting means across the entire orifice to completely cut each of the partially cut extrudate ropes into

individual pieces. The Nabisco patents relate only to the cutting apparatus to create three-dimensional shapes. In addition, the Nabisco Patents fail to solve the problem of diminished features due to expansion at the die, or reduced flow through narrow die areas. Further, the three-dimensional shapes that can be produced by introducing a single partial cut into a food extrudate are extremely limited.

Another extruder die assembly is illustrated in U.S. Pat. No. 3,054,677, assigned to The Quaker Oats Company, which discloses a method for making a dry, ready to eat cereal product by extruding a plurality of ropes or strands through a series of closely aligned orifices in a closed path configuration whereby the extruded strands expand to contact with each other and pass through a cutting device to form hollow, pillow shaped pieces. Prior to extrusion, a breaker plate is mounted behind a screen pack to increase the shearing action and further increase the backpressure. Because the expansion occurs in the open atmosphere after the extruding die, however, the flashed vapor is not captured and is thus vented to ambient air once the extruded mass has exited the die assembly. As a result, the dough strands do not adhere together as well as they would in an enclosure. Further, the '677 Patent requires a separate rotary cutting device away from the die assembly which requires more equipment and floor space. In addition, the rotary cutting device disclosed in the '677 Patent limits the shapes of the resultant food products to crimped, pillow-like shapes. What is needed is a die assembly that can enable a rotating die face cutter to cut multiple stranded, adhered, and extruded dough products.

Consequently, a need exists for an improved apparatus and method for enhancing the quality of dimensional design aspects of extruded, complexly shaped food products. The improved method and apparatus should permit novel symmetrical and asymmetrical shapes to be produced. In one embodiment, it should permit pre-expanded extruded dough of various geometries to be formed into a desired shape having a desired texture and then cut by a rotating die face cutter. In one embodiment, it should permit production of extruded food pieces having substantially non-rounded edges. Further, the improved apparatus and method should, in one

embodiment, provide a means to add color and/or flavor to the extruded, complexly shaped food products.

SUMMARY OF THE INVENTION

The present invention overcomes many of the shortcomings inherent in previous methods and systems addressing extruder die assemblies. The present invention, in one embodiment, comprises an improved extruder die assembly and method for using same to impart a distinct colored and/or flavored pattern into an extrudable food mass during the extrusion process.

The present invention, in one embodiment, comprises an improved extruder die assembly and method for using same to improve the quality of dimensional design aspects of extruded, complexly shaped, direct expanded food products.

In one embodiment, the system comprises an extruder die assembly and method for using same in which the first die comprises a forming section and an injection section fabricated as a matching set. When properly aligned and coupled, the matching set forms a peripheral reservoir manifold, internal to the die assembly, through which a fluid additive may be supplied via a supply port to at least one, and more preferably, a plurality of capillary channels which in turn impart a distinct cross-sectional design into a flowing mass of a first extrudate.

In another embodiment, the system and method for using the present invention includes partitioning the internal peripheral reservoir manifold so that a plurality of supply ports may be used to allow different colors and/or flavors to be injected at different locations in the distinct cross-sectional design.

In another embodiment, the system and method for using same utilizes the first die comprising multiple matched sets of forming sections and injection sections in tandem to impart multiple pattern designs into an extrudable food mass.

In another embodiment, the system and method for using same utilizes multiple matched sets of forming sections and injection sections in tandem to impart multiple pattern designs of differing colors and/or flavors into an extrudable food mass.

In another embodiment, the system and method for using same utilizes a converging nozzle to decrease the extrudate's cross-sectional area while maintaining the distinct cross-sectional design pattern imparted into the extrudate.

Thus, in accordance with one feature of the invention, the present invention is comprised
5 of an extruder die assembly capable of operating at a variety of operating pressures which has improved seal characteristics and is simpler and easier to maintain. Moreover, the performance of the extruder die assembly of the present invention is more stable in that surging of the fluid additive is inhibited thereby resulting in a continuous well defined pattern being injected into the extrudable food mass.

10 In accordance with another feature of the invention, the present invention is comprised of an extruder die assembly whose injection mechanism is less prone to clogging and blockages. The system of the present invention allows the flow of the fluid additive to be momentarily halted without permanently plugging the supply passageways or injection section(s).

A novel feature of the invention is an injection nozzle which supplies fluid additives from
15 an exterior pressurized source to a supply port formed in the extruder die assembly. The subject injection nozzle exhibits superior sealing qualities in conjunction with simplicity and flexibility. The minimal affected space required to receive the subject injection nozzle allows a single extruder die assembly to have more than one supply port fashioned therein. Thus, multiple injection nozzles may be used to supply a single extruder die assembly with multiple colors
20 and/or flavors. The injection nozzle of the present invention also exhibits a unique dual seal characteristic, which is particularly effective in conditions involving high temperature. The subject injection nozzle is also highly flexible in that one injection nozzle may be used interchangeably with another (*i.e.*, each injection nozzle is not unique to a particular supply port).

In one embodiment, the improved system includes an improved extruder die assembly
25 comprising a first die having at least one orifice connected to a second die having at least one orifice. In one embodiment, extrusion through the first die orifices results in a plurality of pre-

expanded extruded ropes. Upon exiting the first die, the pre-expanded extruded ropes flash vapor. In one embodiment, the flashed vapor or steam facilitates the adhesive properties of the dough. The pre-expanded extruded ropes then partially adhere together as the extrudate travels through a bore disposed between the first die and second die. The bore restrains radial expansion. By pre-expanding the extrudate in a first die, orifice channel length, placement, size, shape, geometry, and coefficient of friction can be individually configured to optimize the desired shape. For example, by changing the shape and/or size of the first die orifices, differing flow velocities are achieved through the individual orifices, which can produce novel shapes. Further, by changing the size and placement of the first die orifices, specific three-dimensional shapes, such as a snake or dog, can be produced that more closely resemble the target shape. In one embodiment, all radial expansion occurs prior to exit from the second die permitting production of food products having substantially non-rounded edges. Further, by controlling the coefficient of friction on the inlet surfaces of the second die, the texture of the product can be controlled.

In one embodiment, the present invention permits pre-expanded extruded dough of various geometries to be formed into a desired shape having a desired texture and then cut by a rotating die face cutter.

Hence, this invention produces a method and apparatus that enhances the quality of dimensional design aspects and optionally color and flavor aspects of extruded, complexly shaped food products.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings, wherein:

5 **Figure 1a** is a cut-away perspective view of the extruder die assembly of the present invention;

Figure 1b is a cut-away exploded perspective view of the extruder die assembly of the present invention;

10 **Figure 2a** is an overhead view of the forming section of the extruder die assembly of the present invention;

Figure 2b is a cut-away perspective view through section line 2b of the forming section of the extruder die assembly of the present invention;

Figure 3a is an overhead view of the injection section of the extruder die assembly of the present invention;

15 **Figure 3b** is a cut-away perspective view through section line 3b of the injection section of the extruder die assembly of the present invention;

Figure 4 is a perspective in partially exploded view of the exit face of a die plate assembly attached to a food cooker extruder showing the extruder die assembly of the present invention and associated injection nozzle assemblies;

20 **Figure 5a** is a partial sectional view of the die plate assembly taken along line **5a – 5a** in **Figure 4**, showing the extruder die assembly and injection nozzle of the present invention properly aligned and inserted therein;

Figures 5b and 5c are enlarged sectional views of the interface between the extruder die assembly and associated injection nozzle shown in **Figure 5a**.

Figure 6a is a perspective view of an embodiment of a prior art die assembly.

Figure 6b is a side view of the prior art die assembly depicted in **Figure 6a**.

5 **Figure 6c** depicts the resultant food piece formed from the prior art die assembly depicted in **Figures 6a and 6b**.

Figure 7a is an exit face view of a potential forming die used in a prior art extruder die assembly;

10 **Figure 7b** depicts the resulting direct expanded food piece formed by utilizing the extrudate die assembly shown in **Figure 7a** in a conventional direct expanded food process;

Figure 8a is a perspective view of an embodiment of the extruder die assembly of the present invention;

Figure 8b is a perspective view of the embodiment of the die assembly shown in **Figure 8a** in operation;

15 **Figure 8c** is a perspective view of a resultant extruded food piece formed by one embodiment of the present invention.

Figure 9a is a perspective view of an alternate die pattern used in an embodiment of the extruder die assembly of the present invention;

20 **Figure 9b** is a side view of the embodiment of the extruder die assembly shown in **Figure 9a**;

Figure 9c is a partially cut away perspective view of the of the extruder die assembly shown in **Figure 9a**;

Figure 9d depicts the resulting extruded food piece formed by utilizing the extruder die assembly shown in **Figures 9a-9c**;

Figure 9e depicts an embodiment of the extruder die assembly of the present invention and the resulting extruded food piece formed.

5 **Figure 10a** depicts an example of a food product extruded from a second die having a high coefficient of friction.

Figure 10b-d depict three cross-sections of an extruder die assembly having a step change and the resulting extruded food piece formed in accordance with an embodiment of the present invention.

10 **Figure 10e** depicts an example of a food product extruded from a second die having a step change.

Figures 11a-b depict exemplary embodiments of the extruder die assembly of the present invention and the resulting extruded food piece formed.

15 **Figures 12a-12f** depict examples of first dies that can be used in the extruder die assembly in accordance with various embodiments of the present invention.

Figure 13 is a cutaway exploded perspective view of one embodiment of the extruder die assembly having co-injection capabilities.

Where used in the various figures of the drawing, the same numerals designate the same or similar parts. Furthermore, when the terms “top,” “bottom,” “first,” “second,” “upper,”
20 “lower,” “height,” “width,” “length,” “end,” “side,” “horizontal,” “vertical,” and similar terms are used herein, it should be understood that these terms have reference only to the structure shown in the drawing and are utilized only to facilitate describing the invention.

DETAILED DESCRIPTION

COLOR/FLAVOR INJECTION

An extruder die assembly, generally indicated by reference character **100** in **Figures 1a** and **1b**, includes a forming section **200**, an injection section **300**, and a nozzle section **400**. The three sections comprising the die assembly **100** are, in one embodiment, coaxially aligned and interlocking. Additionally, means for coupling the forming section **200** to the injection section **300** are also included.

The extruder die assembly **100** is designed for adaptation to a wide variety of commercial-grade extrusion devices common in the food industry. The extruder die assembly **100** is inserted into an appropriate compartment within an extrusion device (not shown) such that a first extrudate (*e.g.*, a paste or a cereal dough) is directed down a coaxially aligned passageway **210** within the forming section **200** and combined with a fluid additive (*e.g.*, a food coloring dye or a flowable colored and/or flavored food material) in the injection section **300** via supply port **340** and annular reservoir **R**, whereupon the resulting food mass is compressed through a converging nozzle bore **420** in the nozzle section **400** to produce an extruded food product containing a distinct colored and/or flavored pattern.

While the embodiment illustrated is shown as being generally cylindrical in shape, the exterior housing of the die assembly **100** may be of any shape necessary for adaptation to commercial-grade extrusion devices common in the food industry. Similarly, while passageway **210** and bore **420** are depicted as having a circular cross sectional area, in other embodiments, passageway **210** and bore **420** can be fabricated with a more complex peripheral configuration to define or define-in-part the exterior shape or configuration of the finished piece, including both regular shapes (*e.g.*, stars, rings, geometric shapes) as well as irregular shapes (*e.g.*, animals, vegetables, objects such as trees, cars, *etc.*).

Referring to the figures, and in particular **Figures 2a** and **2b**, the forming section **200** is a generally tubular flange element having a central bore defining a passageway **210**. The inlet **212**

of the passageway **210** is adapted to receive a conduit (not shown) supplying a pressurized first extrudate from an extrusion device (not shown). A plurality of counter-sunk coupling holes **202**, equally spaced around the periphery of the entrance face **204** of forming section **200**, are provided for receiving screws (not shown) for removably coupling the forming section **200** to threaded holes **302** in the injection section **300**. An alignment hole **206** extends through the forming section **200** in parallel alignment with the passageway **210** to receive an alignment knob **306** on the entrance face **304** of the injection section **300**. When properly seated into the alignment hole **206**, the alignment knob **306** ensures that the axial angular alignment of the injection section **300** in relation to the forming section **200** is correct.

The outlet portion of the passageway **210** includes a forming die element **220** which divides the flow of the first extrudate into at least two, and more preferably a plurality of adjacent flowing extrudate passageways such as passageways **a-g** respectively formed by forming die element **220**.

The forming section and injection section are fabricated as a matching set. In general, the outlet portion of the forming section is designed to mate and seal with the inlet portion of the injection section. In one embodiment, an inner peripheral rim formed in the outlet portion of the forming section is specifically designed to slidably couple and align with a central bore in the inlet portion of the injection section. The inner peripheral rim is defined by a peripheral notch formed in the outlet face of the forming section. The peripheral notch is characterized by a peripheral rim wall which is parallel with and generally equidistant from the outer periphery of the central passageway. The inner peripheral rim includes a peripheral groove with a semicircular cross-section. A matching peripheral groove with a semicircular cross-section is formed in the base of the central bore of the inlet portion of the injection section such that when the forming section and injection section are slidably coupled and aligned, an internal peripheral reservoir manifold with a circular cross-section is formed.

Thus, as shown in the figures, and in particular **Figures 2b, 3a, and 3b**, when the present

invention is realized in an embodiment having a generally circular cross section, the inner peripheral rim formed in the outlet portion of the forming section **200** is an annular rim defined by an annular notch, characterized by the annular rim wall **242** and the annular outer ring seal face **240**, around the outer periphery of the outlet face of the forming section **200**. The annular rim in the outlet portion of the forming section **200** slidably fits into a central bore in the inlet portion of the injection section **300** defined by the annular bore wall **308** such that the forming section's annular outer ring seal face **240** seats and seals with the injection section's annular outer seal face **304**, the forming section's intermediate annular seal face **244** seats and seals with the injection section's annular intermediate ring seal face **310**, and the forming section's inner annular seal face **246** and the exit face **248** of the forming die element **220** seat and seal with the entrance face **322** of the injection section's co-injection die insert **320**. Moreover, the matching annular peripheral grooves **230** and **330** form an annular internal peripheral reservoir manifold **R** into which a fluid additive may be supplied. When properly aligned and coupled, the respective annular seals between the forming section **200** and the matching injection section **300** effectively seal and isolate the fluid additive supplied to the reservoir manifold **R** from inadvertent leakage to the upstream side of the forming die element **220** and the outer periphery of the extruder die assembly **100**.

The injection section **300** includes a co-injection die insert **320** which has profile such that when properly aligned with the forming die element **220**, passageways **a'-g'** are respectively adjoined with passageways **a-g** formed by forming die element **220**. When properly aligned and coupled, the seal between the exit face **248** of the forming die element **220** and the entrance face **322** of the injection section's co-injection die insert **320** ensures that the respective adjacently flowing extrudate passageways are unobstructed and contiguous and that the fluid additive contained in the reservoir manifold **R** does not inadvertently leak to the upstream side of the forming die element **220**.

The co-injection die insert **320** includes at least one and more preferably a plurality of

capillary channels **352** in the space between the plurality of passageways. The capillary channels **352** are fluidly connected to the reservoir manifold **R** via channel ports **350**. The reservoir manifold **R** is fluidly connected to a pressurized source of fluid additive (not shown) via supply port **340**.

5 When properly aligned and coupled, the seal between the exit face **248** of the forming die element **220** and the entrance face **322** of the injection section's co-injection die insert **320** ensures that the pressurized fluid additive supplied to the annular internal peripheral reservoir manifold **R** continually charges the capillary channels **352** via channel ports **350** whereupon each capillary channel **352** emits at its downstream exit face a continuous discharge of fluid additive
10 in the general cross-sectional shape of the capillary channel **352** resulting in a continuous band of fluid additive being injected into the transient clefts formed in the first extrudate as it exits the adjacent flowing extrudate passageways such as passageways **a'-g'**. Upon exiting from the individual adjacent flowing extrudate passageways (*e.g.*, passageways **a'-g'**), the individual adjacently flowing columns of first extrudate coalesce to enclose the injected bands of fluid
15 additive within a single flow mass thereby imparting a distinct colored and/or flavored pattern into the food mass.

 In an alternative embodiment of the present invention, the injection section **300** may include multiple supply ports **340** fluidly connected to separate pressurized sources of fluid additive. In such an embodiment, the annular internal peripheral reservoir manifold **R** may be
20 divided into multiple segregated quadrants fluidly connecting individual pressurized sources of fluid additive to specific capillary channels **352** allowing a distinct pattern of multiple colors and/or flavors to be imparted into the food mass.

 In one embodiment of the present invention, the exit face **362** of the injection section **300** is generally designed to mate and seal with the inlet face of the nozzle section **400**. With the
25 exception of the co-injection die insert **320**, the inlet face of the nozzle section **400** is essentially a mirror image of the exit face **362** of the injection section **300**. In general, the nozzle section

400 includes an inlet with a periphery matching the periphery of the forming section's passageway. The nozzle section further includes a passageway coaxially aligned with the forming section's passageway which converges to an outlet. As the passageway converges, the passageway's cross-sectional decreases while its aspect ratio is generally maintained. Thus as
5 shown in the figures, and in particular **Figures 1b** and **3b**, when the present invention is realized in an embodiment having a generally circular cross section, the nozzle section 400 includes an inlet 410 with an inner annular periphery which matches the periphery of the forming section's passageway 210. The nozzle section further includes a passageway 420 coaxially aligned with the forming section's passageway 210 which converges to an outlet 430.

10 In an actual embodiment having a circular cross section as illustrated in **Figure 1b**, the diameter of passageway 420 is reduced from 0.664 inches at inlet 410 to 0.332 inches at outlet 430. In another such embodiment, the diameter of passageway 420 is further reduced from 0.664 inches at inlet 410 to 0.153 inches at outlet 430.

Alternatively, in another embodiment of the present invention, multiple sets of matching
15 forming/injection sections may be adjoined in a tandem or series arrangement. In such an embodiment, the inlet face of a second set's forming section is designed to mate and seal with the exit face of a first set's injection section. Arranging multiple sets of matching forming/injection sections in tandem allows multiple pattern designs of differing colors and/or flavors to be imparted into an extrudable food mass.

20 As previously noted, the extruder die assembly 100 of the present invention is designed for adaptation to a wide variety of commercial-grade extrusion devices common in the food industry. The extruder die assembly 100 is typically inserted into a sealable compartment attached to or within an extrusion device (not shown), such that the inlet 212 of the forming section 200 of the extruder die assembly 100 is connected via a conduit to an output port of the
25 extrusion device. For example, as illustrated in **Figure 4**, such a compartment may comprise a die plate assembly 500 attached to the outlet section of a conventional cooker extruder device.

The die plate assembly **500** includes a main die plate **510** having a main bore **512** defined therethrough for receiving an extruder die assembly **100**. The circumferential dimensions of the main bore **512** is complementary to that of the extruder die assembly **100**, so as to ensure a snug fit and eliminate extrudate leakage therebetween. When an extruder die assembly **100** is inserted
5 into the main bore **512** of the main die plate **510**, the outlet **430** of the nozzle section **400** protrudes slightly past the exit face **514** of the main die plate **510**.

The main die plate **510** also includes an injection port **520** formed in the sidewall **516** of the main die plate **510** for receiving an injection nozzle **600**. The injection port **520** extends through the sidewall **516** to the main bore **512** at an angle generally perpendicular to the
10 longitudinal axis of main bore **512**. The injection port **520** is further positioned such that when an extruder die assembly **100** is inserted into and properly aligned with the main die plate **510**, the injection port **520** aligns with a corresponding supply port inlet **342** formed in the injection section **300** of the extruder die assembly **100**. The main die plate **510** may further include additional injection ports (*e.g.*, **522**) for receiving additional injection nozzles (*e.g.*, **602**), for use
15 with an extruder die assembly **100** having multiple supply port inlets **342** formed in the injection section **300** thereof. When not required, the additional injection ports (*e.g.*, **522**) may be sealed with a suitable plug device (not shown).

In addition, the die plate assembly **500** also typically includes a conventional feed plate (not shown) which seals the entrance face of the main die plate **510** and has a passageway
20 defined therethrough which acts as a conduit between the output port of the extrusion device and the inlet **212** of the forming section **200** of the extruder die assembly **100**. The feed plate may also provide attachment points for connecting the die plate assembly **500** to the outlet section of the extrusion device.

Referring now to the Figures, and in particular to **Figures 5a, 5b and 5c**, which depict
25 various cross-sectional views of the die plate assembly illustrated in **Figure 4**, a novel feature of the invention is shown, which comprises an injection nozzle **600** that supplies fluid additives

from an exterior pressurized source to a supply port **340** formed in the injection section **300** of the extruder die assembly **100**. The injection nozzle **600** of the present invention exhibits enhanced sealing characteristics while supplying pressurized fluid additives to an extruder die assembly **100** inserted in a die plate assembly attached to a conventional cooker-extruder device.

5 The injection nozzle **600** generally comprises an inlet section **610**, a mid-section **620**, and a outlet section **630**. The inlet section **610** is designed to receive and couple with a pressurized additive supply line **670** so as to establish fluid communication with the exterior pressurized source. In the embodiment shown in the Figures, the inlet section **610** comprises a standard hexagonal NPT threaded female fitting which is designed to engage a conventional threaded
10 male fitting **650** attached to the pressurized additive supply line **670**.

 The mid-section **620** comprises an externally threaded barrel having a smooth-bore interior passageway **616** in fluid communication with an inlet space **612** defined in the inlet section **610**. The threaded mid-section **620** allows the injection nozzle **600** to be securely mounted into the threaded injection port **520** formed in the main die plate **510**, thus forming a
15 leak-proof assembly.

 The outlet section **630** comprises a smooth, tapered end having a discharge port **618** at its distal end which is in fluid communication with the interior passageway **616**. The diameter of the discharge port **618** is typically less than the diameter of the supply port **340**. The outlet section **630** is generally paraboloididal shaped having a spherical tip of a given radius r_1 . The
20 spherical tip of the outlet section **630** is complementary with the spherical concavity of a given radius r_2 which defines the supply port inlet **342** formed in the injection section **300** of the extruder die assembly **100**. The complementary shapes of the spherical tip of the outlet section **630** and the supply port inlet **342** provide a relatively larger contact area per unit volume of perforation inside the injection section **300** of the extruder die assembly **100**, thereby resulting in
25 an enhanced sealing mechanism. The resulting increase in the metal-to-metal contact between the outlet section **630** of the injection nozzle **600** and the supply port inlet **342** thereby facilitates

a non-invasive fluid connection with robust sealing characteristics.

Thus, in addition to the threaded portion **614** of the inlet section **610**, which effectively seals the connection between the injection nozzle **600** and the pressurized additive supply line **670**, the injection nozzle **600** of the present invention exhibits a unique dual seal characteristic.

