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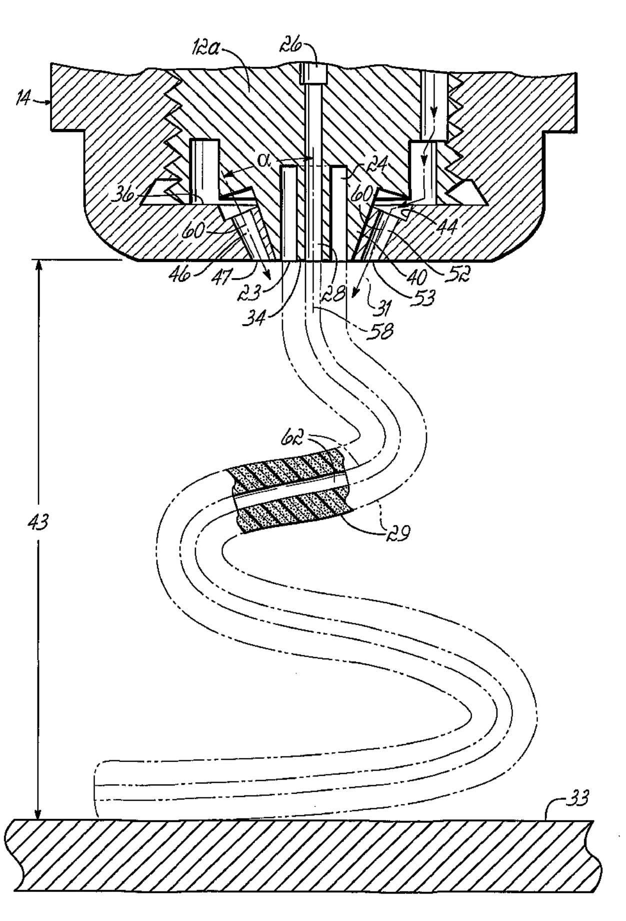

(57) Abstract: Applicators or dispensers (10) configured to dispense a hollow or shaped filament (29) and methods of dispensing in which the hollow or shaped filament (29) is impinged with gas jets (31). The applicator (10) includes a dispenser body (12) configured to discharge the hollow or shaped filament (29) and a plurality of gas outlets (47, 49, 51 , 53, 55, 57) arranged to impinge the filament (29) in the space between the dispenser or applicator (10) and the substrate (33).

WO 2007/055997 A2

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APPLICATORS AND METHODS FOR DISPENSING A LIQUID MATERIAL

Field of the Invention

The present invention generally relates to liquid material dispensing and, more particularly, to applicators with gas jets that impinge a dispensed liquid material filament and methods of dispensing liquid material filaments with gas jet impingement.

Background of the Invention

Dispensers discharge fluid or liquid materials, such as hot melt adhesives, in the form of a thin continuous filament to form a desired pattern onto a moving substrate. Common substrates include, but are not limited to, flat sheets or webs of paper or cardboard of the type commonly used in packaging, or a variety of products in other manufacturing operations. In these familiar dispensing operations, the patterns formed on the substrate may be characterized as either overlapping or non-overlapping. Overlapping patterns include any pattern where the filament crosses over itself in a controlled or predictable pattern, such as spiral patterns, swirl patterns, and overlapping waving or back-and-forth patterns. Non-overlapping patterns include any pattern in which the filament does not cross over itself, such as sinusoidal patterns, non-overlapping waving or back-and-forth patterns, and omega-shaped patterns.

The width of the pattern placed on the substrate can be widened to many times the width of the filament itself. Such overlapping and non-overlapping patterns are especially useful for accurately covering a wide area on a substrate with liquid material dispensed as single filaments or as multiple side-by-side filaments from nozzle passages having small diameters, such as on the order of 0.010 inch to 0.060 inch. This is especially useful at the edges of a substrate and on very narrow substrates, for example, on strands of elastic material used in the leg bands of diapers.

Dispensers capable of dispensing liquid material filaments to form overlapping and non-overlapping patterns on a substrate are distinct from other types of dispensers that discharge continuous filaments that form a chaotic and random pattern on a substrate. Generally, such random pattern dispensers are used in spunbonding manufacturing operations to dispense filaments that form a nonwoven web. The gas impinging these filaments lacks the ability to selectively create overlapping or non-overlapping patterns.