5 First, the threaded mid-section **620** effectively seals the injection port **520** preventing extrudate from leaking out from the interior main bore **512**. Second, the complementary shapes of the spherical tip of the outlet section **630** and the supply port inlet **342** effectively seals the pressurized fluid additives from leaking out to the outer periphery of the extruder die assembly **100**.

10 The dual seal characteristic is particularly effective in conditions involving high temperature. In such conditions, components of the die plate assembly **500** typically expand, oftentimes resulting in a corresponding increase in the gap between the extruder die assembly **100** and the interior main bore **512**. The dual seal characteristic of the injection nozzle **600** allows both sealing mechanisms to be adjusted, independent of one another, in response to
15 changes induced by high temperature conditions.

Furthermore, the injection nozzle **600** of the present invention promotes a simpler and more flexible injection system. For example, while in theory a sealing thread mechanism could be extended along the entire length of the nozzle, this would require a much larger volume of perforation inside the injection section of an extruder die assembly to achieve an equivalent
20 contact and sealing area. Moreover, to insure a continuous threaded seal, the bore of the injection port and the supply port inlet would have to be threaded concurrently, thereby dictating a matched set arrangement comprised of an injection nozzle, an injection section, and a die plate.

On the other hand, the reduced injection section perforation requirement of the injection nozzle **600** of the present invention allows greater flexibility in the number of nozzles used and
25 the positioning of the nozzles in a particular application. Moreover, the injection nozzle **600** of the present invention allows greater simplicity while improving the flexibility of the entire

system in that generic components may be fashioned so as to be essentially interchangeable with like generic components. For example, the injection nozzle 600 may be standardized so as to be interchangeable with any other generic injection nozzle. The dimensions and position of the supply port inlet 342 formed in assorted injection sections may also be standardized allowing a generic injection nozzle having a standardized tip to be used with all of them. In addition, the dimensions of the threaded injection ports on the main die plate may be standardized so as to accommodate all injection nozzles having a generic threaded barrel mid-section. Likewise, the position of the threaded injection ports on the main die plate may be standardized so as to align with the supply port inlet 342 on all extruder die assemblies having a generic injection sections. Thus, by standardizing the injection nozzle 600, the injection port 520, and supply port inlet 342, extruder die assemblies having different forming die elements 220 and co-injection die inserts 320 are easily interchangeable with one another.

While the embodiment of the injection nozzle 600 illustrated in the Figures is shown as a unitary component, it is understood that other variants of the injection nozzle 600 of the present invention may be comprised of separate sections which are selectively coupled to one another.

SHAPES HAVING ENHANCED DIMENSIONAL DESIGN ASPECTS

Figure 8a is a perspective view of an embodiment of the extruder die assembly of the present invention is shown. The improved extruder die assembly comprises a first die 810 and a second die 860. Although the first die 810 and second die 860 are depicted as two separate pieces that fit together, an integral die assembly 800 comprising a first die and a second die can be used.

The die assembly 800 of the present invention involves a staged pressure drop, including a first pressure drop and a second pressure drop, which consequently results in staged radial, longitudinal, and volumetric expansion. The first pressure drop occurs at the first die 810 which can be also called a breaker plate or baffle, and the second pressure drop occurs at the second die 860. The total pressure drop is the sum of the first pressure drop and second pressure drop. Most

of the total pressure drop is taken in the first die **810**. The pressure drop ratio is defined as the ratio of the pressure drop in the first die to the sum of the pressure drops of any subsequent dies. The pressure drop ratio is greater than at least 1.0.

The first die **810** comprises a plurality of orifices, in one embodiment, that resembles a
5 pattern similar to the desired target shape of the extruded food product. For example, the first die assembly **800** in **Figure 8a**, produces an extruded food piece in the target shape of a dog. Orifices in the first die **810**, in one embodiment, correspond and substantially co-axially align with orifice sections in the second die **860**. As used herein, an orifice corresponds to an opening of any shape in a die, and includes but is not limited to a slot or hole. For example, referring to
10 **Figure 8b**, a perspective view of an embodiment of the die assembly shown in **Figure 8a** in operation, orifice holes depicting the head **822** of the dog shape are substantially co-axially aligned with the orifice section depicting the head **872** of the second die. Likewise, the neck orifice **823** is substantially co-axially aligned with the neck orifice area **873**; the body orifices **824** (partially obscured from view) substantially co-axially align with the body orifice area **874**;
15 the leg area orifices **825** are substantially co-axially aligned with the leg orifice area **875**; and the tail orifices **827** are substantially co-axially aligned with the tail orifice area **877**. The size, geometry, and number of orifices indicated by numerals **822** through **827** (all relating to conductance of flow through the first die **810**) can be varied to control the amount of dough flowing into a specific region of the dog shape in the second die **860**. In this way, the
20 dimensional aspects of the head, neck, body, and legs can be better controlled by orifice placement in the first die **810**.

The extruder die assembly **800** of the present invention is designed for adaptation to a wide variety of commercial-grade extrusion devices common in the food industry. While the embodiment illustrated is shown as being generally cylindrical in shape, the exterior housing of
25 the extruder die assembly may be of any shape necessary for adaptation to commercial-grade extrusion devices common in the food industry.

The extruder die assembly is inserted into the appropriate compartment within an extrusion device (not shown) and connected to a coaxially aligned supply conduit having a passageway whereby an extrudate (e.g., a paste or a cereal dough) is directed through the assembly. Although coaxial alignment is preferred in some embodiments, it is not required, and
5 in one embodiment, the die assembly is not coaxially aligned with the supply conduit. Upon exiting the improved extruder die assembly, the extrudate is thereupon directly expanded and cut into individual pieces by a rotating die face cutter.

Referring back to **Figure 7a**, in prior art processes, when extrudate at temperatures greater than 212°F and pressures greater than 15 psia exits the shaped exit port **754**, the

10 extrudate experiences a sudden change in pressure, causing water to change to steam vapor (typically called flash-off) and extrudate expansion occurs as the extrudate exits the die **750**.

As discussed above, expansion occurs in both the radial and longitudinal directions. As taught in the book "Extrusion Cooking" by Mercier, Linko, and Harper (AACC, Inc. 1989.

ISBN 0-913250-67-8), a measure of the radial expansion can be quantified by sectional

15 expansion index (SEI), which is defined as the ratio of the diameter of the extruded product to the die opening diameter. For complex shapes, the sectional expansion index can be calculated from hydraulic diameters. Similarly, a measure of the longitudinal expansion can be quantified by the longitudinal expansion index (LEI), which is defined as the ratio of the exiting velocity from the die orifice of the extruded product after expansion to its average
20 velocity just prior to exiting the die orifice. The product of the sectional expansion index and the longitudinal expansion index is the volumetric expansion index.

Referring to **Figure 8b**, because radial expansion is partially limited by the die bore **865** (shown in phantom), the volumetric expansion occurs more proportionately through the longitudinal expansion component resulting in less radial expansion as the extrudate exits the
25 second die **860**. Hence the resultant food piece length **L2** will be closer to the corresponding length **L1** of the outlet die than **L2** would be absent control of radial expansion during pre-

expansion in the bore **865**. Any radial expansion that occurs subsequent to the die outlet **870** can cause the resultant food piece to have substantially arcuate edges.

In one embodiment, substantially all of the volumetric expansion occurs after the first die **810**. In such an embodiment, as illustrated by **Figure 8c**, substantially all radial expansion subsequent to the second die **860** is prevented. Thus, a much more specific shape can be obtained and the product will exit with substantially L-shaped edges, rather than substantially arcuate edges. Hence, the resultant food piece length **L3** will be substantially equal to the corresponding length **L1** of the outlet die. In sum, the direction of expansion can be controlled in the second die **860** to determine the extent, if any, of radial expansion upon exit from the second die **860**. The amount of radial expansion can be achieved by creating more open volume in the die bore **865** (inlet to second die). In one embodiment, the volumetric expansion of the dough is equal to the bore volume of the second die.

As previously discussed, in prior art die assemblies, the rapid pressure loss within the extruded dough, from a condition of high pressure (greater than 1 atmosphere) to atmospheric pressure, takes place once the extruded mass has exited the die assembly. This rapid loss of pressure causes water vapor flash-off and expansion of the extruded dough in all directions. Unlike the prior art die assembly, in the present invention, a majority of the pressure drop occurs at the first die and thus a majority of the vapor formed is formed at the first die exit but within the chamber formed by the walls of the second die. This rapid loss of pressure while still within the confined space or die bore of the second die causes the dough expansion to form substantially more longitudinally rather than radially. Because the vapor and extrudate are still within the confined space of the die bore, the vapor continues to react with the dough creating sticky surfaces which bind the individual ropes from the first die into a single product. Dependent upon other process conditions, this may have a desirable effect on the surface texture and cell structure characteristics of the product.

Related to the phenomena described above, the spontaneous separation of food

substances in the mixture at the transition between first die exit and second die exit has been observed. The spontaneous separation and migration of susceptible matter in the mixture can be controlled by the design of the pre-expansion die assembly. Crystalline sugar, for example, liquefied by the extrusion process, can separate from the dough and migrate to the periphery of the conduction, imparting significantly different attributes to the final extruded food product. This is of particular relevance when more than a two-stage pressure drop as discussed below is designed. Thus, although only a two-stage pressured drop is discussed, additional stages can be used by adding additional dies, orifice plates, breaker plates, baffles, etc. or by changing the pressure by some other means such as changing the pipe diameter.

In operation, in the embodiment shown in **Figure 8b**, the extrudate **820** upon exiting the first die **810**, pre-expands into a plurality of ropes -- one rope for each orifice. The ropes, upon exiting the first die **810**, expand and flash vapor. The hot, steamy dough ropes **820** are "sticky" and have a tendency to adhere to one another. As the sticky ropes **820** exit the first die **810**, the ropes **820** enter into a bore **865** or channel that restricts radial expansion and facilitates adherence of the sticky ropes to one another in the bore **865** prior to exiting in the shape **870** of the second die **860**. In alternative embodiments, a bore **865** configuration between said first die orifices and second die orifice is selected from the group consisting of a parallel configuration, a divergent configuration, a convergent configuration, and combinations thereof. In a preferred embodiment, a convergent configuration is used to further enhance restriction of radial expansion. A convergent configuration is also preferred for achieving bite sized food pieces. A convergent configuration is also preferred for multiple stranded products because it increases the amount of area in first die **810** for multiple orifices.

An advantage achieved by using the above embodiment of the die assembly is the enhanced design aspect of the definition of narrow members of the extrudate. For example, as shown on **Figure 8b**, the neck **893**, legs **895**, and tail **897**, illustrate an extrudate from the

present invention, that are more defined than the same respective areas as shown on **Figure 7b**, an extrudate from a prior art die assembly. Use of the novel die assembly permits shapes that more accurately portray the target shape. Thus, in one embodiment, a high definition extruded food product is made from the die assembly of the present invention.

5 As previously indicated, in one embodiment of the present invention, most of the total pressure drop occurs in the first die **810**. The pressure drop through the first die **810** can be controlled by manipulating several factors including, but not limited to, friction factor, orifice channel length, size, shape, and number of the first die orifices. The pressure drop through the second die **860** can also be controlled by manipulating several factors including, but not
10 limited to, friction factor, orifice channel length, convergence or divergence angle of bore **865**, size and shape of the second die orifice.

THREE DIMENSIONAL SHAPES

Similarly, the flow velocity and flow velocity profile of the extrudate through each individual orifice can be varied by manipulating factors including, but not limited to, friction
15 factor, orifice channel length, orifice size, orifice shape, orifice pattern (arrangement of holes), and convergence or divergence angle of bore **865**. For example, **Figure 9a** is a perspective view and **Figure 9b** is a side view of an alternate die pattern used in an embodiment of the extruder die assembly of the present invention. The first die **910** comprises a plurality of rectangular shaped slots or orifices **920** disposed on a beveled portion
20 **940** bounded by an outer flat circumferential area **930** and an inner flat circular area **950**. The first die **910** can mate with the second die **960** having a round orifice **970**. The shapes discussed herein for first die orifices **920** and second die orifices **970** are shown for purposes of illustration and not limitation. Similarly, the number of orifices comprising the first die can vary in number, shape, as well as angle of entry and exit. Moreover, the placement of the
25 orifices need not be symmetrical.

Chapter 3 of the book "Extrusion Dies" by Walter Michaeli (Hanser. 2003. ISBN 1-

56990-349-2) teaches that die conductance (K for Newtonian and K' for Non-newtonian) mathematically describes the resistance to flow for a liquid flowing through an orifice, the higher the conductance number the lower the resistance to flow. The conductance, K , is a function of the geometry of the orifice, including shape, open area, length, convergence, and wall adhesion. These geometric factors therefore describe the parameters that can be controlled within the die assembly to control flow rate and pressure drop. Their relationship with conductance being, conductance (K) is the product of volumetric flow rate (ζ) and dough viscosity (η) divided by the pressure drop (ΔP). Or in other words, the pressure drop (ΔP) is equal to the product of the volumetric flow rate (ζ) and dough viscosity (η) divided by the conductance (K). Therefore, to control the die design parameters that create pre-expansion, lowering the die conductance (K) increases the pressure drop (ΔP) across a die orifice. The die conductance for various shapes of die orifices are known to those in the art, and available in Table 3.1 and Figure 3.5 of the above referenced book.

Figure 9c is a partially cut away perspective view of the extruder die assembly shown in **Figures 9a and 9b**. Typically, the extrudate, at a pressure greater than one atmosphere, and more typically between about 500 psig and about 2500 psig and a temperature greater than 212°F, and more typically between about 250°F and about 425°F is pressed against the die assembly **900**. The extrudate enters the first die **910** and flows through the orifices **920**. The flow rate of the extrudate through each first die orifice **920** is determined by the conductance of that orifice. The larger the orifice, the higher the conductance and the higher the flow. Conversely, the smaller the orifice, the lower the conductance, resulting in a relatively lower flow rate. Conductance can also be modified by lengthening or shortening the channel of each orifice **920**. In the embodiment shown in **Figure 9c**, orifices comprising channels are disposed in the beveled area **940** of the first die **910**. Having a beveled area **940** is one way to achieve a varying intra-channel length. For example, the distance of channel length from the distal portion **922** of each orifice **920**, namely that portion adjacent to the outer flat circumferential area **930**, is

longer than the channel length of the opposite side, or proximate portion of each slot **920**, namely the inner portion **923** adjacent to the inner flat circular area **950**. Thus, there is less conductance for dough flow at the distal radial edge **922** than at the proximate radial edge **923** of the orifice. This variable resistance, which results in one embodiment from a varying intra-channel length, causes a non-symmetrical dough velocity profile as the dough travels through the orifice channel **920**. The closer the dough is to the center **950** of the first die **910**, the faster the dough travels through that portion of the orifice channel **920**. Likewise, the further the dough is from the center **950** of the first die **910**, the slower the dough travels through that portion of the orifice channel **920**. As a result the faster dough exiting the first die **910** will curl around the slower dough exiting the same orifice channel into a dough rope. Each dough rope can be adhered to one another as the ropes enter the bore **965** before proceeding to the second die exit **970** where the extrudate is cut into pieces. **Figure 9d** depicts the resulting food piece formed by using the extruder die assembly shown in **Figures 9a-9c**. As shown in **Figure 9d**, a food product piece mimicking the target shape of a piece of popcorn is achieved. Thus, in one embodiment, an asymmetrical three-dimensional extruded food product is made from the die assembly of the instant invention.

Figure 9e depicts an embodiment of the extruder die assembly of the present invention and the resulting extruded food piece formed. In this embodiment, pre-expanded dough extruded through the first die **910e** orifices **920e** comprises a plurality of ropes, which then are sent through a converging section **965e** before exiting the second die **970e** as a three-dimensionally shaped extruded food piece **980e**. Conductance can also be modified by adjusting the angles of the orifice inlet or the orifice outlet. Alternatively, the entrance angles can be eliminated and a rounded inlet can be used. The entrance can also be tapered.

TEXTURE ASPECTS

Appearance can be modified by changing the coefficient of friction of the orifice channels. The higher the coefficient of friction on an inner die wall surface, the rougher the

surface finish of the food product piece. As used herein, a high coefficient of friction is defined as a coefficient of friction above about 0.80. A high coefficient of friction slows movement of the outer surface of the dough (wall dough), or the dough traveling adjacent the die wall. The inner dough travels at faster speeds causing the wall dough to tear away from the inner dough due to shear forces. Thus, a rough surface results upon exit from the second die. A steel surface having a roughness average greater than 125 micro inches per ANSI B46.1 can provide a high coefficient of friction. **Figure 10a** depicts an example of a food product **1080a** extruded from a second die having a high coefficient of friction. As depicted in the Figure, the food product extruded through a second die having a high coefficient of friction contains numerous randomly spaced wrinkles on the outer surface.

In one embodiment, a step change is used to create an extruded food product having a rough texture or an irregular texture. **Figure 10b** depicts three cross-sections of an extruder die assembly having a step change and the resulting extruded food piece formed in accordance with an embodiment of the present invention. As used herein, a step change occurs when the bore diameter **BD** immediately adjacent to the second die is greater than the second die diameter **OD**. Each cross-section depicts a first die **1010** having a plurality of first die orifices **1020** and a second die **1060** having a second orifice **1070**. In one aspect, pre-expansion of the dough occurs in a die bore having a parallel configuration **1065a**. In other aspects, pre-expansion of the dough occurs in a die bores having a divergent **1065b** or a convergent configuration **1065c**. Each bore has a bore diameter **BD** adjacent to the orifice diameter **OD**. Thus, a step change can occur by using any bore configuration that leads to an orifice **1070** at the second die having an orifice diameter **OD** smaller than the adjacent bore diameter **BD**. The step change from the bore diameter **BD** to the orifice diameter **OD** causes tearing as the pre-expanded dough is extruded through the second die orifice **1070**, resulting in an extruded food product **1080b** having a rough texture.

In an embodiment similar to that discussed above in reference to **Figure 8c**, substantially

all the volumetric expansion occurs after the first die **1010** in a die bore **1065a 1065b 1065c**. In such an embodiment, because substantially all radial expansion subsequent to the second **1060** is prevented, the resultant extrudate diameter **ED** exiting the second die **1060** is substantially equal to the second die orifice **1070** diameter **OD**.

5 A second die having a relatively low coefficient of friction on the inner die wall surface results in a smooth surface finish on the food product piece due to the resultant flow velocity profile. As used herein, a low coefficient of friction is defined as a coefficient of friction below about 0.20. A material having an average roughness of less than 32 micro inches per ANSI B46.1 can provide a relatively low coefficient of friction. The low coefficient of friction can be
10 accomplished by a variety of methods including, but not limited to, a polished, machined surface, electroplating, or by using a low coefficient coating such as Teflon®. A second die having a coefficient of friction between about 0.20 and 0.80 can produce extrude food pieces having a standard surface finish.

OTHER SHAPES

15 **Figure 11a-b** depicts exemplary embodiments of the extruder die assembly of the present invention and the resulting extruded food piece formed. In one embodiment, dough is extruded through the first die **1110a** orifices **1120a** to make a plurality of ropes and then routed through a converging bore **1165** before exiting the second die **1170** as a flat square extruded food piece **1180a**. The resultant extruded food product **1180a** is a substantially flat
20 square or rectangle. Absent pre-expansion, the resultant extruded food product **1180a** would have wrinkling due to radial expansion. In an alternative embodiment, an alternate first die **1110b** having a single slot **1120b** is used to produce a similarly shaped food product **1180b**. Hence, a single or multi-stranded pre-expanded extruded dough of various geometries can be formed into a desired shape having a desired texture and then cut by a rotating die face cutter.
25 In yet another embodiment, the first die orifice and second die orifice can be substantially square or rectangular in shape. In such an embodiment, if substantially all radial expansion

occurs prior to exit from the second die in a die bore disposed between the two orifices, an extrudate mimicking a porous, bread-like appearance can be made and cut with a die face cutter. In one embodiment, a porous food product having a visible open cellular structure is made. Further, in one embodiment, the first die can comprise a forming die element that
5 mates with a co-injection die insert to combine color and/or flavor with the novel shape characteristics of the extrudate produced from the instant invention. Thus, the outer edges could be darkened to further mimic the appearance of a sliced piece of bread.

Figure 12a-12f depict examples of first dies that can be used in the extruder assembly in various embodiments of the present invention. As shown in **Figures 12a-12f**, numerous
10 patterns of orifice sizes and geometries can be utilized as a first die. For example, as shown in **Figure 12b**, at least one (center orifice) of a plurality of first die orifices comprises a different cross-sectional area. As shown in **Figure 12c**, at least one of a plurality of orifices comprises a different shape. Again, the shapes discussed herein for first die orifices are shown for purposes of illustration and not limitation. First die orifice shapes can be selected
15 from the group consisting of square, oval, rectangle, circle, semi-circle, triangle, trapezoid, crescent, and combinations thereof. Furthermore, as illustrated by **Figure 8a**, the first die orifice pattern can resemble target shapes. The patterns discussed herein are given for purposes of illustration and not limitation. First die patterns can be selected from the group consisting of letters, plants, animals, shapes, and combinations thereof. As shown in **Figures**
20 **12e and 12f**, first die orifices can be arranged in a non-symmetrical pattern.

SHAPES WITH COLOR/FLAVOR INJECTION

Figure 13 is a cut-away exploded perspective view of one embodiment of the die assembly of the present invention having co-injection capabilities. **Figure 13** illustrates one example of how the first die can comprise a forming die element **1310a** that mates with a co-
25 injection die insert **1310b** to combine color and/or flavor with the novel shape characteristics of the extrudate produced from the instant invention. The injection die insert **1310b** further

comprises at least one capillary channel **1352** in the space between the plurality of orifices **1320** in communication with at least one injection port outlet to enable at least one color (food dye) and/or at least one flavor, or other food substance to be co-injected into selected portions of the extrudate substantially at the first die **1310a**, **1310b**. Although an injection port outlet **1313** can be directed towards the die inlet **1310a** or within various orifice **1320** channels, or at the first die exit (as shown), it is preferably directed at the first die exit to avoid clogging.

As previously indicated, several of these configurations can be stacked upon in order to achieve multiple color, or flavor effects. Other food substances can also be used in addition to food dyes and flavors, for example edible oils acting as lubricants, to achieve a particular product design. Thus, numerous shapes having an enhanced quality of dimensional design aspects can be colored to even further enhance the representation of an extruded food product. For example, a first die comprising a forming die element mated with a co-injection die insert having a plurality of first die orifices and a second die orifice patterned in the shape of a zebra can be used to produce an extruded food piece having black stripes in the shape of a zebra. Similarly, an orange color and a black color could be injected into a plurality of first die orifices patterned in the shape of a tiger. Shades of green could be injected into a plurality of first die orifices patterned in the shape of a snake.