Impinging a continuous solid filament of liquid material with plural gas jets to provide a controlled pattern of liquid material on the substrate has many advantages, some of which are explained above. Generally, multiple dispensing applications would benefit from dispensed patterns having an amplitude (i.e., pattern width on the substrate) and/or frequency that exceed the amplitudes and frequencies currently available when using dispensing continuous filaments. In addition, multiple dispensing applications would benefit from the ability to effectively increase the width covered by the discharged filament on the moving substrate without changing the mass of liquid material per unit length of the filament.

For these and other reasons, it would be desirable to provide improved applicators and methods for creating an overlapping or non-overlapping filament pattern on a substrate.

Summary of Invention

In accordance with an embodiment of the invention, an applicator comprises a dispenser body including a liquid material passage communicating with a liquid material outlet and a plurality of first gas outlets positioned near the liquid material outlet. The liquid material passage is configured to discharge a stream of a liquid material from the liquid material outlet as a hollow filament. Each of the first gas outlets configured to emit a corresponding one of a plurality of streams of a first gas that impinges the hollow filament after discharge from the liquid material outlet to cause movement of the filament.

In another embodiment of the present invention, an applicator comprises a dispenser body includes a liquid material passage with a liquid material outlet configured to discharge a stream of a liquid material and a plurality of gas outlets positioned about the liquid material outlet. The liquid material outlet is shaped to produce a plurality of filament lobes as the stream of the liquid material is discharged. Each of the gas outlets emits a corresponding one of a plurality of gas streams that impinges the lobes of the filament after discharge from the liquid material outlet to cause movement of the filament.

In another aspect of the present invention, a method of forming a hollow filament of a liquid material comprises extruding a stream of the liquid material and

introducing a gas into an open core of the stream as the stream is being extruded to form the hollow filament. The forming method further includes impinging the hollow filament with a plurality of gas jets to cause movement of the hollow filament.

In another aspect of the present invention, a method of forming a continuous filament of a liquid material comprises extruding a stream of the liquid material with continuous filament having a plurality of lobes. The method further includes impinging the lobes of the filament with a plurality of gas jets to cause movement of the filament

These and other advantages of the present invention shall become more apparent from the accompanying drawings and description thereof.

Brief Description of Drawings

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the detailed description given below, serve to explain the principles of the invention.

Fig. 1 is a perspective view of a liquid material dispenser constructed in accordance with an embodiment of the invention.

Fig. 2A is a top view of the liquid material dispenser of Fig. 1.

Fig. 2B is a bottom view of the liquid material dispenser of Fig. 1 with the nozzle removed.

Fig. 3 is an exploded cross-sectional view taken generally along line 3-3 of Fig. 2A.

Fig. 3A is a detailed view of a portion of Fig. 3.

Fig. 4 is an exploded cross-sectional view taken generally along line 4-4 of Fig. 2A.

Fig. 5 is a bottom view of the liquid material dispenser of Fig. 1.

Fig. 6 is a cross-sectional view similar to Fig. 3A in which the nozzle is mounted to the dispenser body.

Fig. 7 is a bottom view similar to Fig. 5 of a liquid material dispenser constructed in accordance with an alternative embodiment of the invention.

Fig. 7A is a diagrammatic side view of the hollow filament dispensed from the liquid material dispenser of Fig. 7.

Fig. 8 is a bottom view similar to Fig. 7 of a liquid material dispenser constructed in accordance with an alternative embodiment of the invention.

Fig. 8A is a diagrammatic side view of the hollow filament dispensed from the liquid material dispenser of Fig. 8.

Fig. 9 is a bottom view similar to Fig. 7 of a liquid material dispenser constructed in accordance with an alternative embodiment of the invention.

Fig. 9A is a diagrammatic side view of the hollow filament dispensed from the liquid material dispenser of Fig. 9.

Fig. 10 is a bottom view similar to Fig. 7 of a liquid material dispenser constructed in accordance with an alternative embodiment of the invention.

Fig. 10A is a diagrammatic end view of the hollow filament dispensed from the liquid material dispenser of Fig. 10.

Fig. 11 is a bottom view similar to Fig. 7 of a liquid material dispenser constructed in accordance with an alternative embodiment of the invention.

Fig. 11A is a diagrammatic end view of the hollow filament dispensed from the liquid material dispenser of Fig. 11.

Fig. 12 is a perspective view of a liquid material dispenser constructed in accordance with an alternative embodiment of the invention.

Fig. 13 is a bottom view of the liquid material dispenser of Fig. 12.

Fig. 14 is a detailed view of a portion of Fig. 13.

Fig. 15 is a perspective view of a liquid material dispenser constructed in accordance with an alternative embodiment of the invention.

Fig. 16 is a graphical representation of the oscillation frequency as a function of fiber hollowness.

Fig. 17 is a schematic representation of a pattern traced by a hollow filament after landing on a substrate.

Fig. 18 is a graphical representation of the oscillation frequency for a prior art filament and a plus-shaped filament of the invention as a function of swirl gas pressure.

Fig. 19 is a graphical representation of the oscillation width for the filaments of Fig. 18 as a function of swirl gas pressure.

Fig. 20 is a graphical representation of the oscillation frequency for a prior art filament and for various filaments of the invention as a function of swirl gas pressure.

Detailed Description

With reference to Figs. 1, 2A and 3, an applicator or liquid material dispenser 10 generally includes a dispenser body 12 and a nozzle 14 removably secured by a threaded engagement with a lower portion 12a of the dispenser body 12. The lower portion 12a has a smaller diameter than an upper portion 12b, which is barrel shaped. Extending axially along the length of the dispenser body 12 is a plurality of liquid supply passageways 16, 18, 20, 22 each in fluid communication proximate to the nozzle 14 with an annular liquid material passage 24 (Fig. 3A). The liquid supply passageways 16, 18, 20, 22 are inclined axially so as to converge in a direction toward the annular liquid material passage 24 and intersect at one end with the liquid material passage 24.

An opposite end of each of the liquid supply passageways 16, 18, 20, 22 communicates with a liquid supply 21 (Fig. 3) for receiving amounts or a flow of a liquid material, including but not limited to molten hot melt adhesives and other molten synthetic polymers. Liquid supply 21 may include a pneumatically-actuated or electrically-operated valve mechanism (not shown) to regulate the flow of liquid material to dispenser 10. Provided on the upper portion 12b of the dispenser body 12 is a mounting flange 25 adapted to interface the dispenser 10 with the liquid supply 21 and to mount the dispenser 10 at a position suitable for dispensing a continuous hollow filament 29 of liquid material onto a substrate 33 (Fig. 6) to produce a desired overlapping or non-overlapping pattern on the substrate 33. Typically, the substrate 33 is moved relative to liquid material dispenser 10 so that the hollow filament 29 deposits on a moving substrate 33.

Among the nozzles 14 suitable for use in the invention are the family of Controlled Fiberization (CF®) applicator nozzles commercially available from Nordson Corporation (Westlake, Ohio). Such CF® applicator nozzles may have, for example, either six (6) gas openings or twelve (12) gas openings, the latter of which are referred to as high-frequency nozzles. The nozzle 14 may consist of a mounting section and a separate disk carrying the gas openings. Similar applicator nozzles are disclosed in U.S. Patent Nos. Re 33,481, 4,969,602, 5,065,943, 5,194,115 and 5,169,071, the disclosures of which are hereby incorporated by reference herein in their entirety. In an alternative embodiment, the present invention contemplates that the nozzle 14 may be an integral, one-piece construction with the dispenser body 12 and, hence, non-removable.

With reference to Figs. 1, 2B and 4, a central gas supply passageway 26 extends axially along the length of dispenser body 12 at a location generally between the liquid supply passages 16, 18, 20, 22. The gas supply passageway 26 receives a flow of a gas, such as nitrogen or process air, from a gas supply 15 (Fig. 1) communicating with gas supply passageway 26 by way of a port 17 (Fig. 4) extending radially through dispenser body 12. The gas supply 15 may be any gas supply capable of precision flow metering useful for controlling the hollow area in the core of the hollow filament 29 formed by the dispenser 10. Precision mass flow controllers suitable for use in metering the flow of gas from gas supply 15 to gas supply passageway 26 are commercially available, for example, from Emerson Process Management - Brooks Instrument of Hatfield, Pennsylvania. The gas supply 15 may also be provided with a backpressure regulator, such as those used in the FoamMix® family of applicators commercially available from Nordson Corporation (Westlake, Ohio), the assignee of the present invention.