As previously indicated, conductance through the orifices **1320** of the first die **1310a**, **1310b** can be manipulated by adjusting the length and/or friction factor of the orifice **1320** channel, by placement of the orifices **1320** within the first die **1310a**, **1310b**, by the open surface area (size) of each orifice **1320**, and/or by the curvature of each orifice **1320** inlet. The resistance can also be changed by injecting a gas or liquid fluid in selected portions of an orifice **1320** channel. After exiting the first die **1310a**, **1310b**, the extrudate passes through a converging bore **1365** in the nozzle section **1300c** of the die assembly **1300** prior to exiting the second orifice **1370**. A more detailed description of a co-injection die assembly is

presented in U.S. patent number 6,854,970 filed on July 18, 2003.

It will now be evident to those skilled in the art that there has been described herein an improved extruder die apparatus and method for imparting a distinct colored and/or flavored pattern into an extrudable food mass during extrusion. Moreover, an
5 injection nozzle having enhanced sealing characteristics and facilitating a non-invasive fluid connection to the improved extruder die apparatus has also been described. Further, it will be evident to those skilled in the art that an improved extruder die apparatus and method for complexly shaped food products having an enhanced quality of dimensional design aspect has been described herein. Although the invention hereof has been
10 described by way of a preferred embodiment, it will be evident that other adaptations and modifications can be employed without departing from the spirit and scope thereof. For example, multiple extrusion die assemblies may be utilized in a parallel arrangement by a single extruder device. The terms and expressions employed herein have been used as terms of description and not of limitation; and thus, there is no intent of excluding
15 equivalents, but on the contrary it is intended to cover any and all equivalents that may be employed without departing from the spirit and scope of the invention.

In sum, while this invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes, in form and detail may be made therein without departing from the spirit
20 and scope of the invention.

CLAIMS:

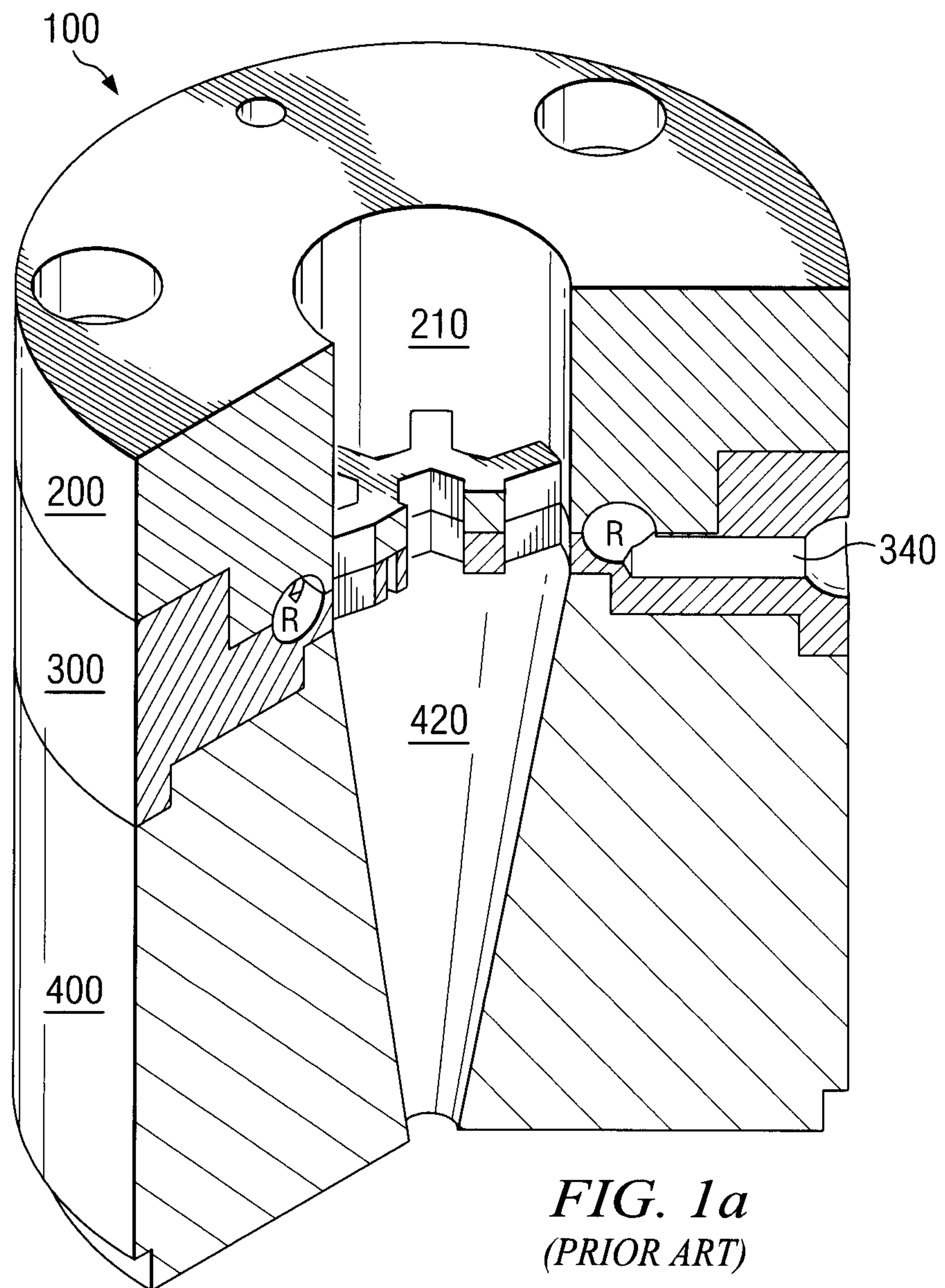
What is claimed is:

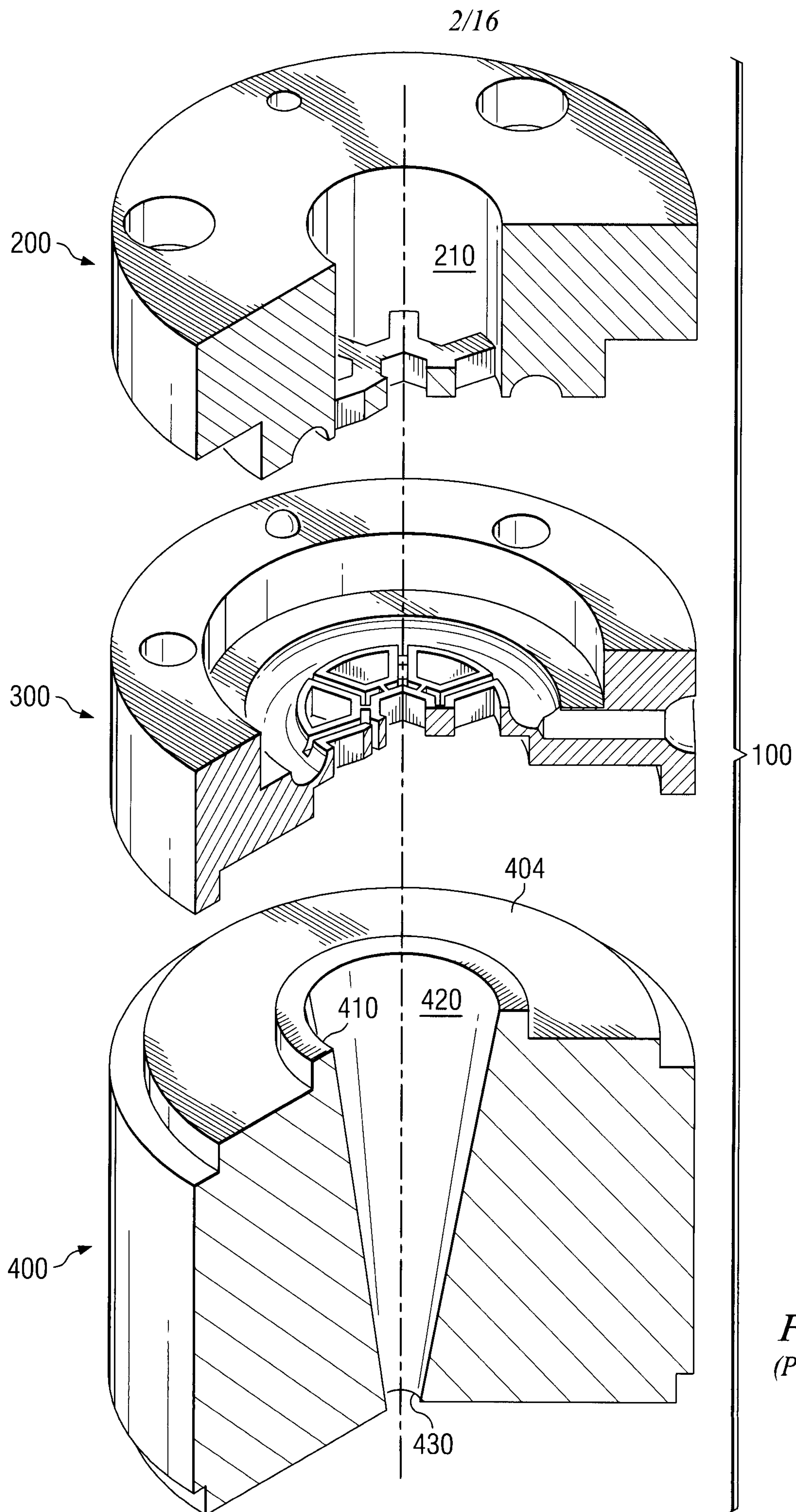
1. A method for making an extruded food product having a desired target shape said method comprising the steps of:
 - a) supplying a first die comprising at least one first die orifice wherein said first die orifice is configured to obtain said desired target shape;
 - b) supplying a second die having a second die orifice wherein said second die orifice is configured to obtain said desired target shape, wherein said second die is connected to said first die;
 - c) extruding a dough through said first die resulting in a first pressure drop into a bore disposed between the first die and second die thereby:
 - forming a pre-expanded dough rope by each said first die orifice from said dough;
 - flashing vapor from said pre-expanded dough rope;
 - restraining expansion in a radial direction with said bore disposed between the first die and second die; and
 - d) extruding said pre-expanded dough rope through said second die resulting in a second pressure drop thereby forming an extruded food product having said desired target shape.
2. The method of claim 1 wherein said first die at step a) further comprises a forming die element mated with an injection die insert.
3. The method of claim 2 wherein said injection die insert further comprises at least one capillary channel in communication with at least one injection port outlet.
4. The method of claim 3 wherein at least one flavor is injected through said injection port outlet.

5. The method of claim 3 wherein at least one color is injected through said injection port outlet.
6. The method of claim 3 wherein at least one food substance is injected through said injection port outlet.
7. The method of claim 1 wherein said first die orifice at step a) is selected from the shapes consisting of square, oval, rectangle, circle, semi-circle, triangle, trapezoid, crescent, and combinations thereof.
8. The method of claim 1 wherein said target shape at step a) is selected from the group consisting of letters, plants, animals, shapes, and combinations thereof.
9. The method of claim 1 wherein said first die orifice at step a) comprises a varying intra-channel length.
10. The method of claim 1 further comprising a plurality of first die orifices at step a).
11. The method of claim 10 wherein at least one of said plurality of said first die orifices at step a) comprises a different cross sectional area than at least one remaining first die orifice.
12. The method of claim 10 wherein said at least one of said plurality of said first die orifices at step a) comprises a different channel length than at least one remaining first die orifice.
13. The method of claim 10 wherein at least one of said plurality of said first die orifices at step a) comprises a varying intra-channel length.

14. The method of claim 10 wherein at least one of said plurality of said first die orifices at step a) comprises a shape that is different from the shape of the remaining said first die orifices, and wherein said shapes are selected from the group of shapes consisting of square, oval, rectangle, circle, semi-circle, triangle, trapezoid, crescent, and combinations thereof.
15. The method of claim 10 wherein at least one of said plurality of said first die orifices at step a) comprises a different coefficient of friction.
16. The method of claim 1 wherein said second die orifice at step b) comprises a step change.
17. The method of claim 1 wherein said second die at step b) comprises a friction coefficient wherein said friction coefficient is chosen based upon desired texture.
18. The method of claim 1 wherein the first pressure drop at step c) creates separation and migration of at least one food substance in said dough in said bore.
19. The method of claim 1 wherein said bore at step c) comprises a bore configuration wherein said bore configuration is selected from the group consisting of a parallel configuration, a divergent configuration, a convergent configuration, and combinations thereof.
20. The method of claim 1 wherein substantially no radial expansion occurs during the extruding at step d).
21. The method of claim 1 further comprising the step of:
 - e) cutting said extruded food product with a rotating face cutter.

1/16





3/16

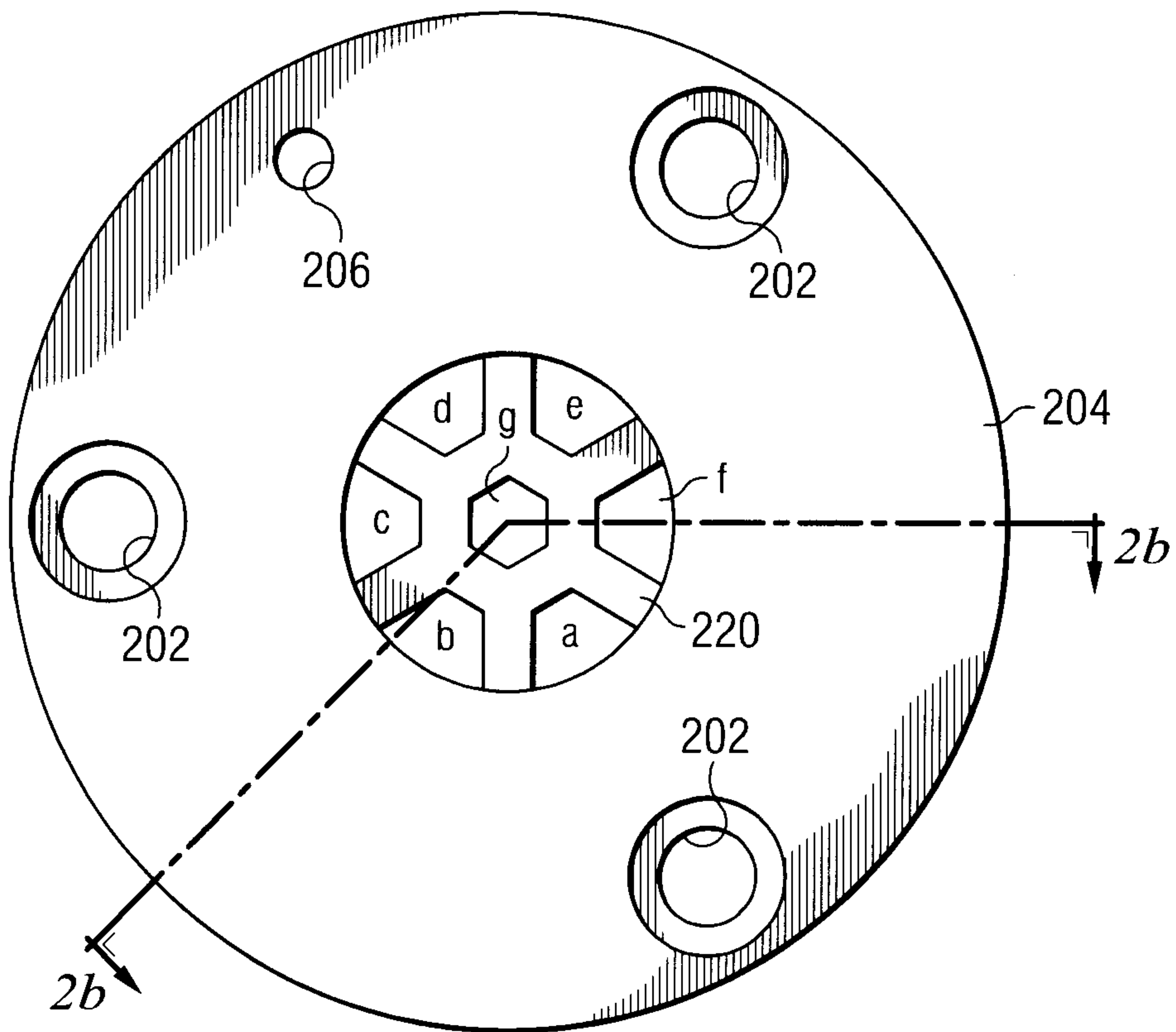


FIG. 2a
(PRIOR ART)

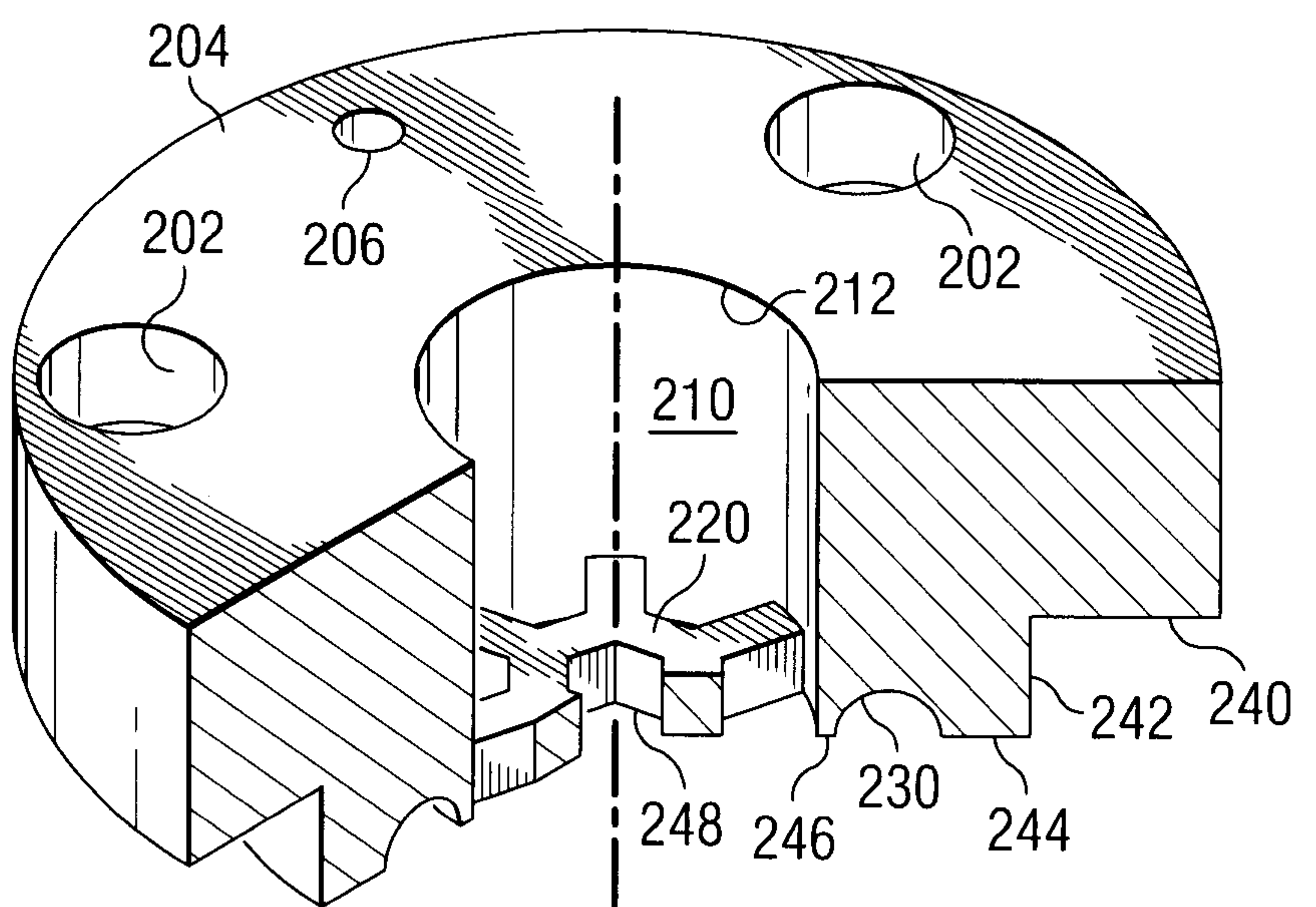


FIG. 2b
(PRIOR ART)

4/16

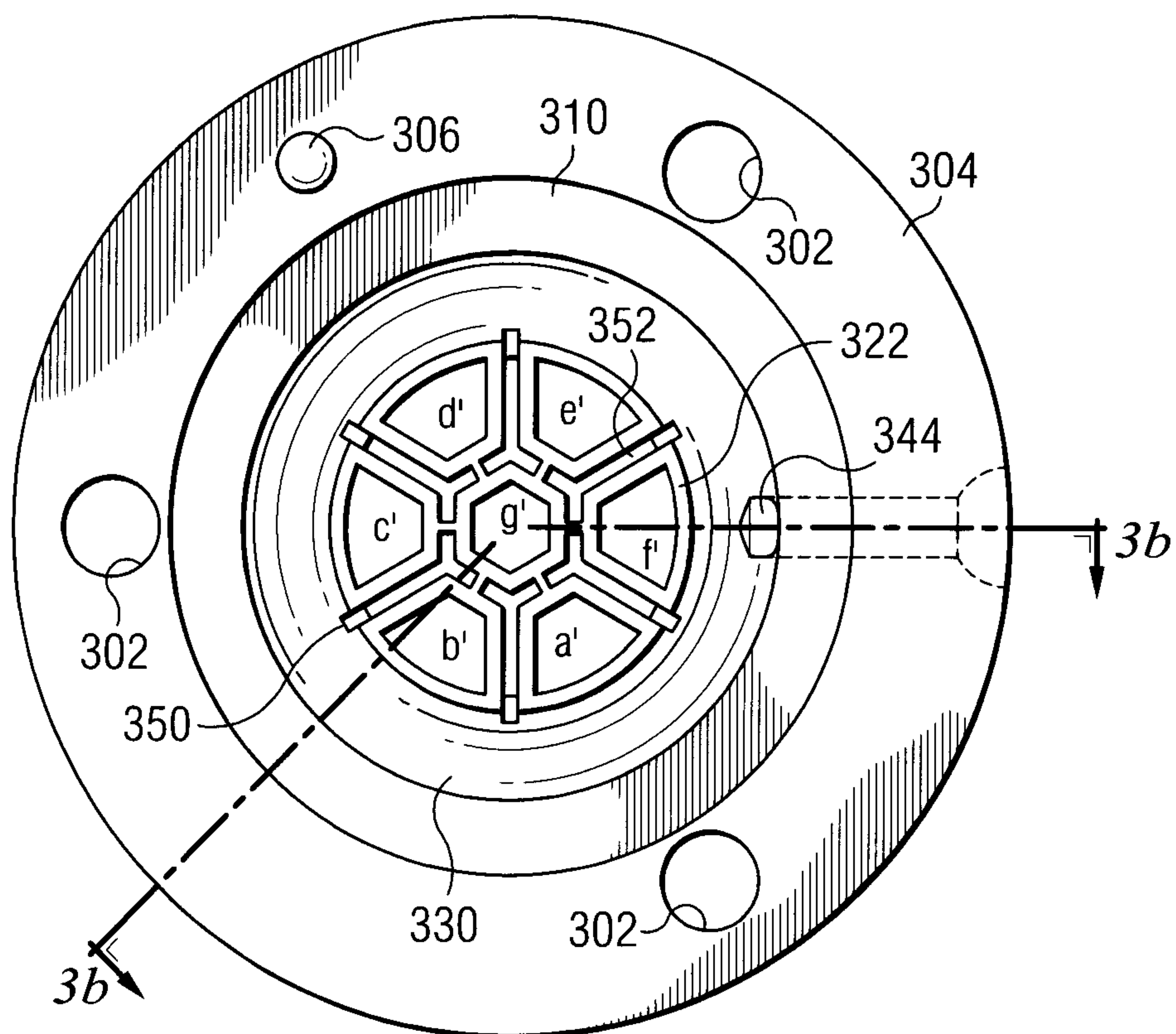


FIG. 3a
(PRIOR ART)

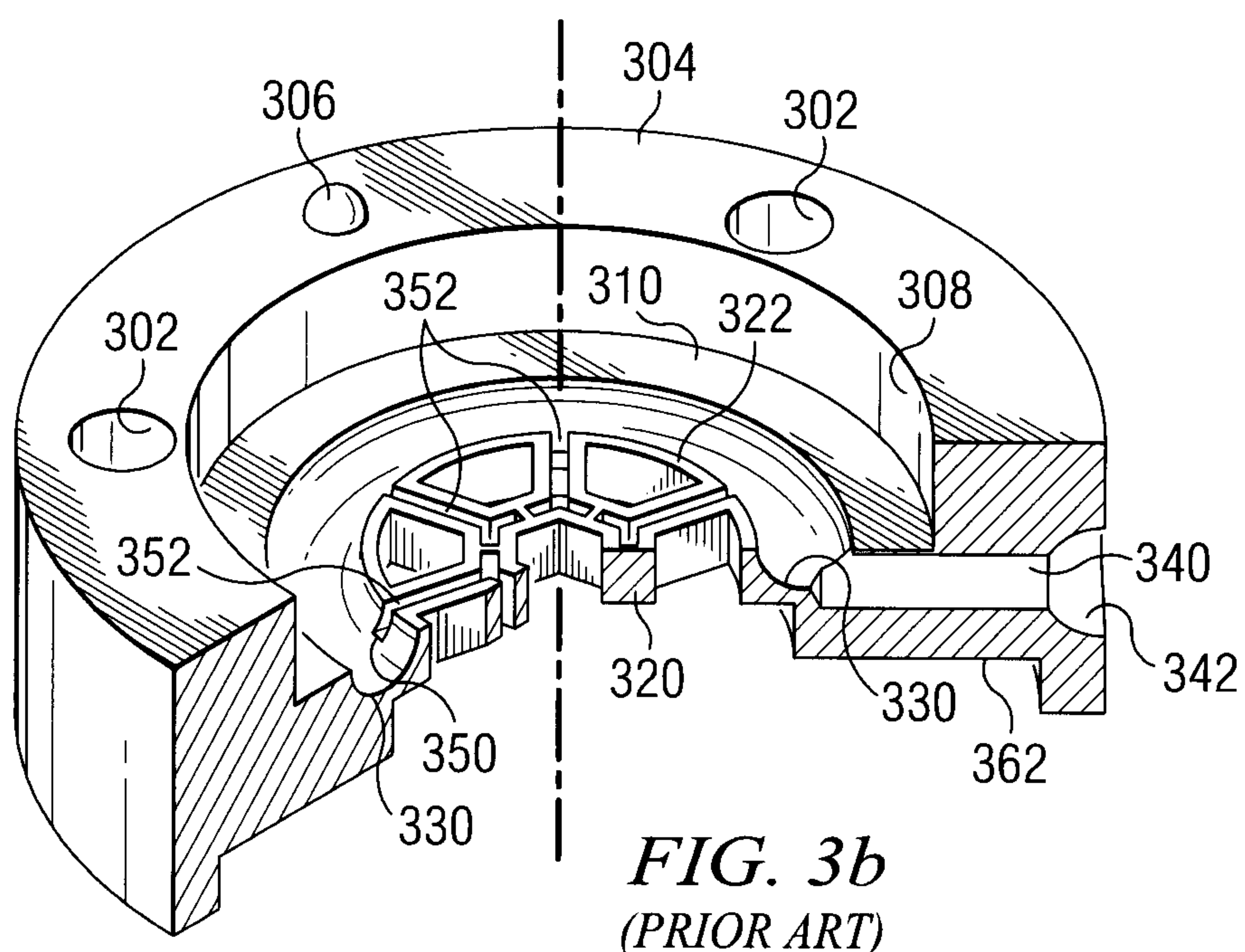
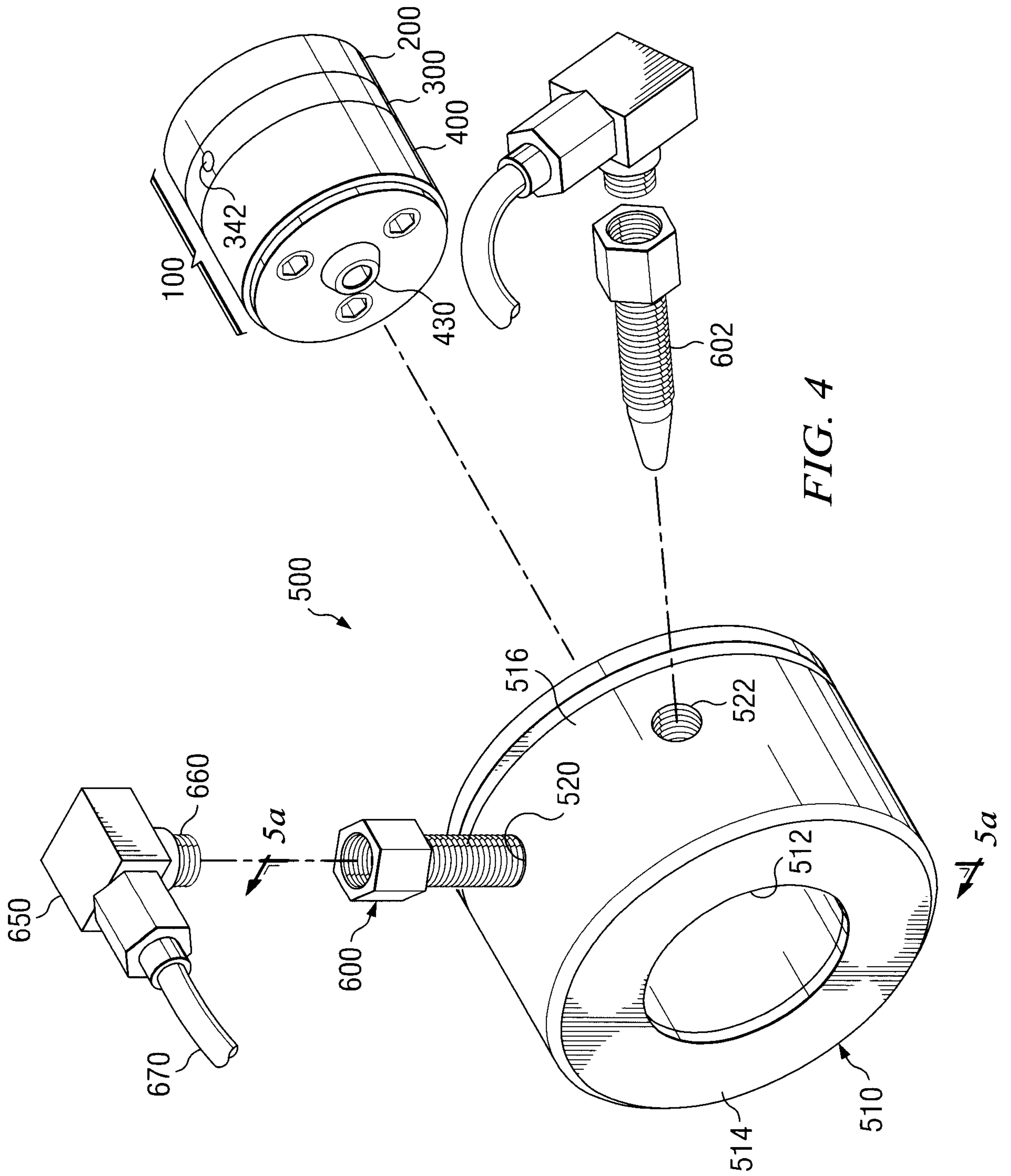


FIG. 3b
(PRIOR ART)