A gas passage 28 communicating with the gas supply passageway 26, which constitutes the smallest diameter portion of passageway 26, is positioned inside the annular liquid material passage 24. The liquid material passage 24 and the gas passage 28 may be arranged coaxially along a common central axis or the gas passage 28 may be non-concentric. A tubular dividing wall or partition 34 separates the gas passage 28 from the annular liquid material passage 24 and thereby defines the gas passage 28. The liquid material stream discharged from annular liquid material passage 24 combines with the gas stream discharged from gas passage 28 to define the hollow filament 29. The gas stream occupies a central region or core 62 (Fig. 6) of the stream of liquid material discharged from liquid material passage 24 and, thereby, cooperates with the annular shape of the liquid material passage 24 to create the continuous hollow filament 29. The enclosed gas in the core 62 keeps the surrounding liquid material from collapsing inward and coalescing into a solid filament.

With reference to Figs. 2B, 3, 3A and 4, an annular trough 30 defined in the lower portion 12a of dispenser body 12 receives a flow of gas, such as nitrogen or process air, from a gas supply passageway 32 (Fig. 4) extending axially through the dispenser body 12. This may be the same gas supplied to central gas supply passageway 26 or a different gas. The gas supplied to gas supply passageway 32 originates from a gas supply 11 (Fig. 1) coupled by a supply port 13 (Fig. 4) for communication with gas supply passageway 32. The concentric arrangement of gas passage 28 and annular liquid material passage 24 causes the gas emitted by an outlet 27 of gas passage 28 to be injected into the core of the annular stream of liquid material emitted from annular liquid material passage 24. In cross-section profile viewed from a perspective parallel to the filament length, the resulting hollow filament 29 has a hollow, axially-extending core surrounded by a tubular shell of semi-solid or partially-solidified liquid material. Preferably, the hollow core is a continuous open void extending axially along the length of the continuous hollow filament 29.

The diameter of the hollow filament 29 is preferably larger than the diameter of a solid filament of equivalent mass per unit length and, in addition, the surface area per unit mass of the hollow filament 29 is greater than the surface area per unit mass of a solid filament of equivalent mass per unit length. The area of the unfilled core to the area of the surrounding tubular liquid material in cross-section is a function of, among other things, the type of liquid material constituting the filament 29 and the characteristics of the gas type and gas stream emitted from gas passage 28.

With reference to Figs. 2B, 3, 3A, 4, 5, and 6, the nozzle 14 is removably mounted with the dispenser body 12. When a mounting surface 36 of the nozzle 14 is seated against a mounting surface 38 of dispenser body 12, a frustoconical discharge tip 40 of the dispenser body 12 projects into a correspondingly dimensioned frustoconical clearance opening 42 centrally defined in the nozzle 14. Discharge tip 40 and clearance opening 42 have substantially identical included angles. Recessed in the mounting surface 36 of nozzle 14 is an annular groove 44 that communicates with a plurality of separate gas passages 46, 48, 50, 52, 54, 56 defined within nozzle 14. The annular groove 44 encircles the frustoconical clearance opening 42.

Located on discharge tip 40 is an annular liquid material outlet 23 (Fig. 5) of the liquid material passage 24 from which liquid material is discharged. The liquid material outlet 23 is defined at the intersection between liquid material passage 24 and an exposed surface 41 of discharge tip 40. The plane of the liquid material outlet 23 may be substantially co-planar with respective gas outlets 47, 49, 51, 53, 55, 57 of gas passages 46, 48, 50, 52, 54, 56.

The present invention contemplates that the dispenser 10 may have other gas passage configurations for emitting gas streams 31 effective to move the hollow filament 29 in the controlled pattern that ultimately produces the desired pattern of liquid material on the substrate 33. Although dispenser 10 is illustrated as having six gas passages 46, 48, 50, 52, 54, 56 and corresponding gas outlets 47, 49, 51, 53, 55, 57, respectively, the invention is not so limited.

Gas passages 46, 48, 50, 52, 54, 56 in nozzle 14 receive gas from the gas supply passage 32 of the dispenser body 12. This gas is diffused and slowed down in the annular trough 30 so that none of the gas passages 46, 48, 50, 52, 54, 56 directly receives the gas. Consequently, the gas flow is more uniform and balanced for all gas passages 46, 48, 50, 52, 54, 56, as arrayed about the annular liquid material passages 24 from which the hollow filament 29 is discharged. The annular liquid material passage 24 is centrally located in the frustoconical tip 40 and the free surface of the partition 34 projects from the nozzle 14 and below a plane containing the gas outlets 47, 49, 51, 53, 55, 57.

The gas outlets 47, 49, 51, 53, 55, 57 are arranged adjacent to the annular liquid material passage 24 with a ring-shaped configuration effective to discharge gas to impinge the hollow filament 29. The impinging gas causes the hollow filament 29 to move in a controlled pattern and to produce the desired pattern of liquid material on the substrate 33. Typically, the gas outlets 47, 49, 51, 53, 55, 57 are arranged about the annular liquid material passage 24 at a constant radius measured relative to a central axis 58 and with equal angular spacings. In one embodiment of the present invention, the gas outlets 47, 49, 51, 53, 55, 57 of the gas passages 46, 48, 50, 52, 54, 56 are disposed with a radially symmetric hexagonal arrangement about the annular liquid material passage 24 and, hence, are offset radially from annular liquid material passage 24. Diagonally opposite pairs of gas outlets 47, 49, 51, 53, 55, 57 are disposed in planes that are at least nearly parallel to each other and equidistant from annular liquid material passage 24. The gas outlets 47, 49, 51, 53, 55, 57 may be offset the same distance from a central axis of the gas passage 28, which is coaxial with liquid material passage 24.

A respective centerline 60 of each of the gas passages 46, 48, 50, 52, 54, 56 is each inclined relative to the centrally-located annular liquid material passage 24 such that the corresponding gas jets or streams 31 emitted from gas outlets 47, 49, 51, 53, 55, 57, respectively, are aligned at a shallow acute angle relative to the direction of motion of the discharged hollow filament 29. The acute angle is approximately tangential to the motion direction. The gas passages 46, 48, 50, 52, 54, 56 are also directed in a generally tangential manner relative to the annular liquid material passage 24 and are all angled in either a clockwise direction or a counterclockwise direction about the annular liquid material passage 24 so that the gas streams 31 cooperate to transfer momentum to the hollow filament 29 for defining the pattern. The angular alignment of the gas passages 46, 48, 50, 52, 54, 56 relative to the liquid material passage 24 is apparent in Figs. 5 and 6. The tangential angle of the gas passages 46, 48, 50, 52, 54, 56 is referenced relative to the central axis 58 about which the liquid and gas passages 24, 28 are coaxially aligned and is defined as the acute angle, α, between the centerline 60 of each of the gas passages 46, 48, 50, 52, 54, 56 and the central axis 58.

The hollow filament 29 dispensed from dispenser 10 has a tubular sidewall of liquid material that, in certain embodiments of the invention, may be a molten hot melt adhesive or a molten polymer. The molten liquid material is heated to a temperature sufficient for supplying a stream of the molten liquid material to dispenser body 12 and emitted from annular liquid material passage 24 with a core occupied by gas. The gas-filled core of hollow filament 29 is preferably not collapsed by the impinging gas from gas outlets 47, 49, 51, 53, 55, 57.

In one specific embodiment of the invention, the clearance opening 42 is angled at 26° relative to the axial centerline of the nozzle 14 to form a wider entrance diameter to a narrower exit diameter of about 0.011". The gas passages 46, 48, 50, 52, 54, 56 are each oriented at a tangential angle of about 31° so the emitted gas jets from the gas outlets 47, 49, 51, 53, 55, 57 generally tangentially intersect the outer surface of the hollow filament 29 discharged from liquid material passage 24. Each of the individual gas passages 46, 48, 50, 52, 54, 56 is 0.018" in diameter, as are the gas outlets 47, 49, 51, 53, 55, 57, and the gas outlets 47, 49, 51, 53, 55, 57 are arranged with equal angular spacings on a 0.118" diameter circle centered on the frustoconical clearance opening 42.

The present invention contemplates that the dispenser 10 may have other configurations of cooperating liquid material passage(s) and/or gas passage(s) effective for producing continuous hollow filament 29 and other arrangements of gas passages 46, 48, 50, 52, 54, 56 and gas outlets 47, 49, 51, 53, 55, 57 for steering the hollow filament 29 to define the controlled pattern in a space 43.