5/16



6/16

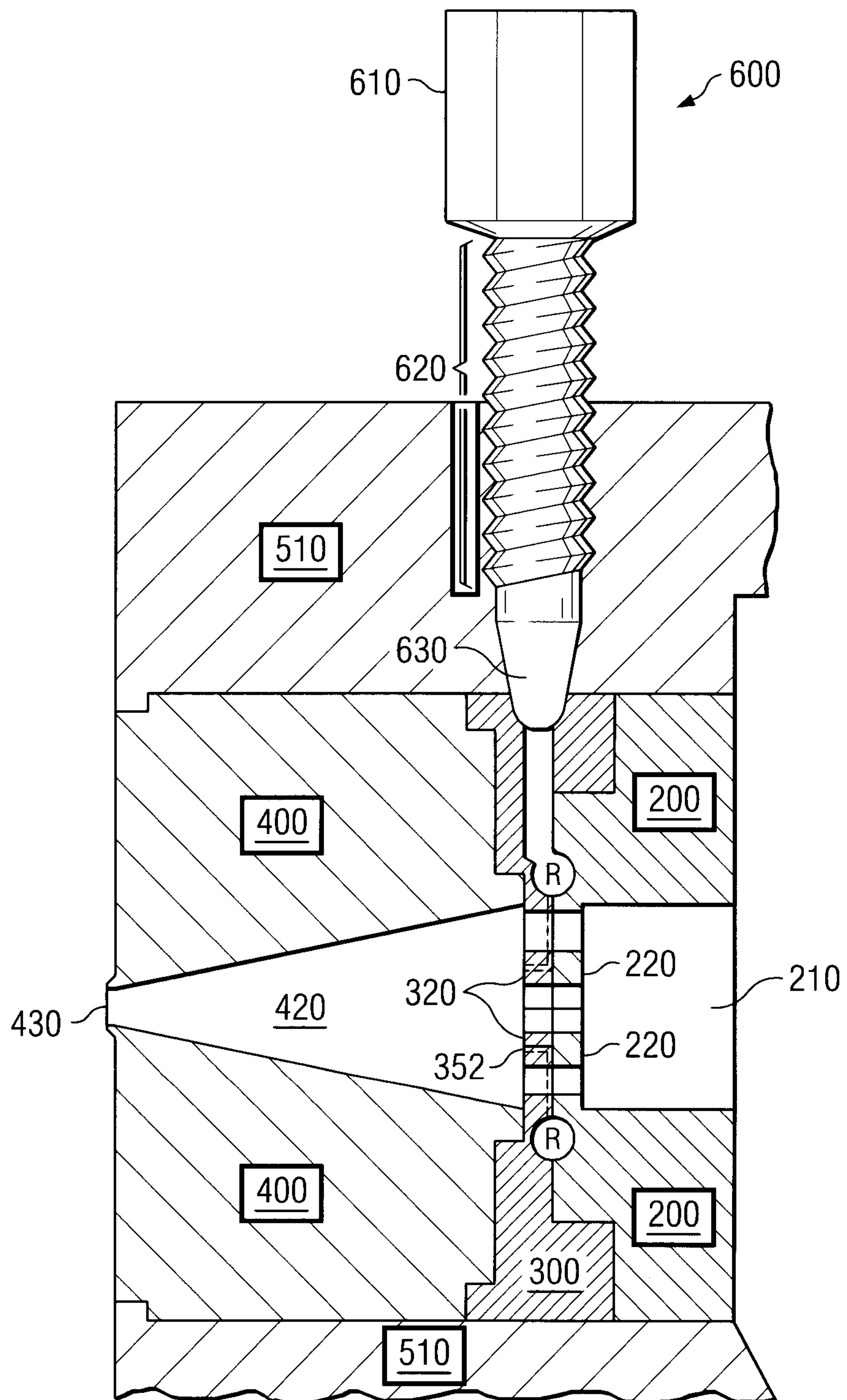


FIG. 5a

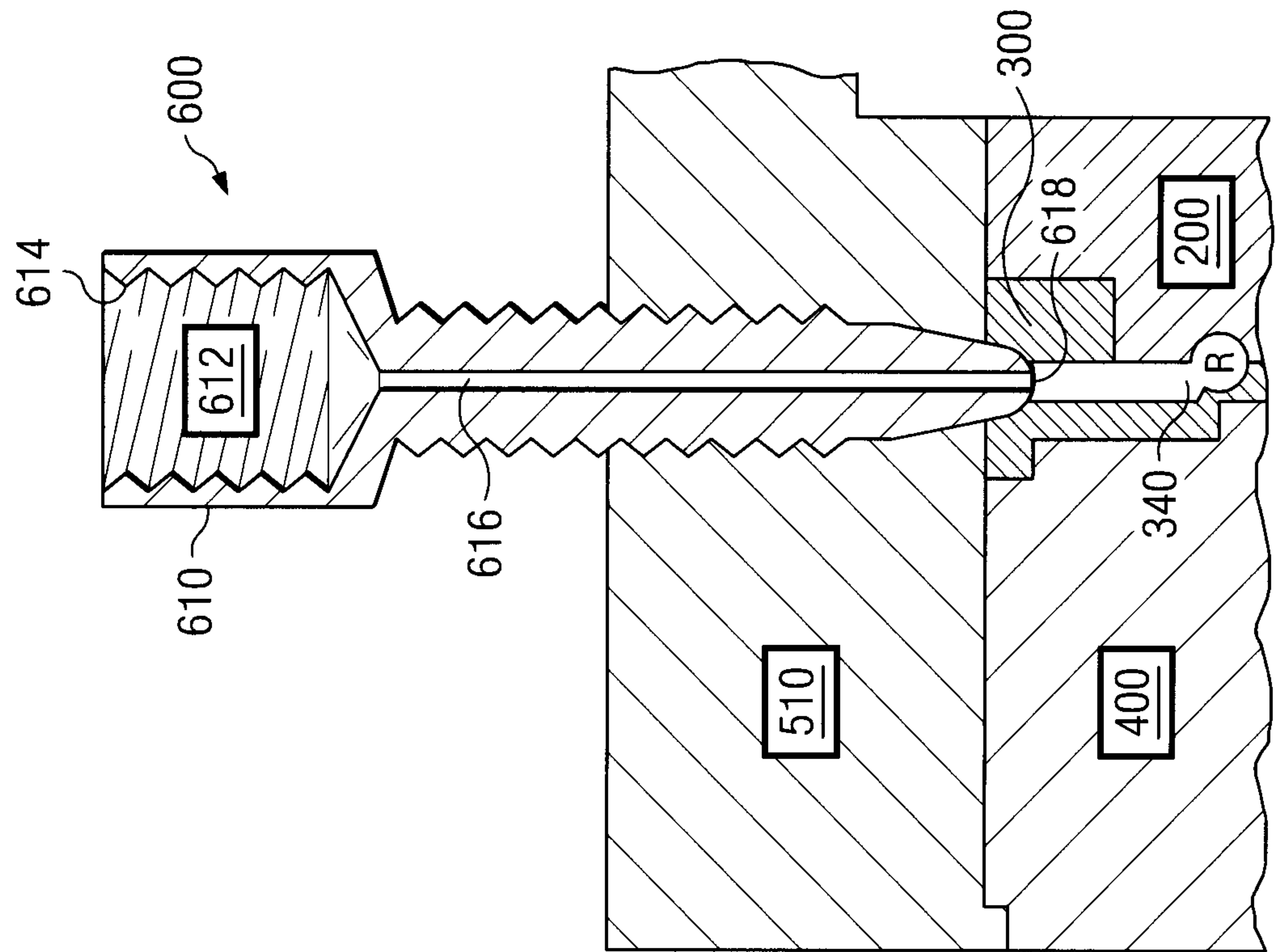


FIG. 5c

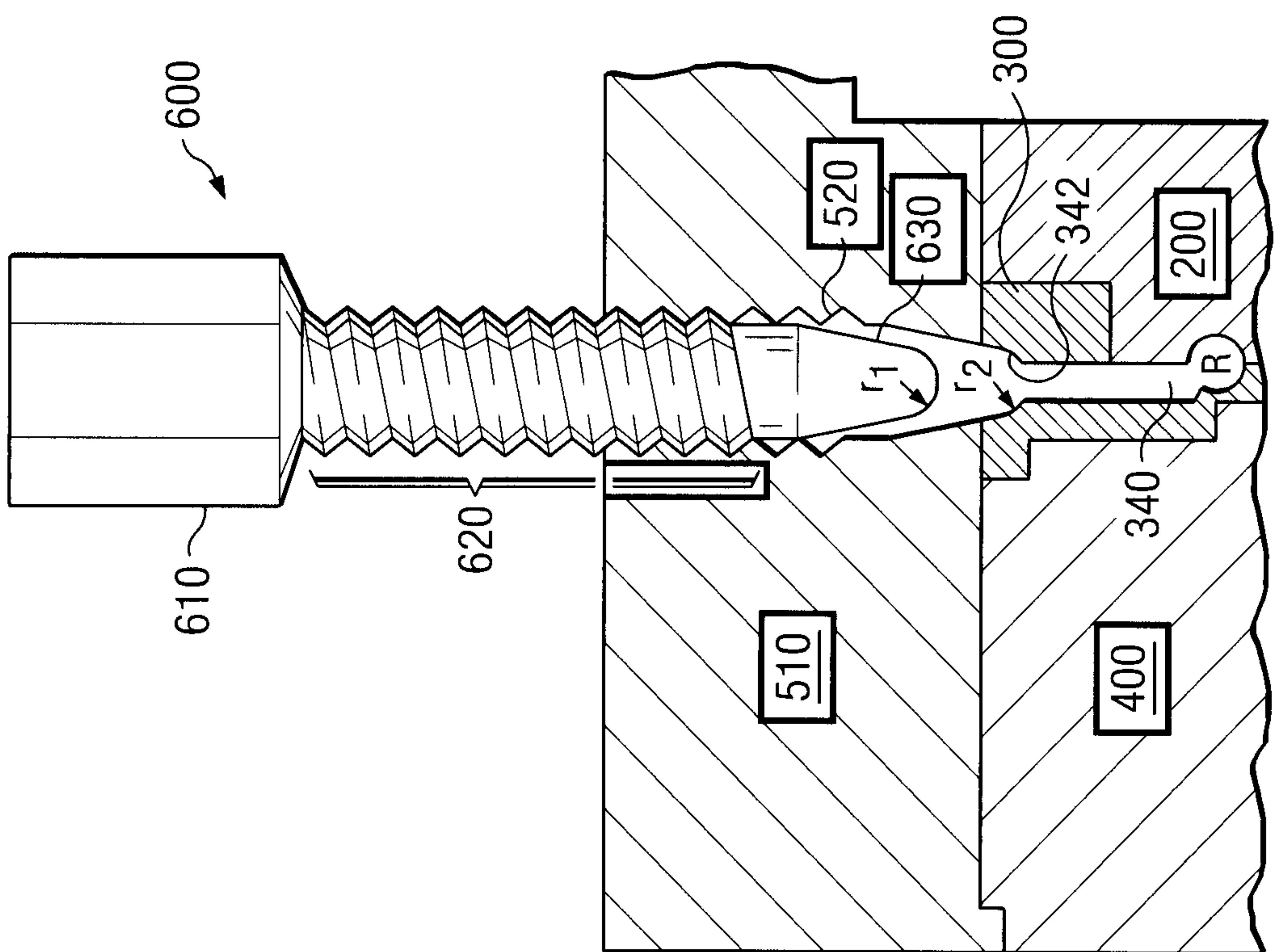


FIG. 5b

8/16

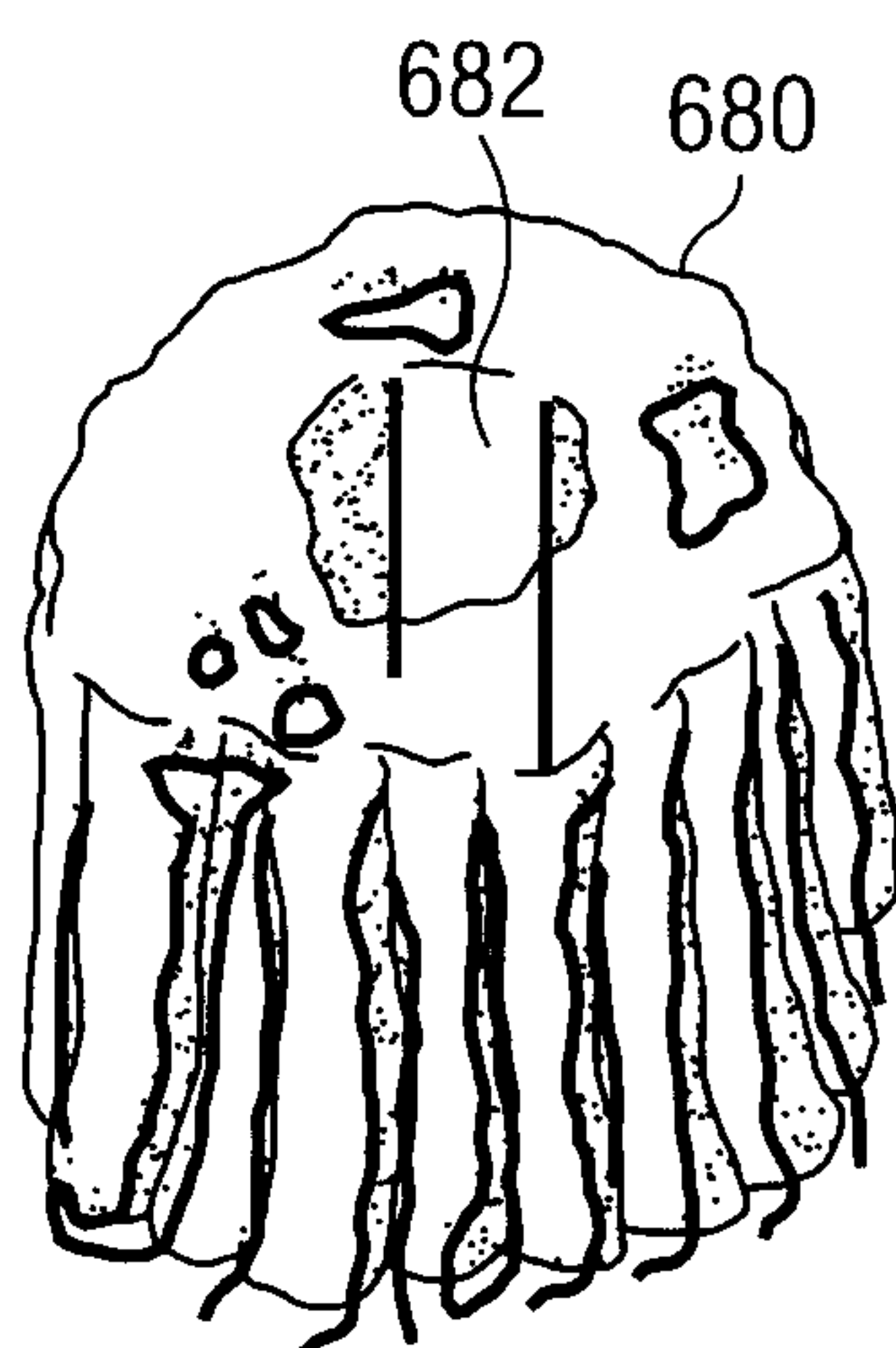
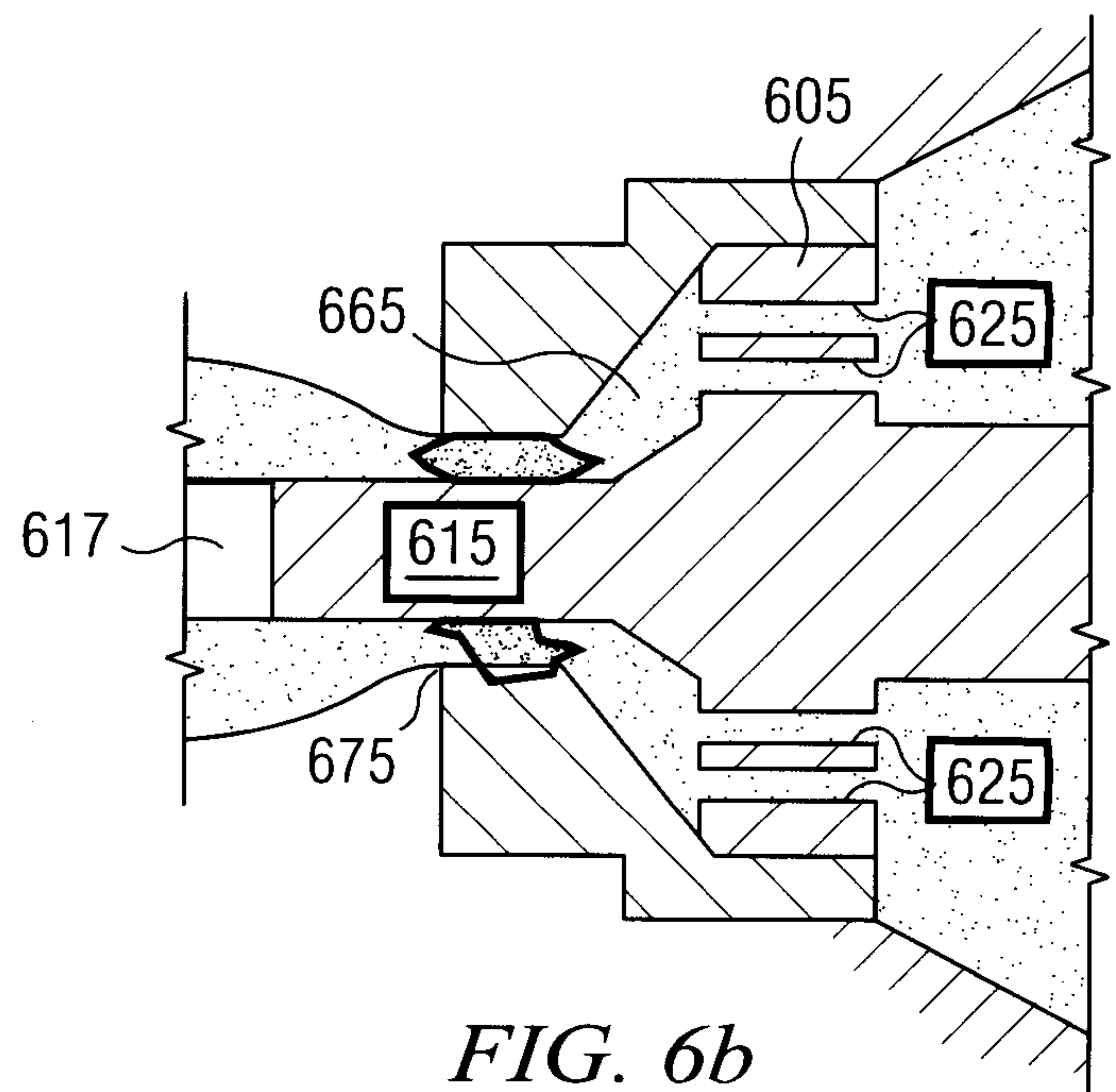
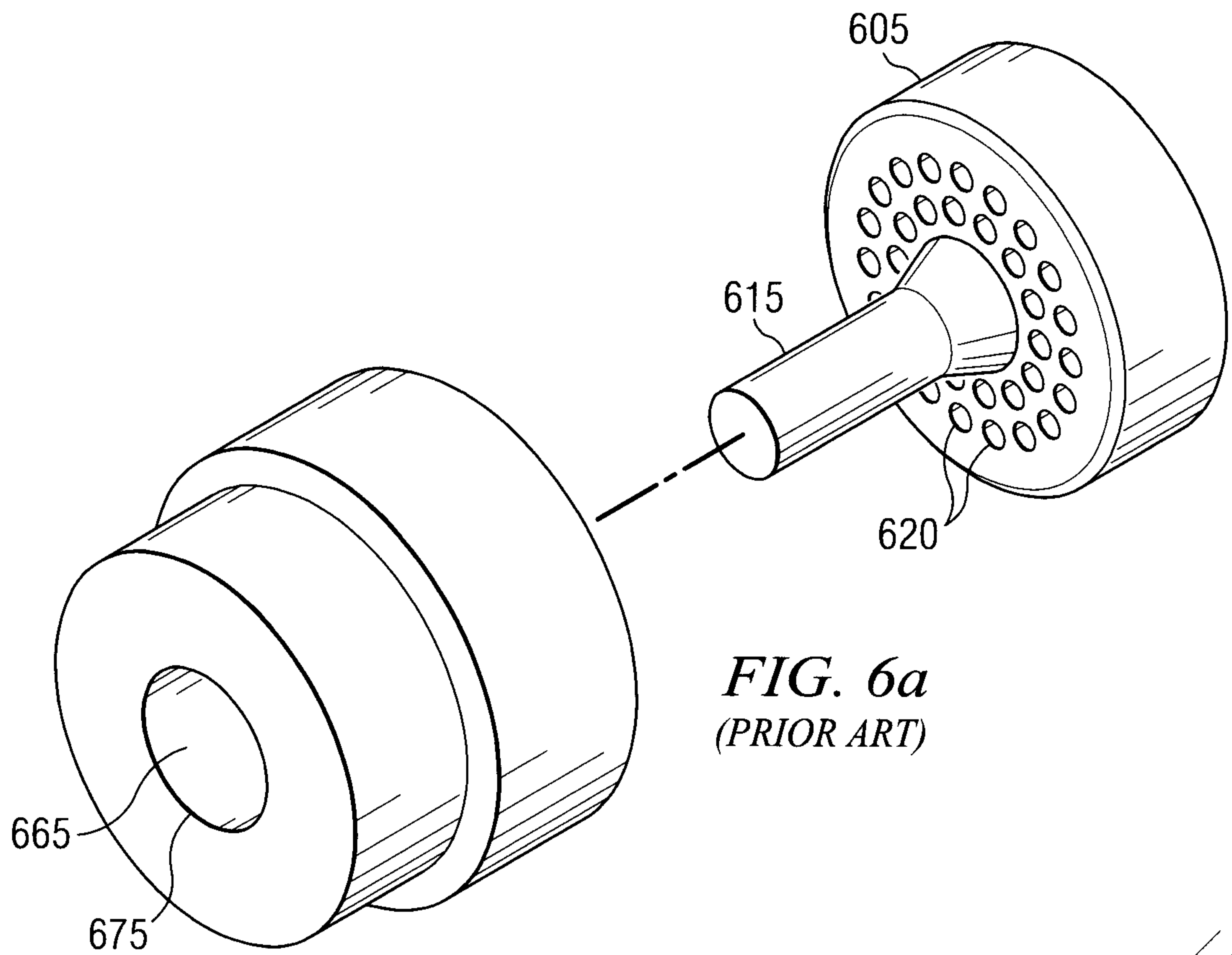


FIG. 6c
(PRIOR ART)

9/16

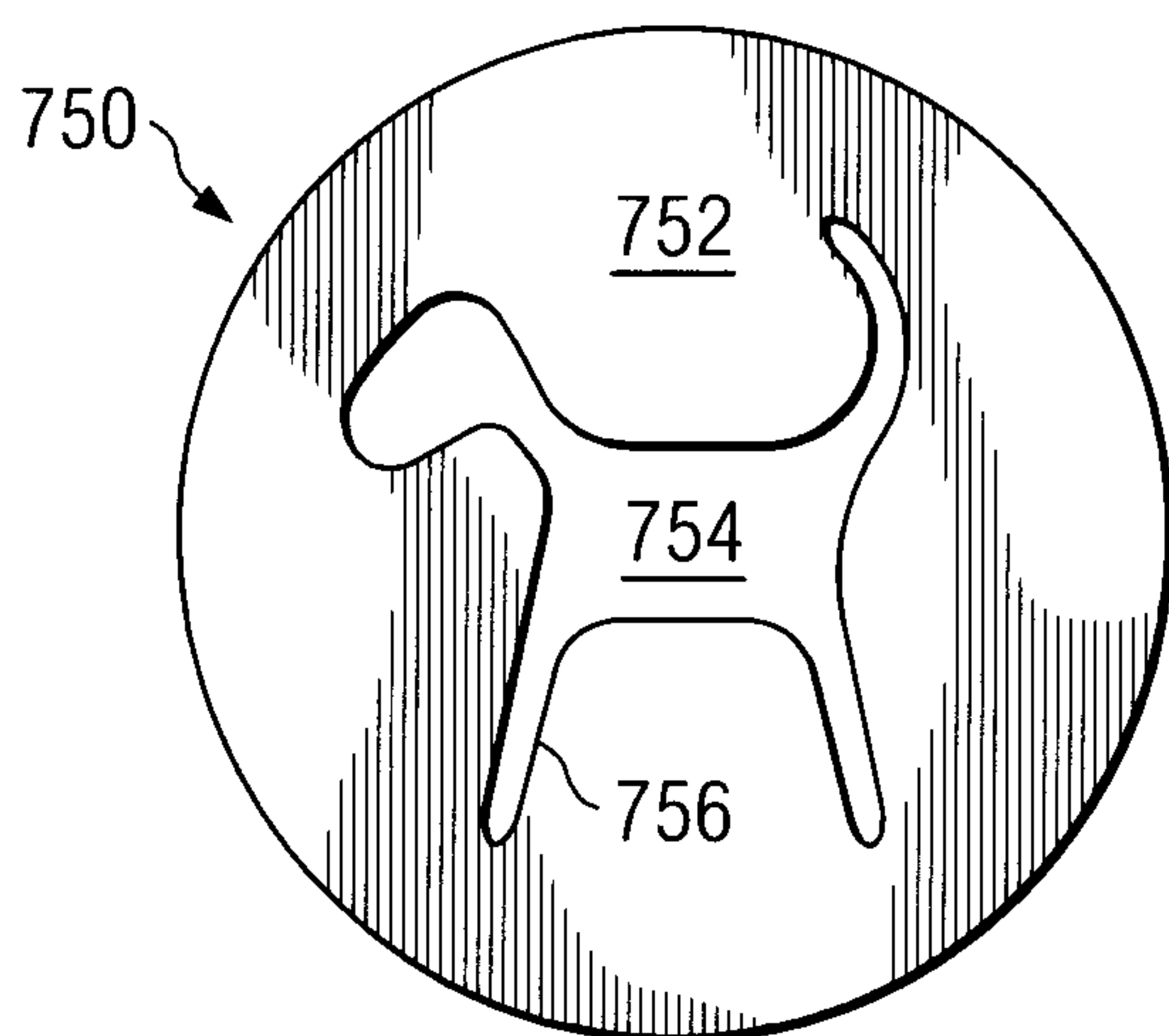


FIG. 7a
(PRIOR ART)

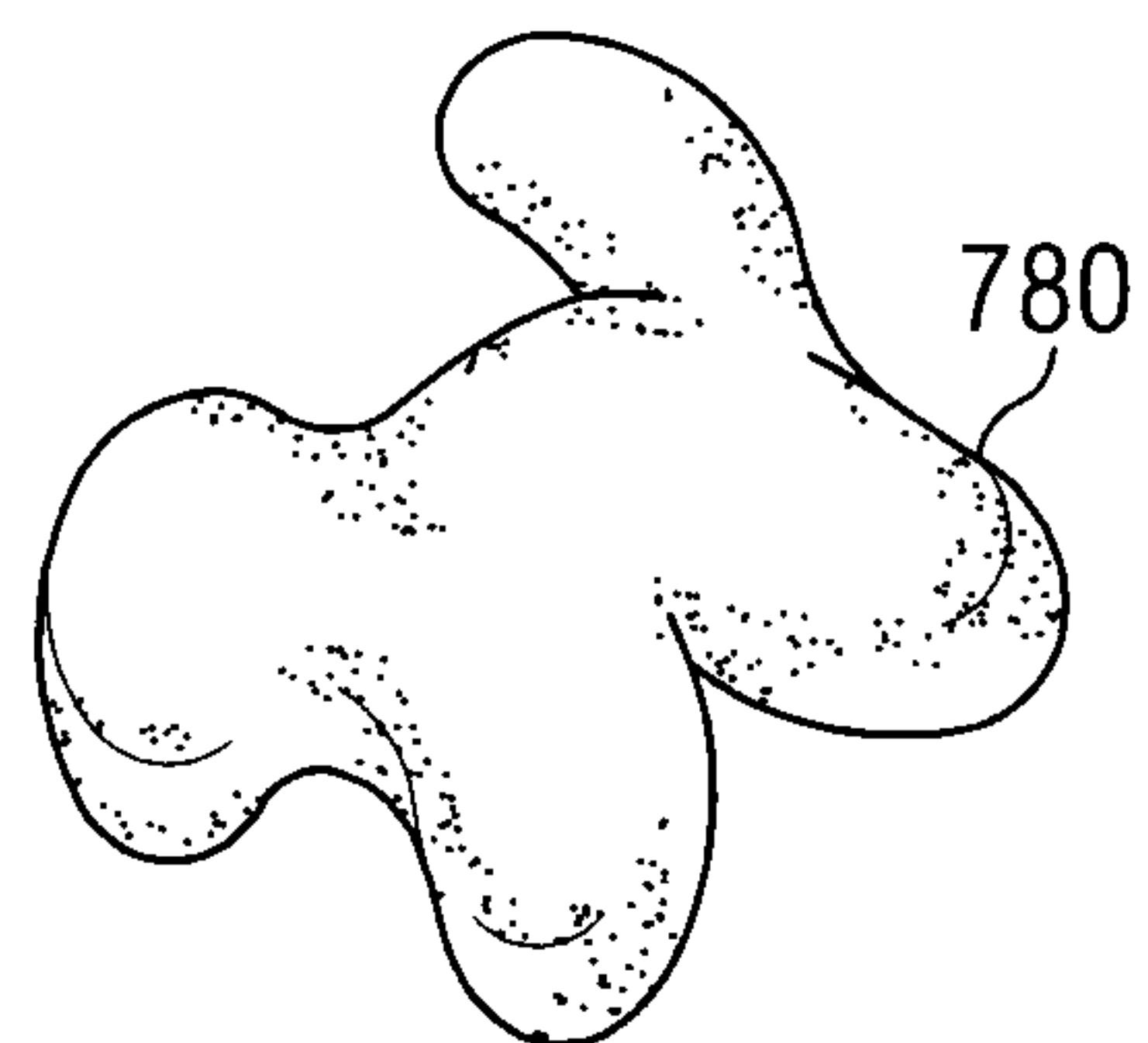


FIG. 7b
(PRIOR ART)

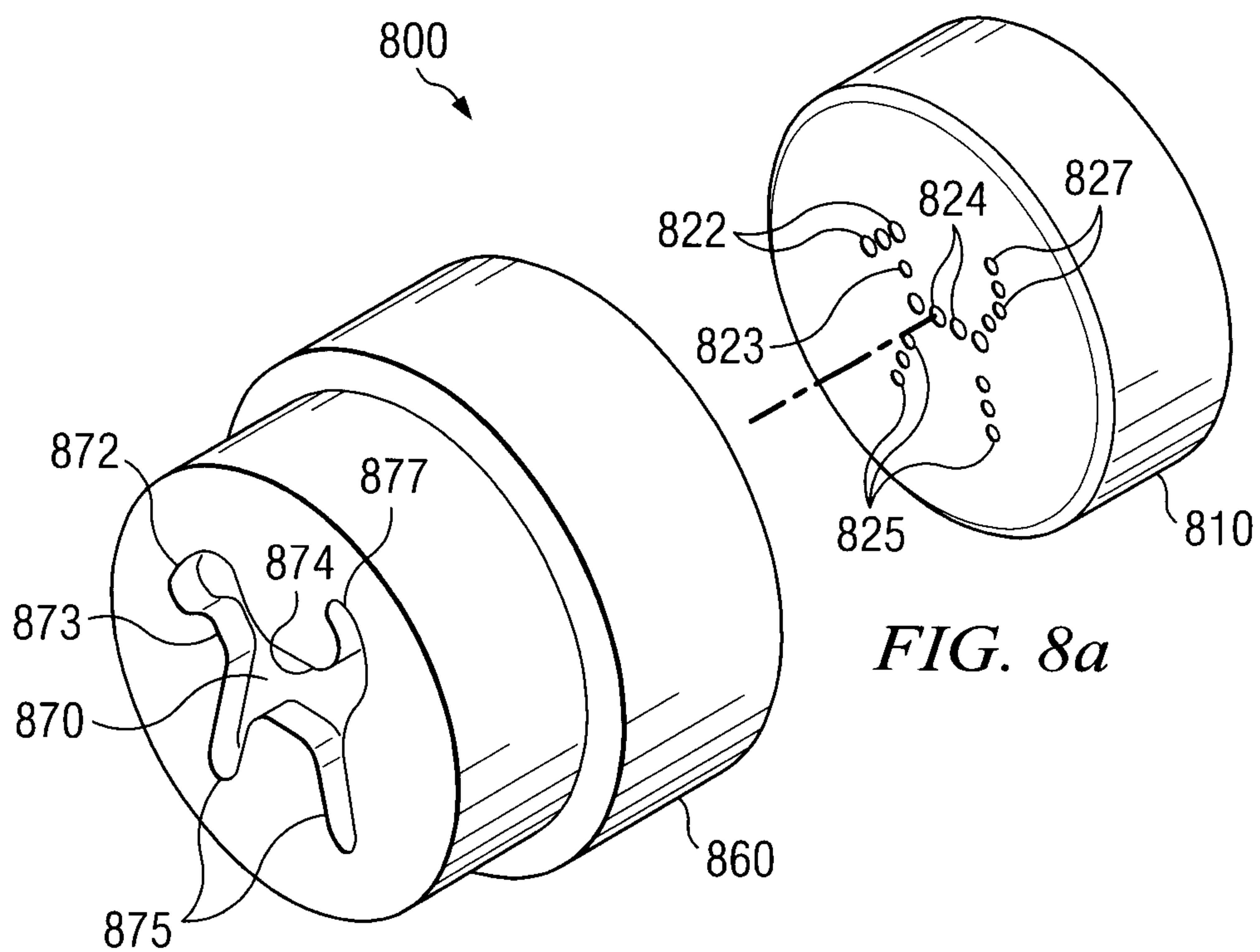
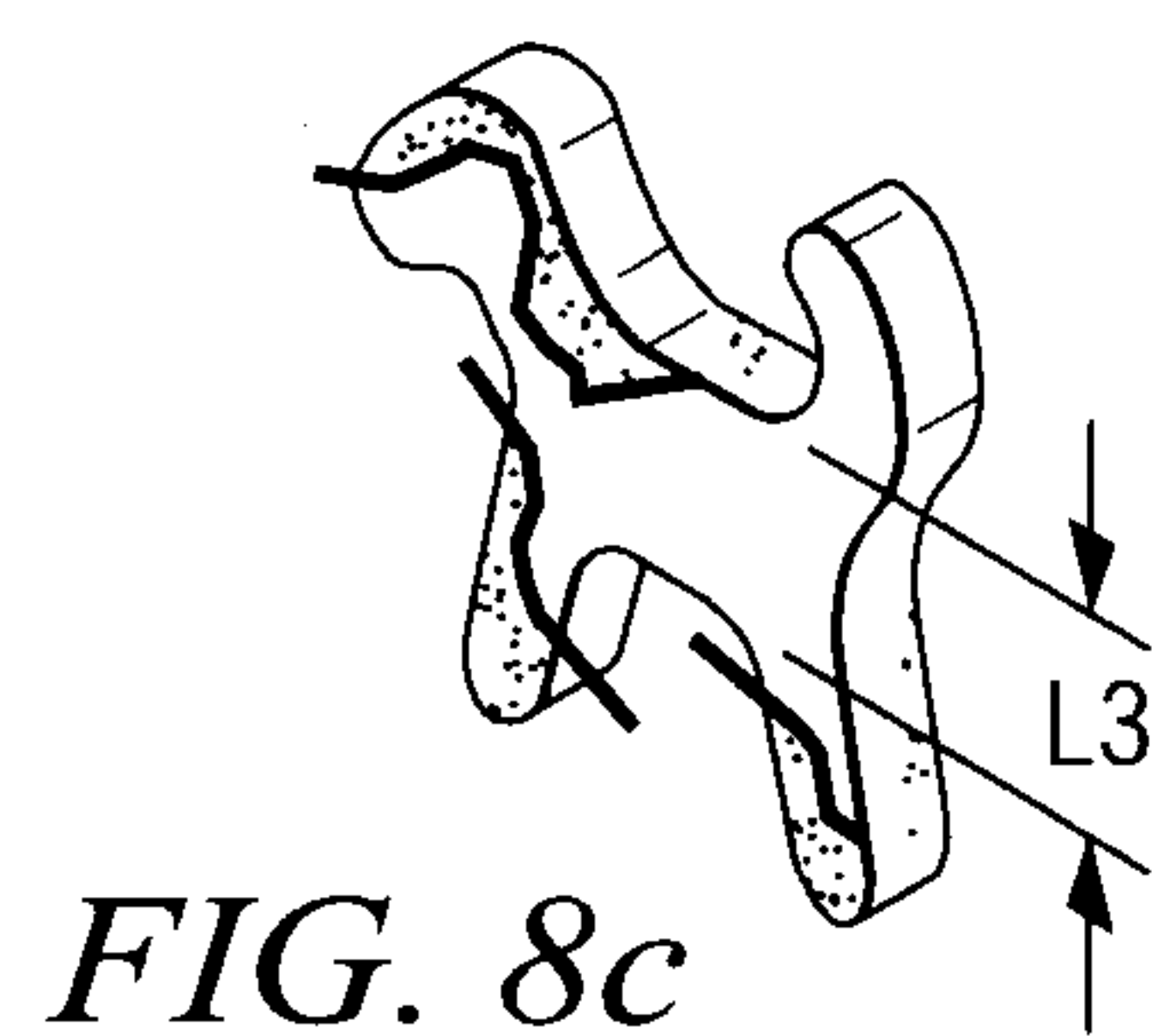
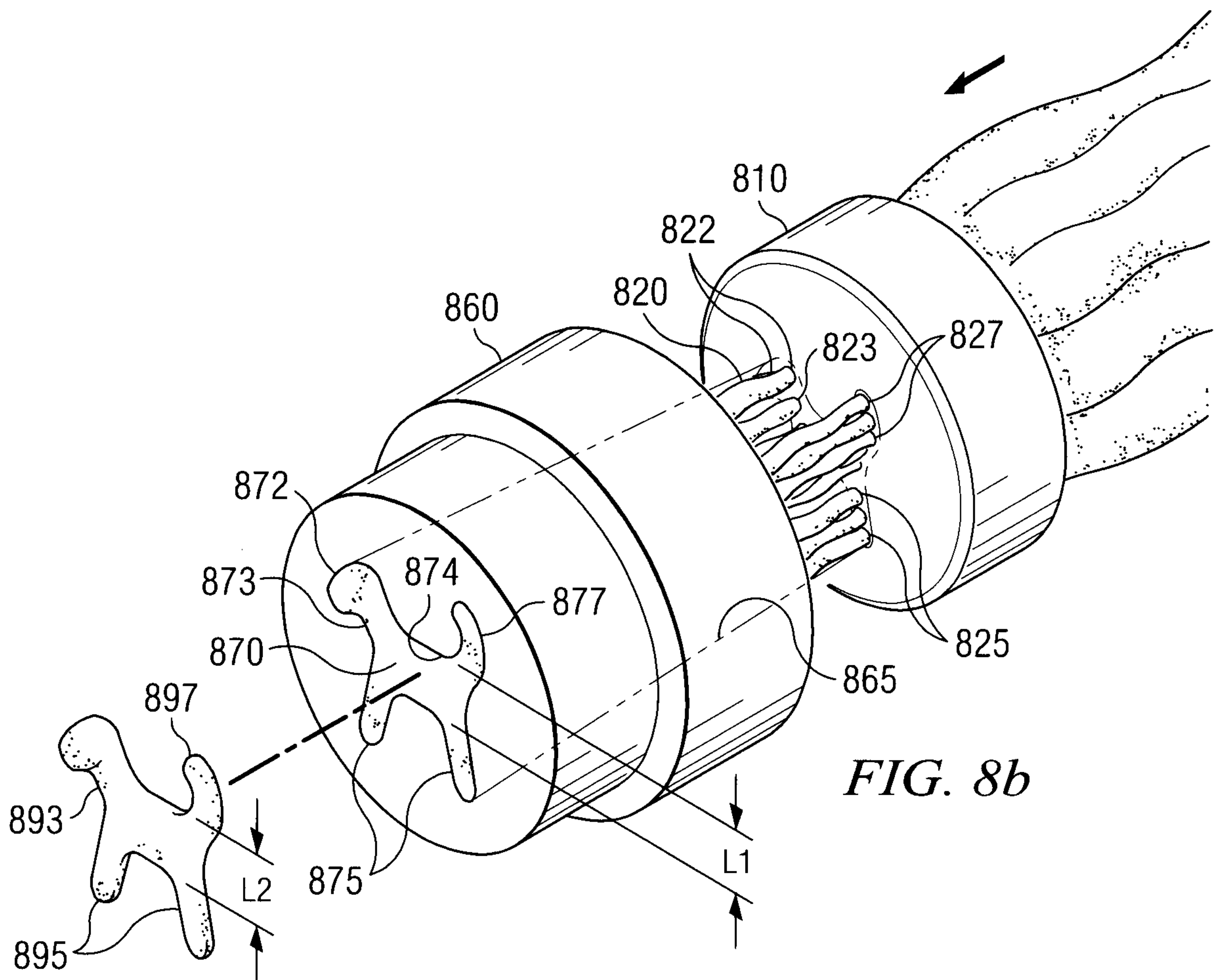


FIG. 8a

10/16



11/16

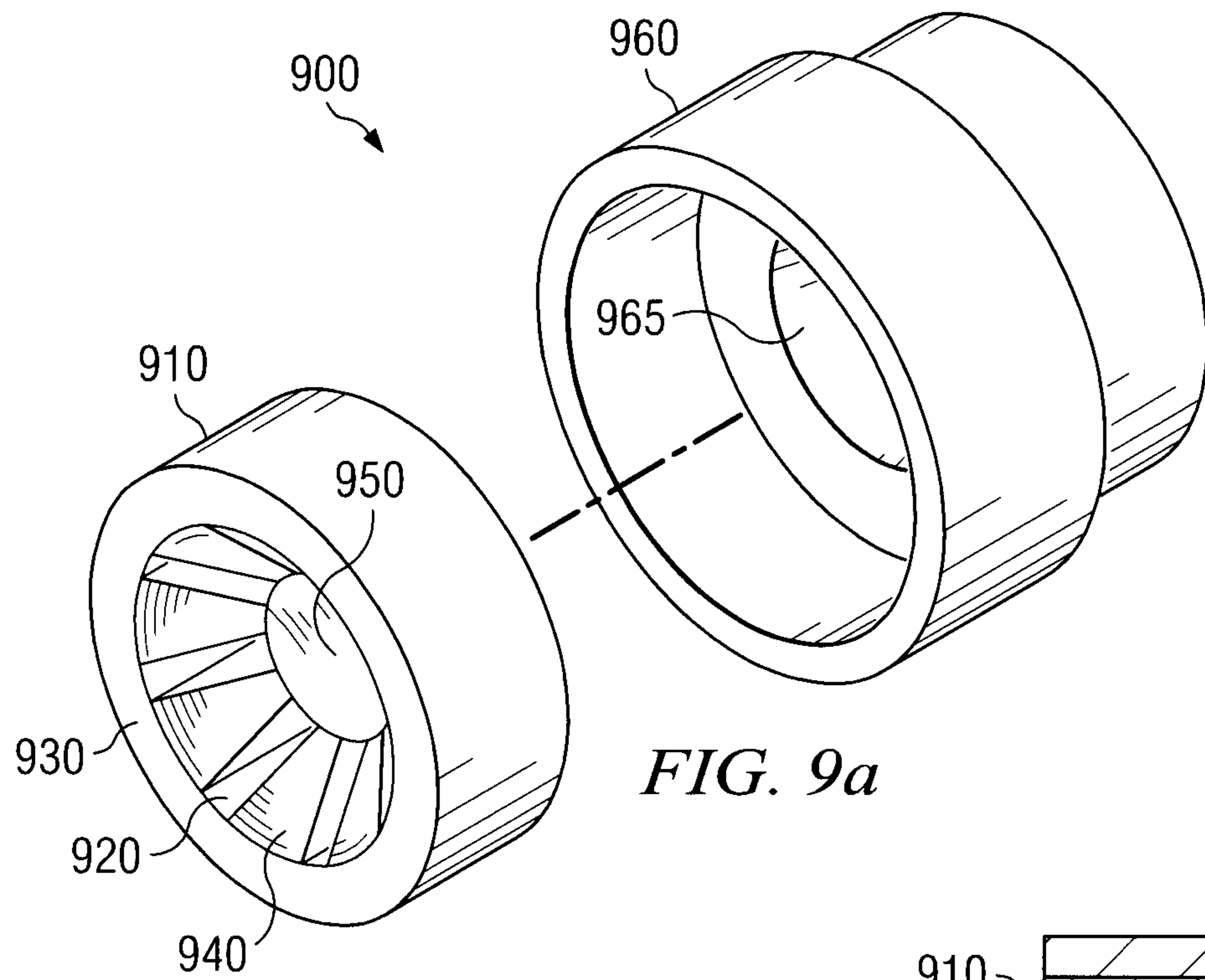


FIG. 9a

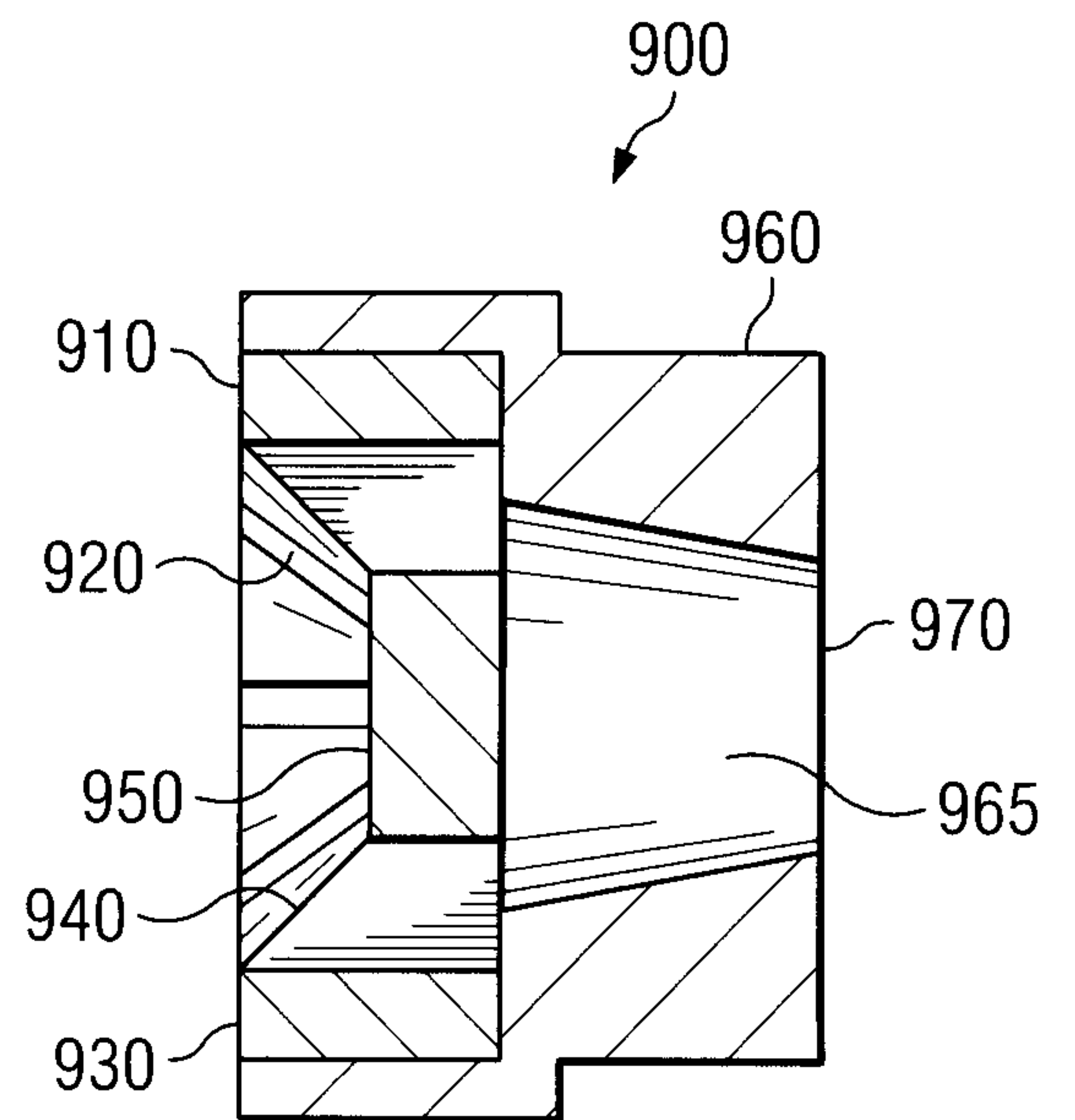


FIG. 9b

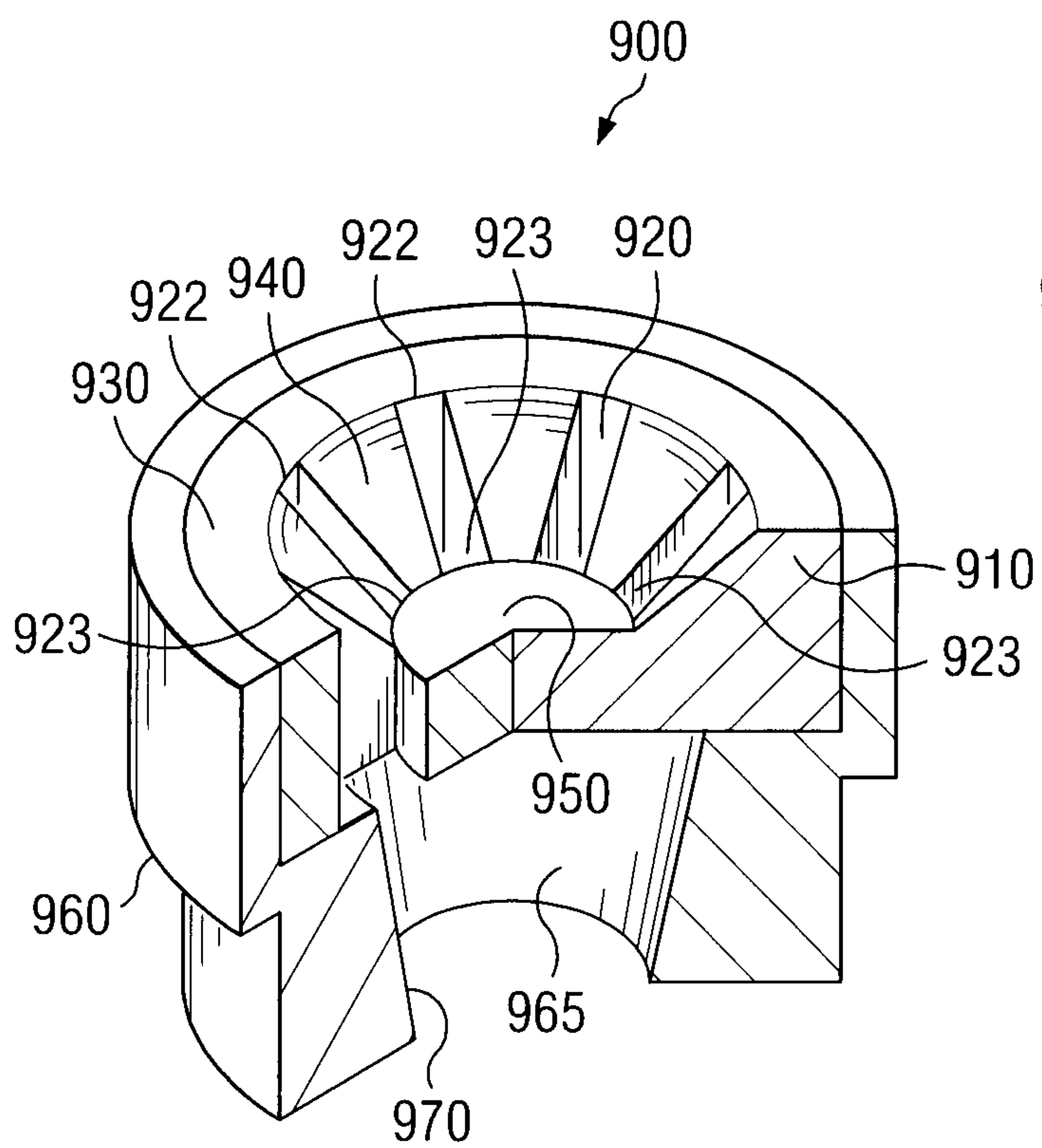


FIG. 9c

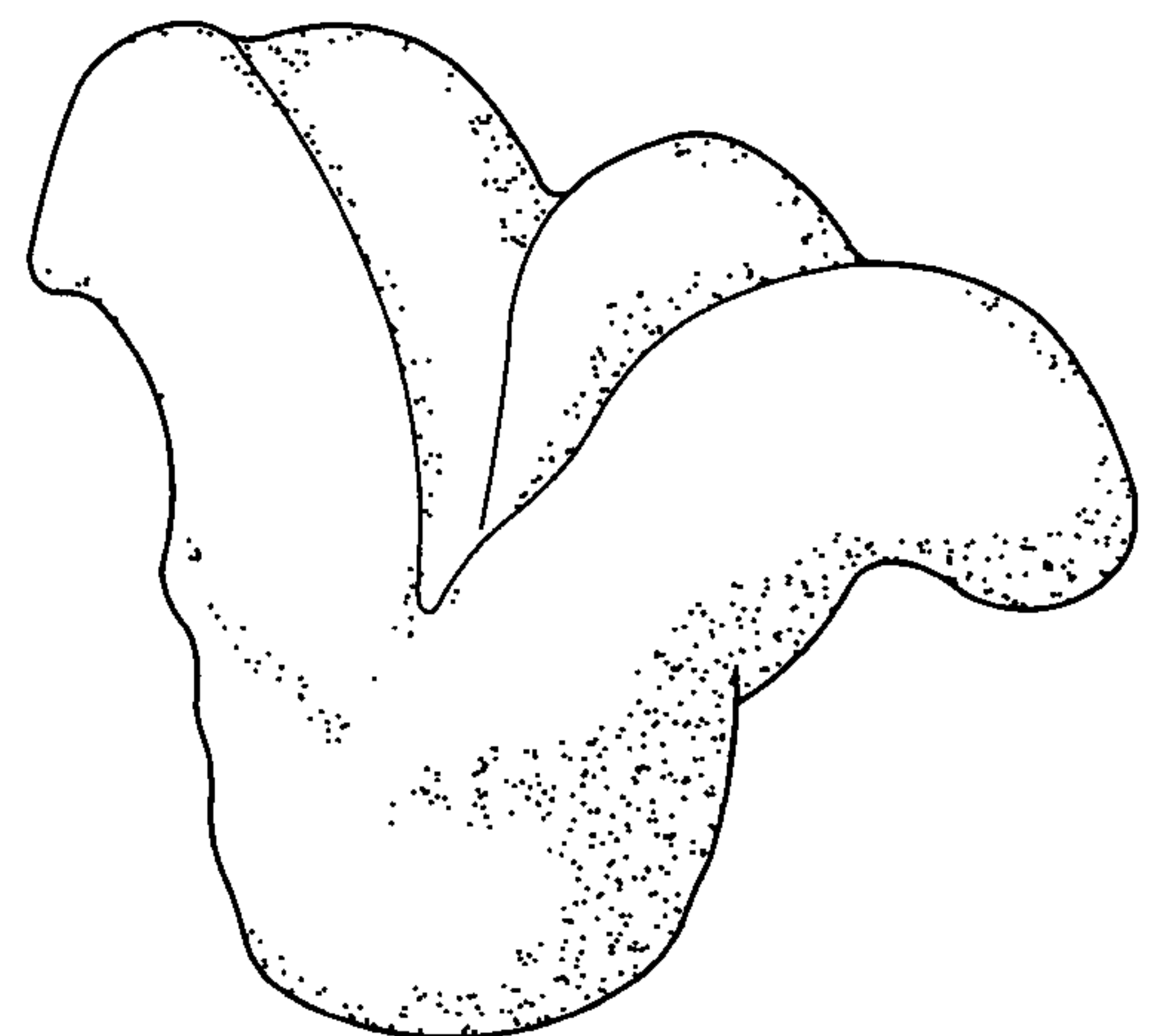
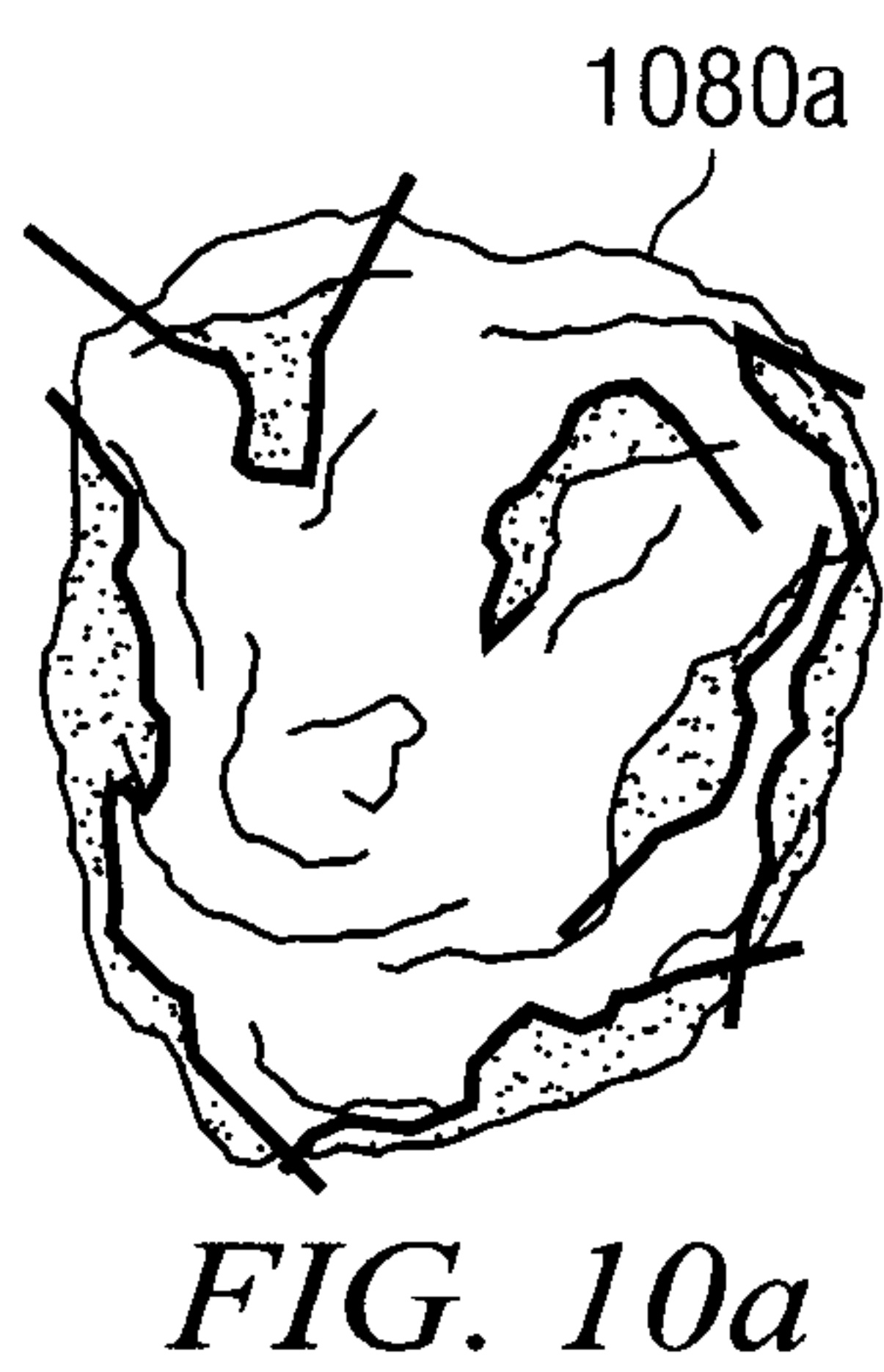
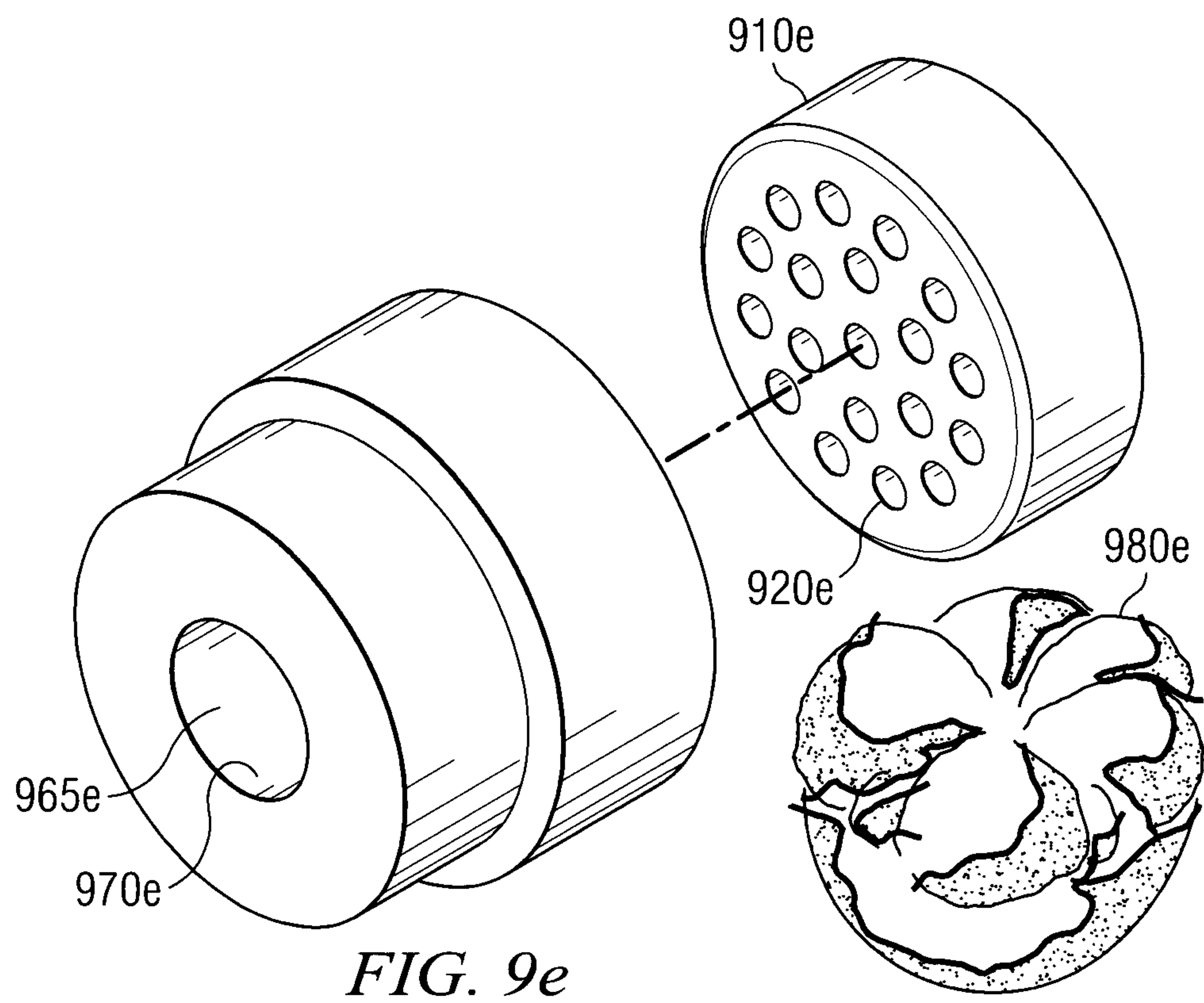