The gas streams 31 discharged from the gas outlets 47, 49, 51, 53, 55, 57 impinge or impact the airborne hollow filament 29 discharged from the annular liquid material passage 24 to provide a controlled pattern in space 43 separating the liquid material outlet 23 from substrate 33. Ultimately, the controlled pattern of motion in space 43 produces an overlapping or non-overlapping desired pattern of liquid material on the substrate 33. Depending on the specific application, the temperature of the gas streams 31 may be about 9°C to 15°C above the application temperature of the liquid material and is supplied at a gas pressure of about 2 psi to about 30 psi.

Because the filament 29 is hollow and has an enhanced diameter relative to a solid filament, the ratio of the filament surface area to filament mass per unit length is increased as compared with a solid filament that would have a lesser diameter for an equivalent mass of liquid material per unit length. As a result, impinging the hollow filament 29 with the gas streams 31 from the gas outlets 47, 49, 51, 53, 55, 57, while the hollow filament 29 travels in the space 43, has a greater effect upon the controlled overlapping or non-overlapping pattern traced by the hollow filament 29 in space 43 and also upon impact with the substrate 33. This enhanced effect may increase the amplitude of filament motion, increase the frequency of filament motion, or both, as compared with the amplitude and frequency of conventional patterns produced by impacting a solid filament of equivalent mass per unit length with equivalent gas streams 31. Typically, the amplitude of motion for the controlled pattern can be increased by decreasing the frequency and vice-versa, as these parameters are inversely related or complementary. In comparison with solid filaments, the hollow filament 29 provides a thicker fiber at lower add-on, which provides an improved bond strength at an equivalent add-on, and has a higher stretch ratio because the gas streams 31 are more effective in stretching the hollow filament 29 having a greater effective surface area.

The amplitude and/or frequency of the controlled pattern traced by hollow filament 29 in space 43 and the pattern traced on the substrate 33 may increase with increasing hollowness when other dispensing parameters are held constant. In one embodiment of the present invention, the controlled pattern has a frequency that is approximately uniform as a function of time or periodic.

Given a targeted frequency and amplitude for a controlled pattern, moving a hollow filament 29 with multiple gas jets will reduce gas consumption in comparison with a solid filament of equivalent mass per unit length. Specifically, the gas velocity of the gas streams 31 discharged from the respective gas outlets 47, 49, 51, 53, 55, 57 of gas passages 46, 48, 50, 52, 54, 56 may be reduced, which reduces the mass flow requirement for the gas supply to the corresponding gas jets. This will also reduce any turbulence introduced by the gas streams 31 because of the reduction in gas velocity, which may result in improved control of filament amplitude reflected in edge control on the substrate 33 and less contamination due to reductions in the number of airborne particles induced by the reduced velocity gas jets.

The present invention that it may be advantageous to impinge a hollow filament 29 of the same diameter as a solid filament (i.e., with less mass per length) with the gas streams 31. Specifically, such hollow filaments 29 vibrate more rapidly than comparable solid filaments of the same diameter because of the inherent resonant frequency of hollow versus solid filaments.

With reference to Figs. 7 and 7A in which like reference numerals refer to like features in Fig. 5 and in accordance with an alternative embodiment of the invention, the liquid material dispenser 10 may be modified such that a hollow filament 63 (Fig. 7A), which is similar or identical to hollow filament 29 (Fig. 6), is produced without the assistance of active gas injection into the filament core. Instead, the hollow core is formed passively by gas entrained from the ambient environment surrounding the liquid material dispenser 10. The dispenser body 12 includes a plurality of, for example, four liquid material passages 64, 66, 68, 70 each having a corresponding one of a plurality of outlets 65, 67, 69, 71 emerging on surface 41 of discharge tip 40 from which liquid material is discharged. The liquid material outlets 65, 67, 69, 71 are arranged symmetrically in a ring or arc about a solid center with a discontinuity 61 between each of the adjacent pairs of outlets 65, 67, 69, 71.

During operation of liquid material dispenser 10, a discrete stream of liquid material is transferred through the liquid material passages 64, 66, 68, 70 and dispensed from the corresponding liquid material outlets 65, 67, 69, 71, respectively. Adjacent liquid material streams are separated by gaps 72 that define open breaches so that gas from the ambient environment surrounding the liquid material dispenser 10 can enter and be entrained into the center of the separate outlet streams. Each of the gaps 72 coincides with one of the discontinuities 61. Downstream from the liquid material dispenser 10, the individual streams of liquid material coalesce or combine to form single hollow filament 63. When the separate outlet streams combine, the entrained gas results in a hollow filament core of filament 63.