FIG. 9d

12/16



13/16

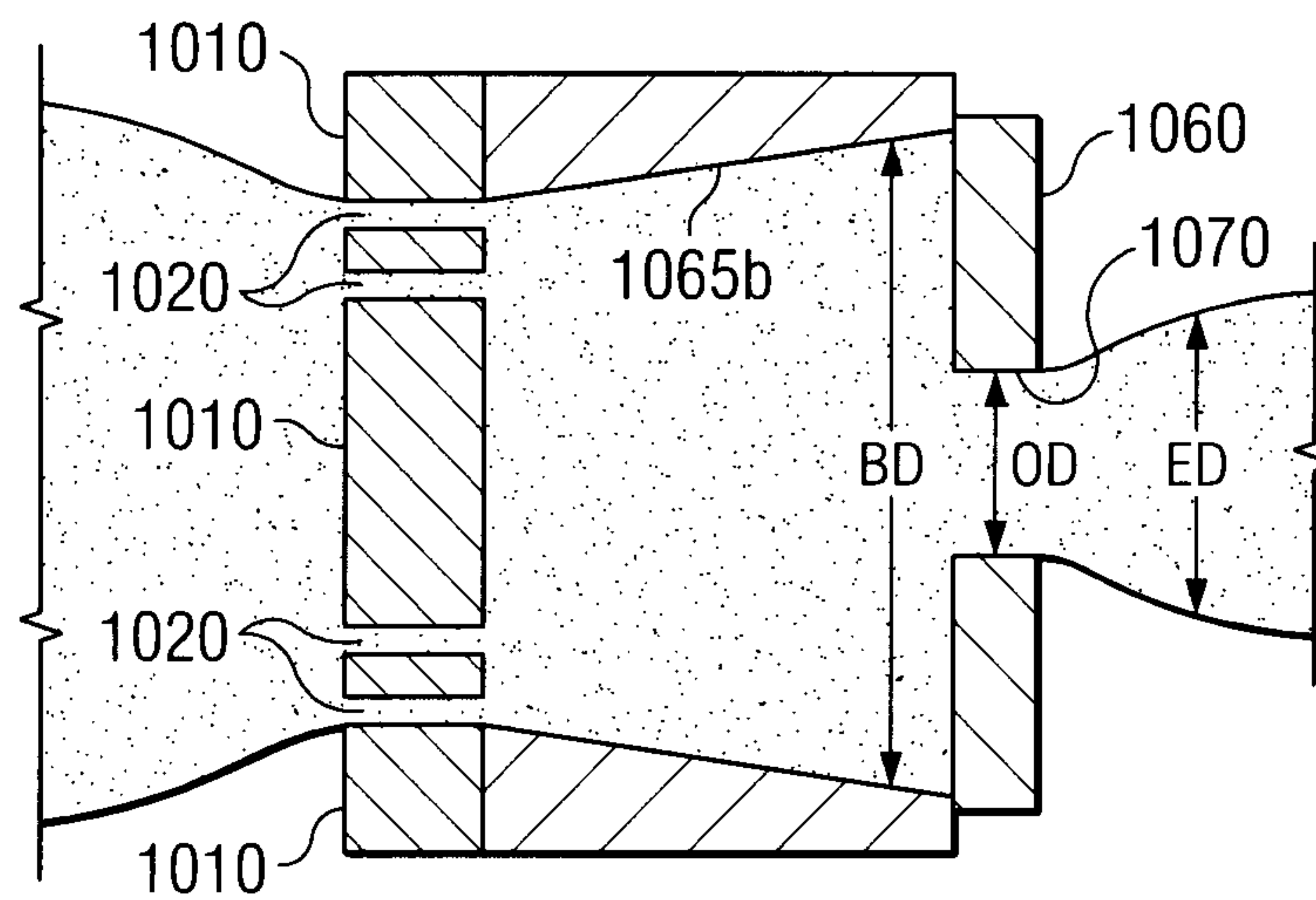


FIG. 10b

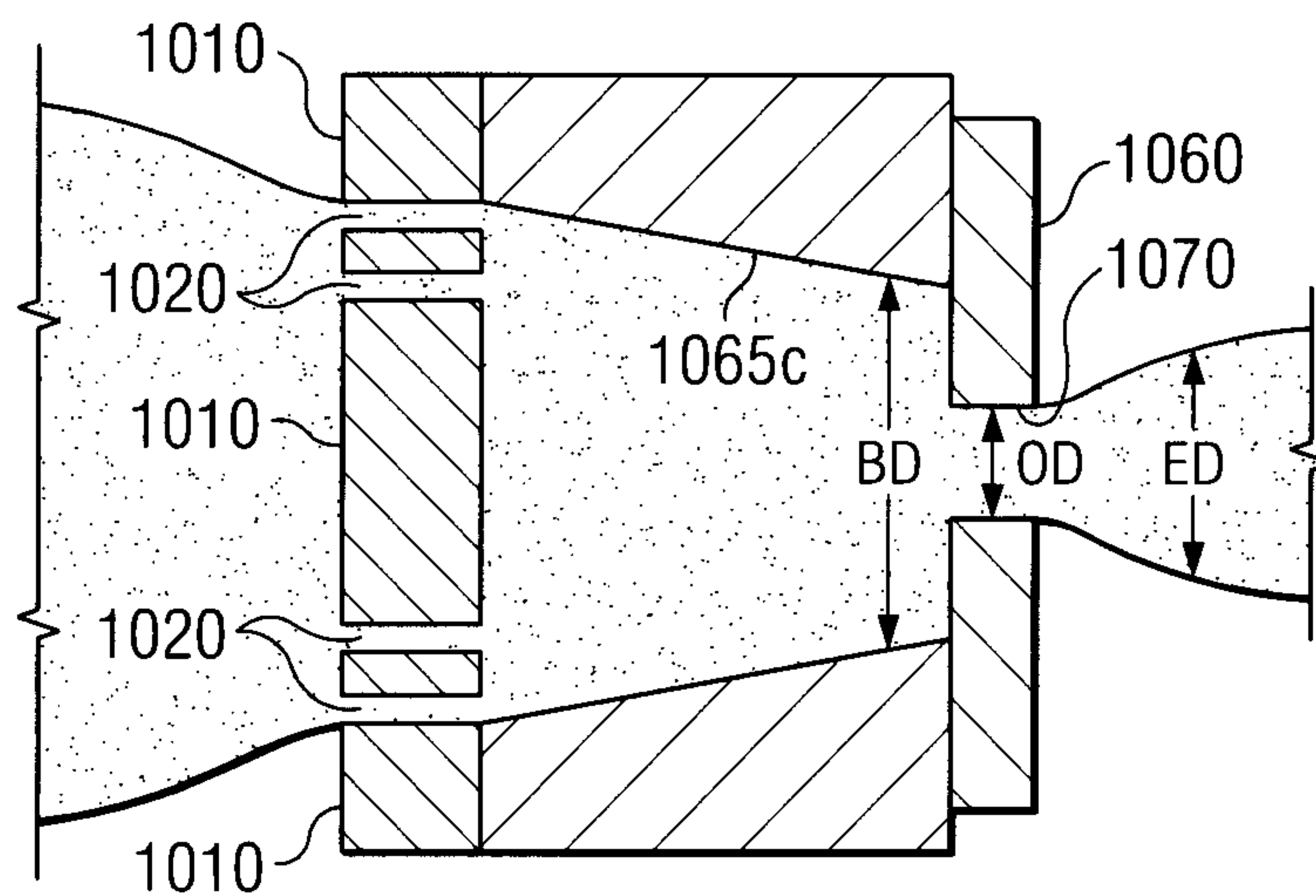


FIG. 10c

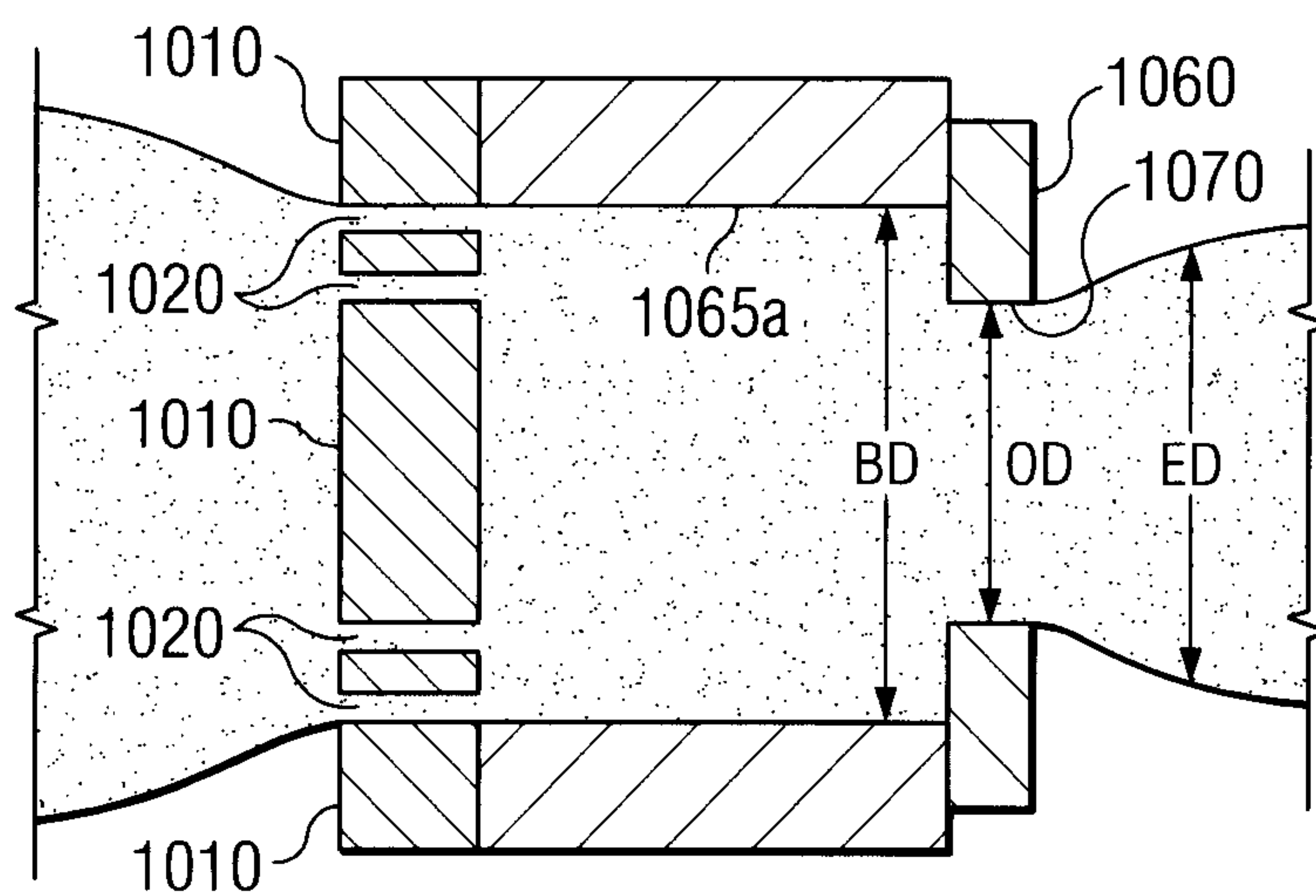
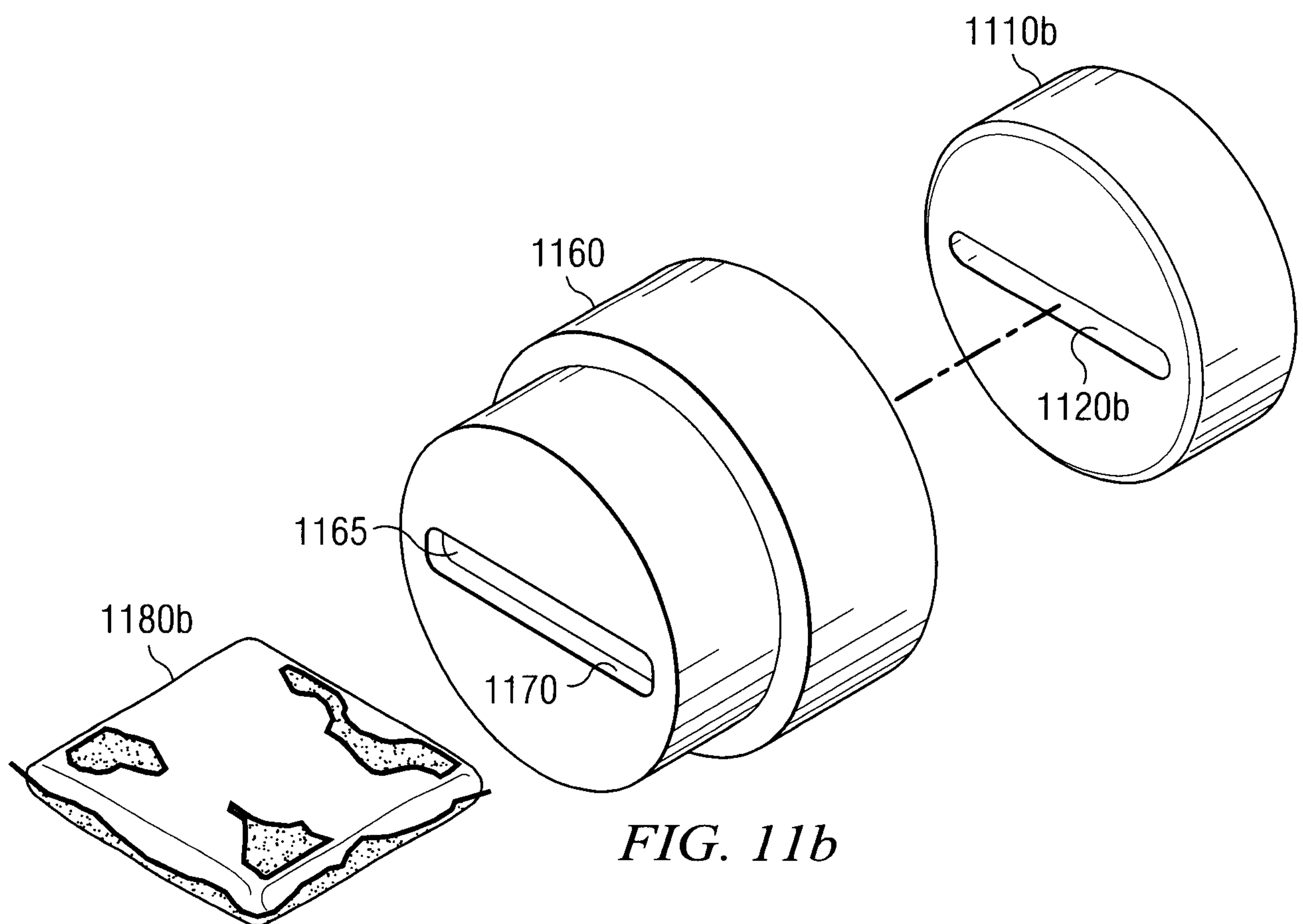
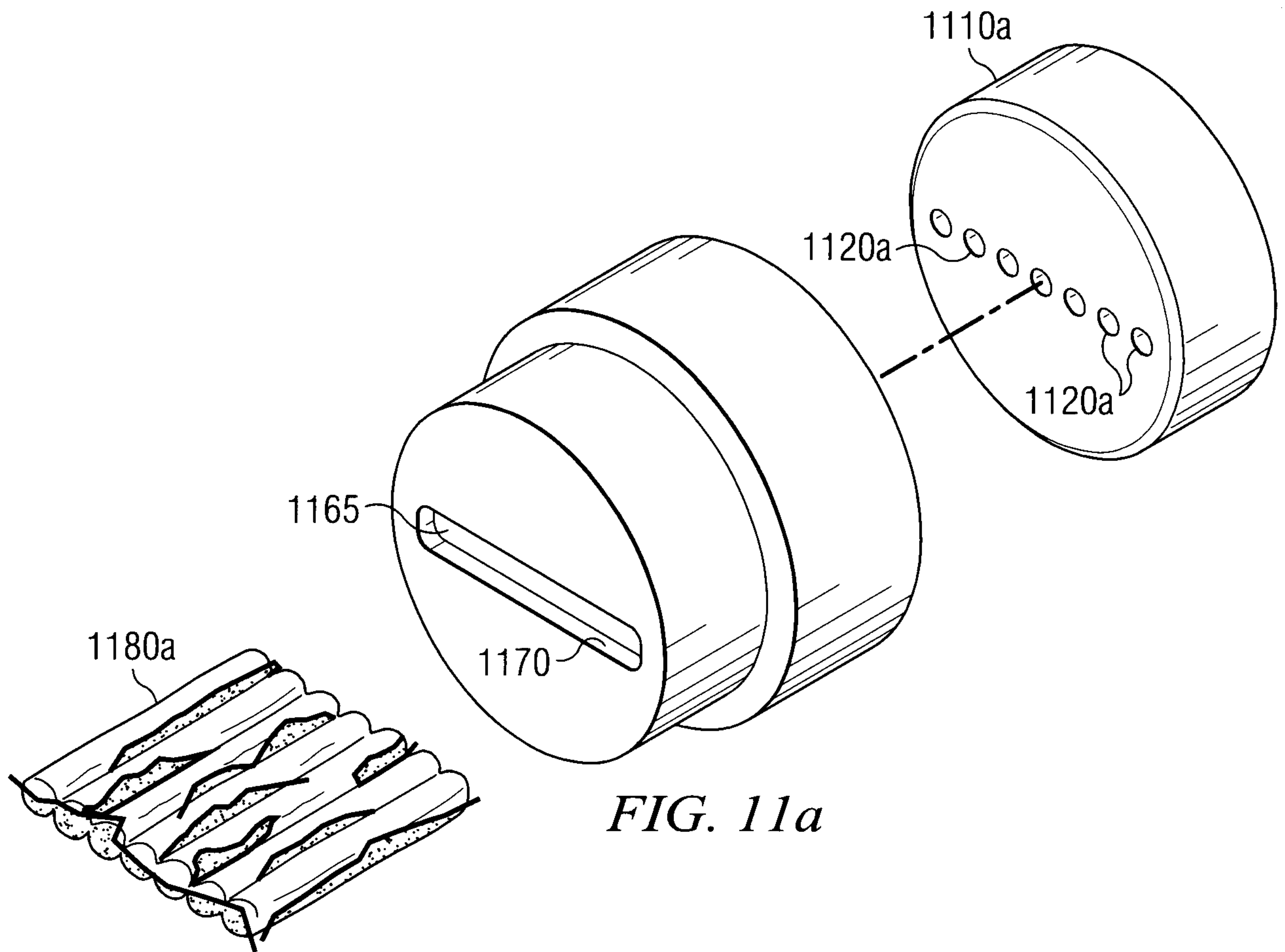


FIG. 10d

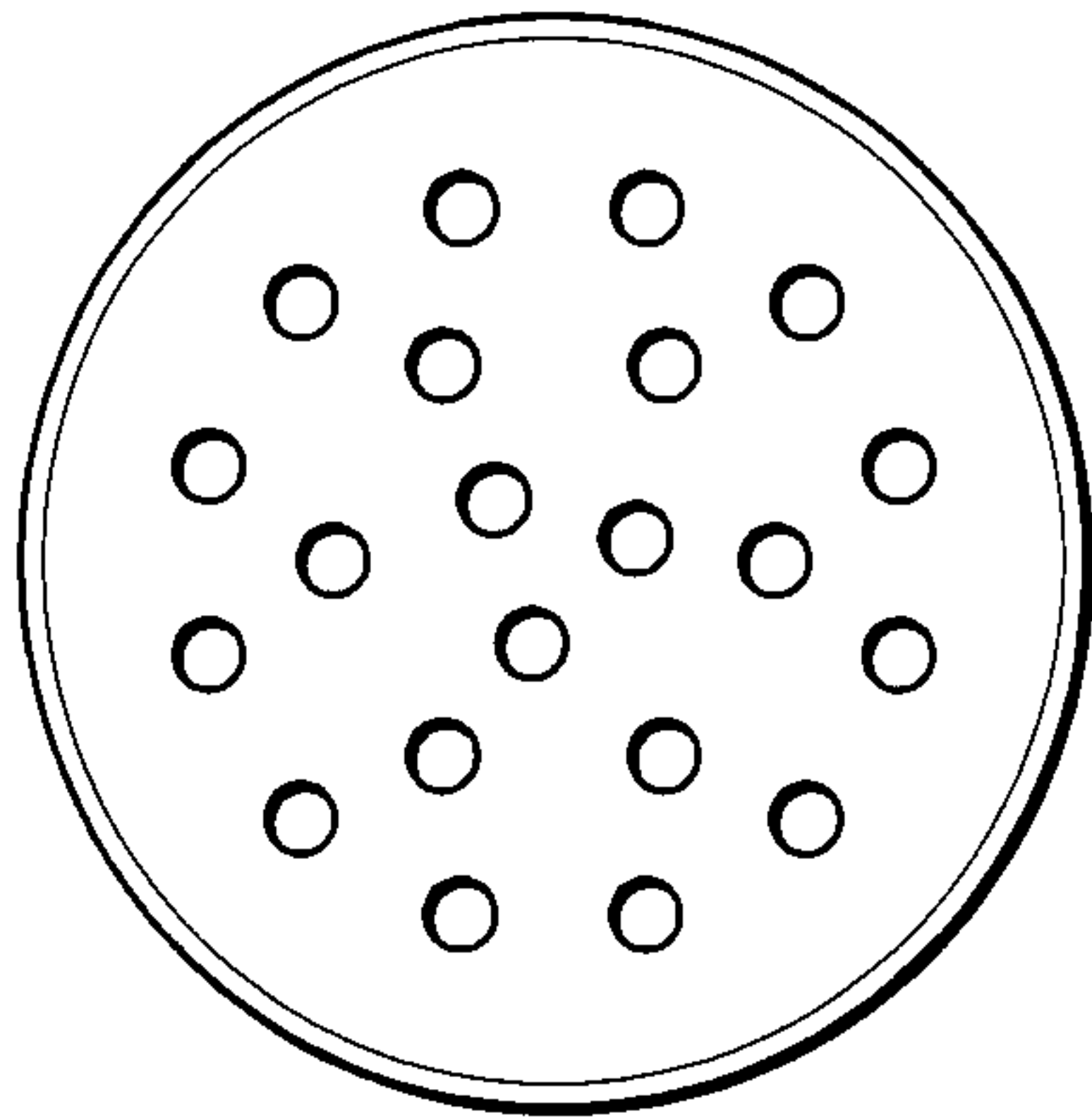
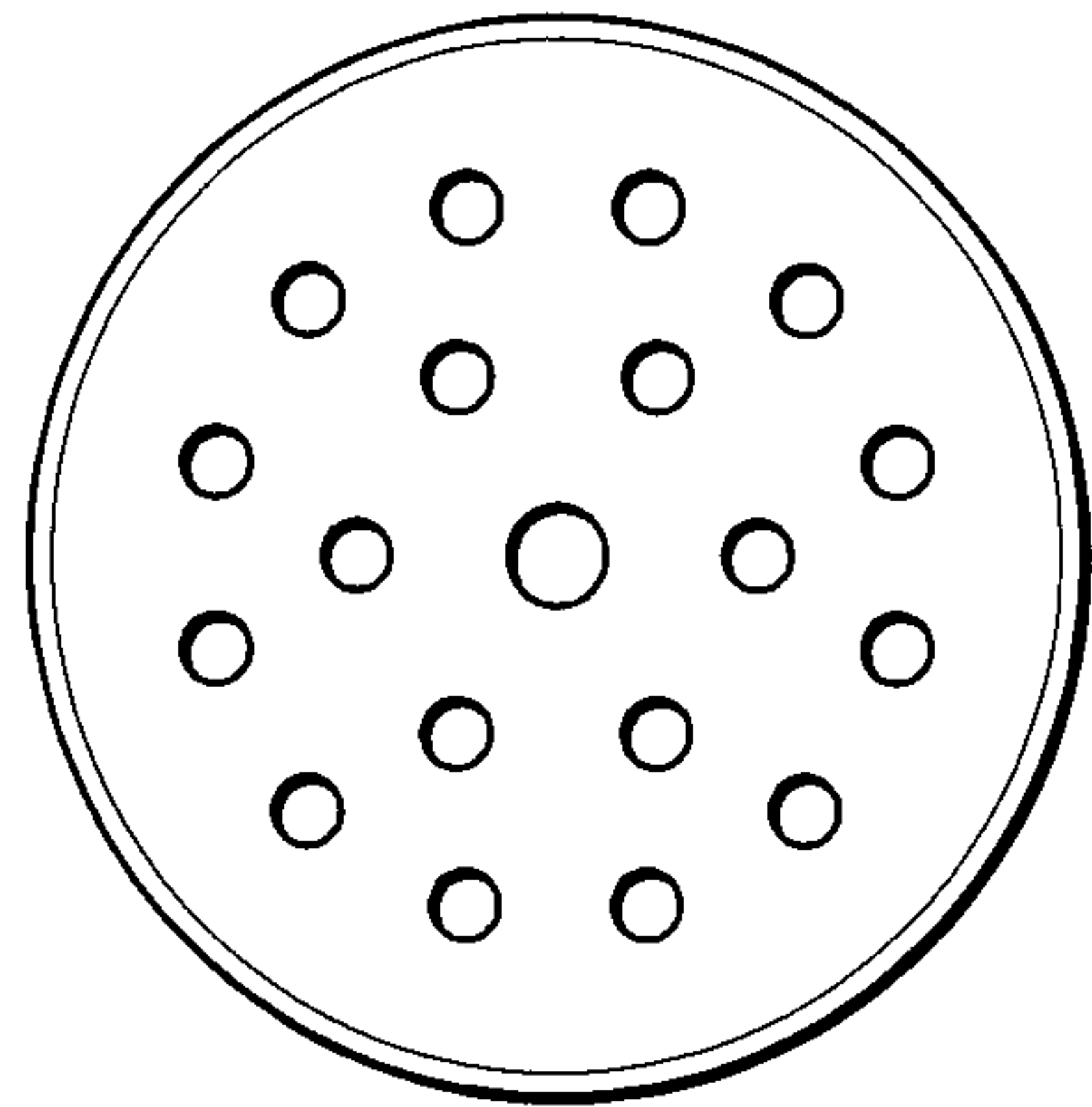
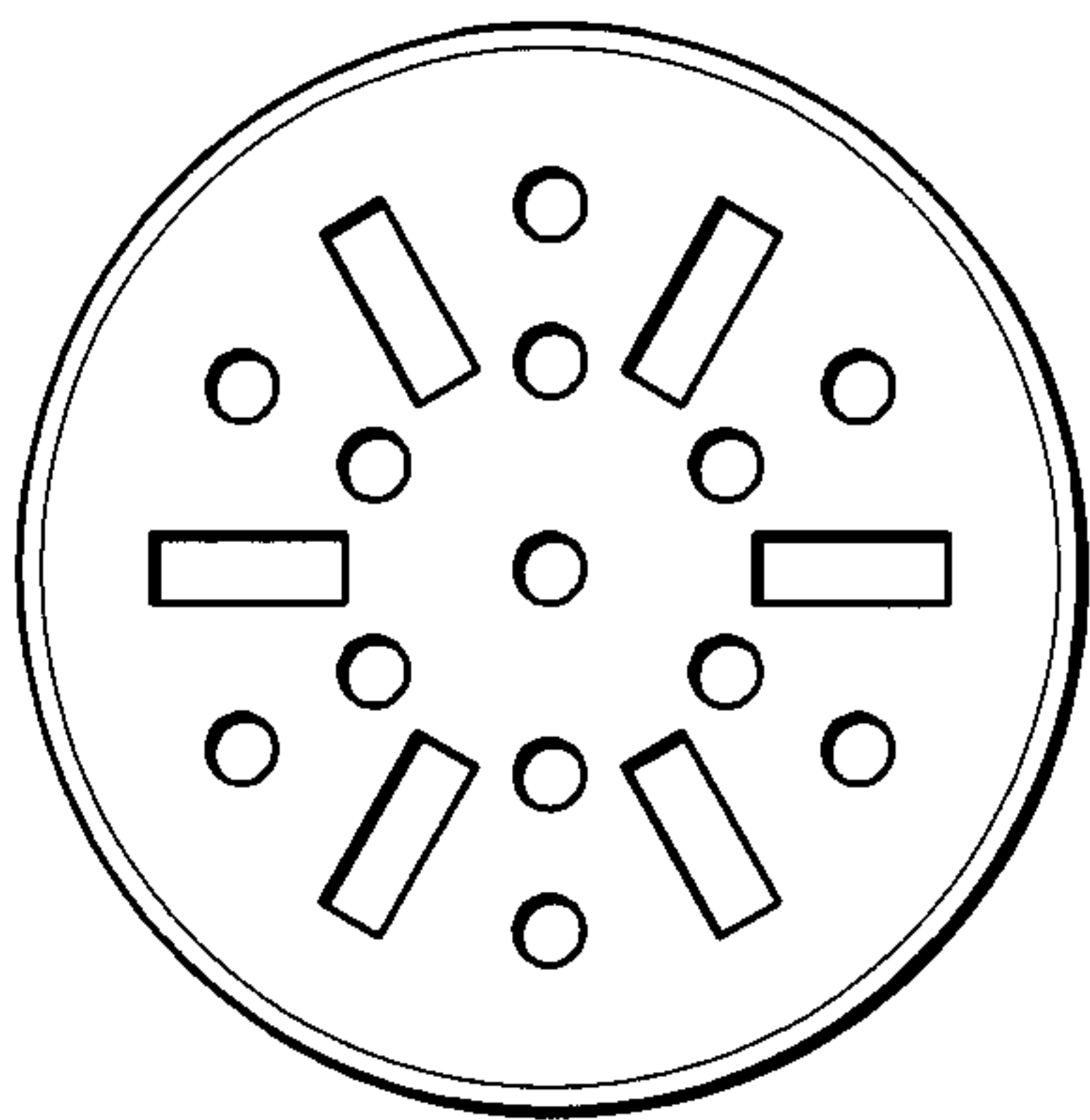
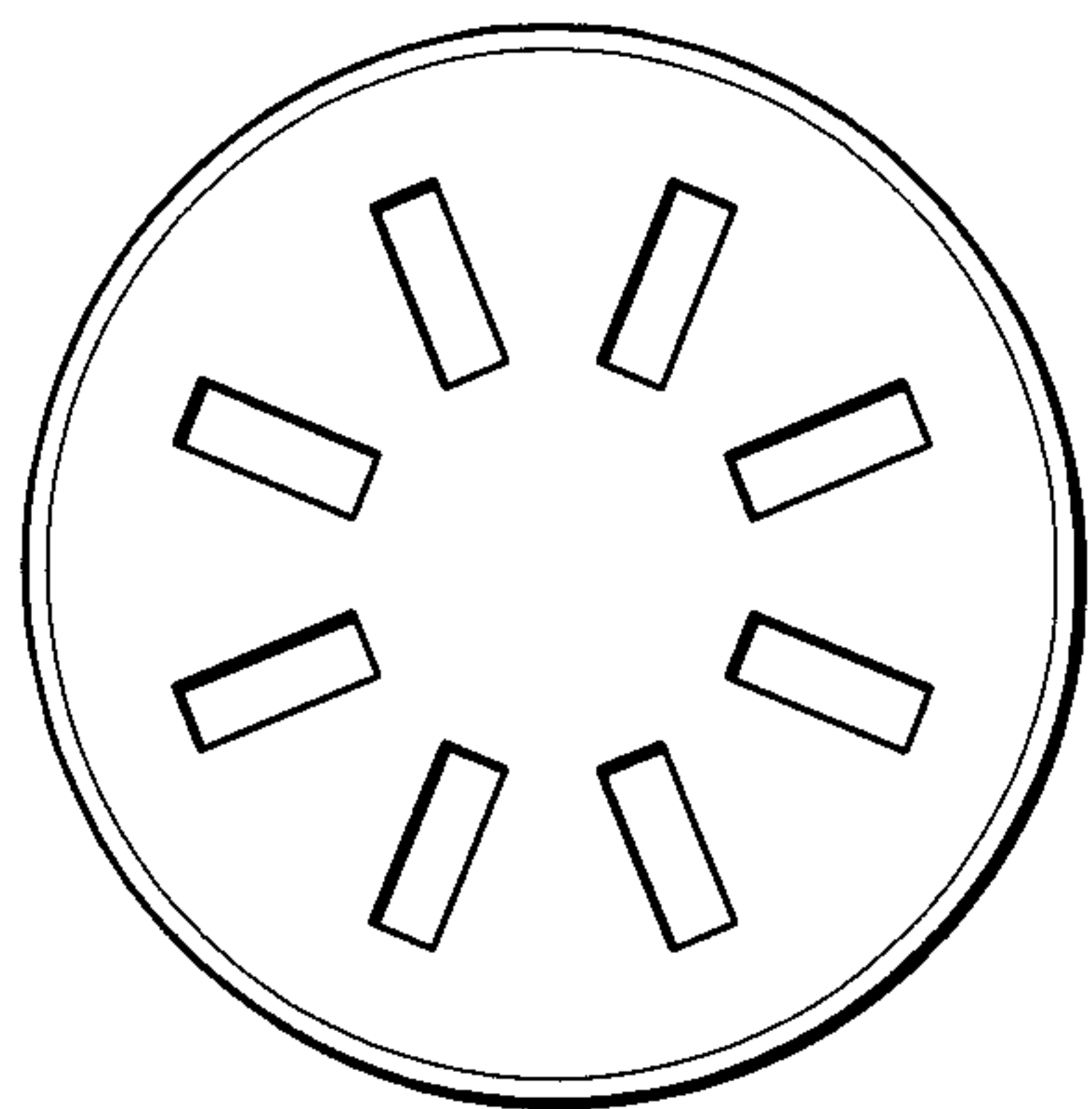
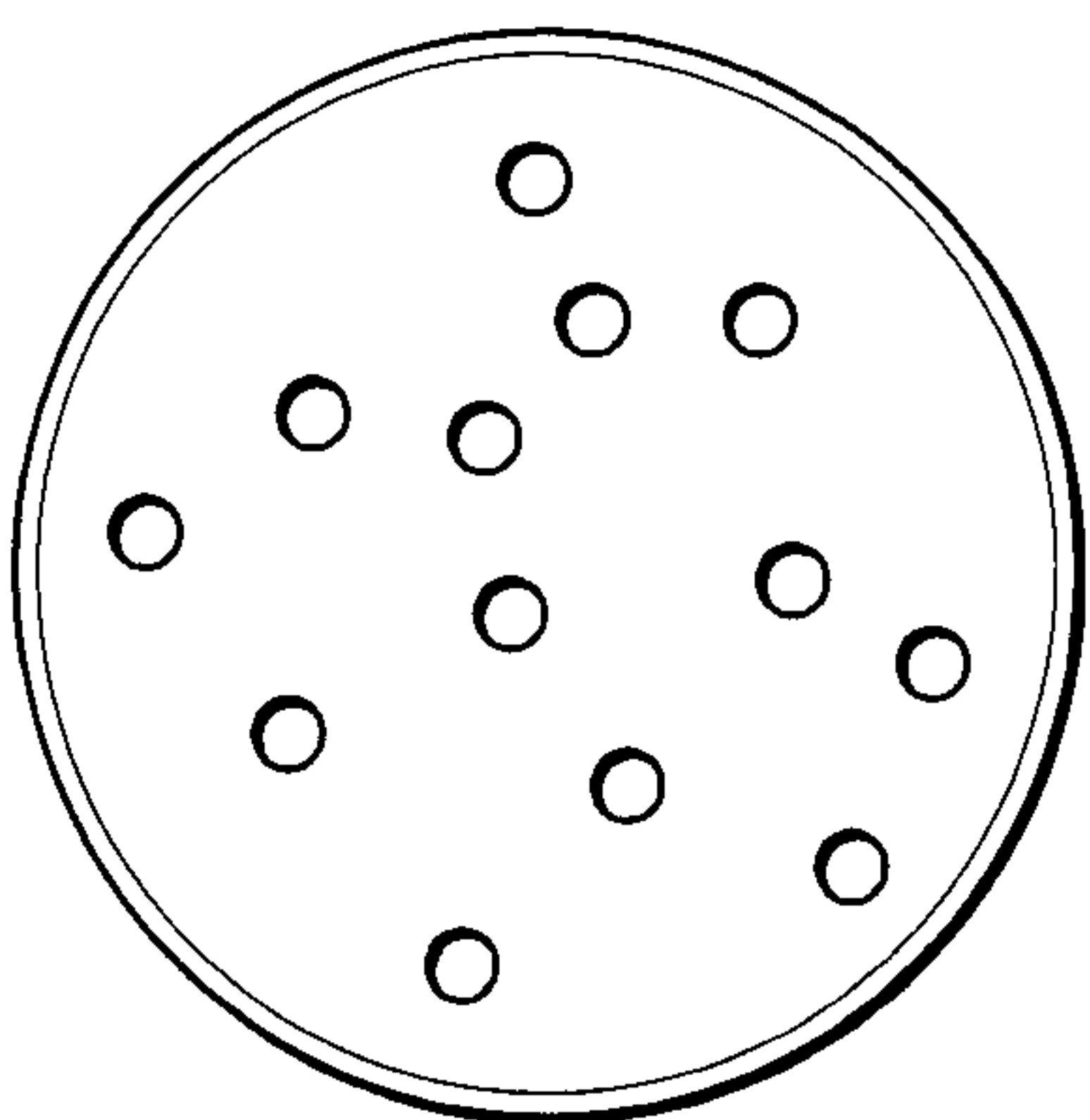
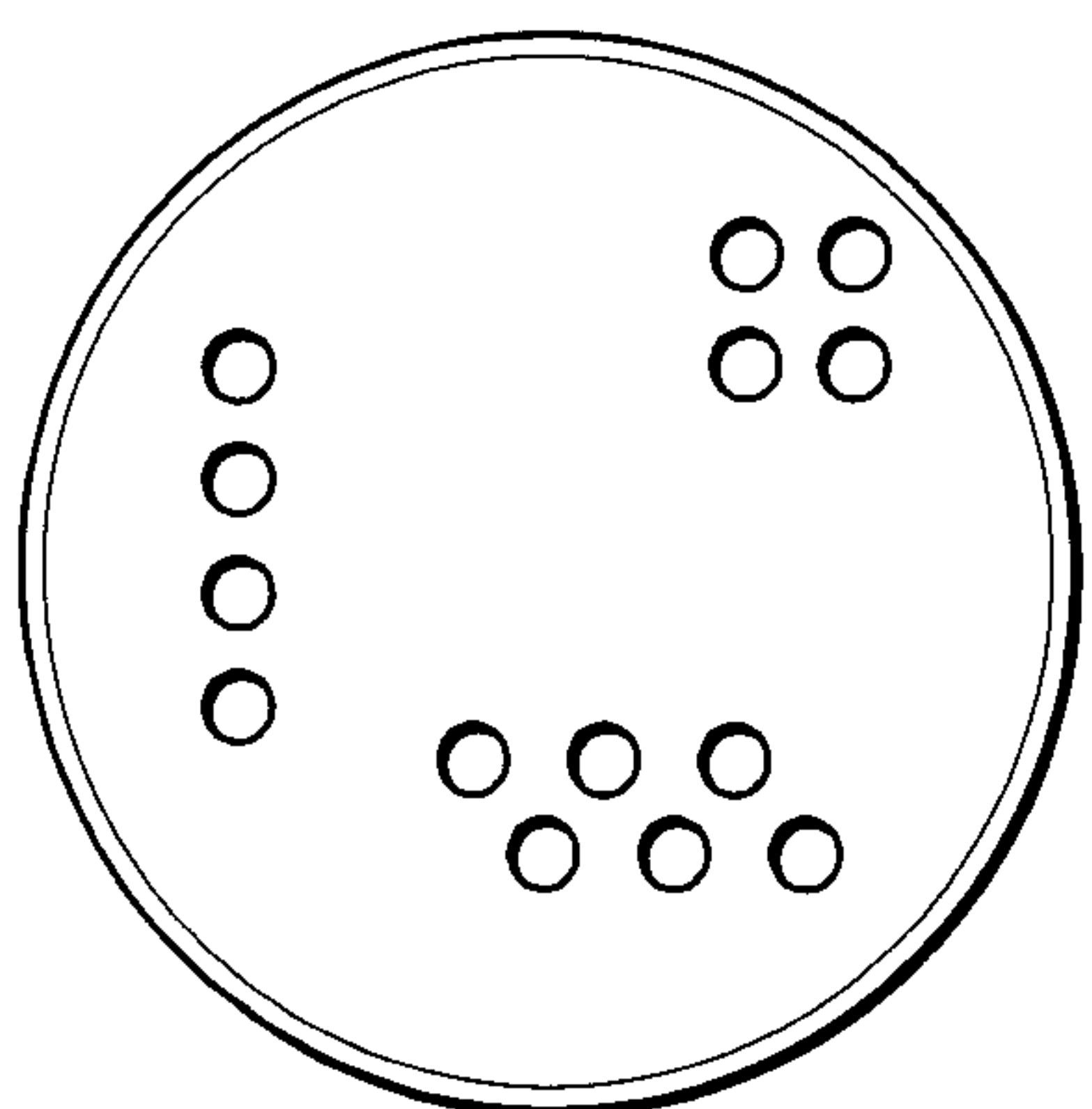


FIG. 10e

14/16



15/16

*FIG. 12a**FIG. 12b**FIG. 12c**FIG. 12d**FIG. 12e**FIG. 12f*

16/16