The set of liquid material outlets 65, 67, 69, 71 has an open planar geometrical shape surrounding a solid center and discontinuities 61 in the open planar geometrical shape such that ambient gas flows from the environment through each discontinuity 61 and into the core of the liquid material stream. The shape of the set of liquid material outlets 65, 67, 69, 71 is not closed because the nearest end points of adjacent pairs of outlets 65, 67, 69, 71 define boundaries.

With reference to Figs. 8 and 8A in which like reference numerals refer to like features in Figs. 7 and 7A and in accordance with an alternative embodiment of the invention, the liquid material dispenser 10 may be modified to include an arc-shaped or C-shaped liquid material passage 74. The liquid material passage 74 includes an arc-shaped or C-shaped outlet 75 formed by the intersection of passage 74 with surface 41. A discontinuity 76 is defined in discharge outlet 75 between the confronting ends of the C-shape.

The filament 78 (Fig. 8A) discharged from liquid material passage 74 will initially have a C-shape reflecting the geometry of the outlet 75. Gas from the environment surrounding the liquid material dispenser 10 is suctioned through an opening or breach 80 in the filament sidewall coinciding initially at surface 41 with the location of the discontinuity 76 and is incorporated into the center of the liquid material outlet stream. As the filament streams away from the liquid material passage 74, the breach 80 in the filament sidewall will heal and close. The entrained gas is reflected structurally as a hollow gas-filled core of filament 78. The gas discharged from gas outlets 47, 49, 51, 53, 55, 57 does not significantly impact the gas entrainment.

The liquid material outlet 75 has an open planar geometrical shape surrounding a solid center. The discontinuity 76 in the open planar geometrical shape permits ambient gas to flow from the environment and into the core of the liquid material stream. The shape of the liquid material outlet 75 is not closed because the end points are its boundaries.

With reference to Figs. 9 and 9A in which like reference numerals refer to like features in Figs. 7 and 7A and in accordance with an alternative embodiment of the invention, the liquid material dispenser 10 may be modified to include a triangular-shaped liquid material passage 82 that includes a triangular-shaped outlet 84 at the intersection of passage 82 with surface 41. The liquid material outlet 84 includes a discontinuity 86 near one corner and through which gas may be entrained to produce the core of a hollow filament 88 (Fig. 9A) similar or identical to hollow filament 29 (Fig. 6).

The filament 88 discharged from liquid material passage 82 will initially have a triangular shape reflecting the geometry of the outlet 84. Gas from the environment surrounding the liquid material dispenser 10 is suctioned through an opening or breach 90 in the filament sidewall and into the center of the liquid material outlet stream. The gas discharged from gas outlets 47, 49, 51, 53, 55, 57 does not significantly impact the gas entrainment. As the filament 88 streams away from the liquid material passage 82, the breach 90 in the filament sidewall will heal and close to complete the gas trapping.

The liquid material outlet 84 has an open planar geometrical shape surrounding a solid center. The discontinuity 86 in the open planar geometrical shape permits ambient gas to flow from the environment and into the core of the liquid material stream. The shape of the liquid material outlet 84 is not closed because the end points of outlet 84 are its boundaries.

The use of open figure outlet geometries, as shown in Figs. 7-9, results in the formation of hollow filaments without the use of active gas injection into the filament core, as described with regard to Figs. 1-6. This simplifies the construction of a liquid material dispenser because the geometry of the liquid material outlet provides gas entrainment for forming a hollow filament core.

With reference to Figs. 10 and 10A in which like features refer to like reference numerals in Fig. 5 and in accordance with an alternative embodiment of the invention, the liquid material dispenser 10 may be modified to include a liquid material passage 92 that has a liquid material outlet 94 defined at the intersection between surface 41 and passage 92. The liquid material outlet 94 includes a plurality of, for example, four arms generally having a plus-shape or cross-shape. In cross section, a continuous filament 96 (Fig. 10A) discharged from the discharge passage 92 will have a solid cross section and a plus or cross shape reflecting the geometry of the outlet 94. The filament 96 includes four arms or lobes 96a-d projecting from a central solid core 97 defined at the intersection of the lobes 96a-d and evenly distributed about the circumference of the solid core 97. The lobes 96a-d extend along the length of the filament 96 and each of the lobes 96a-d coincides with one arm of outlet 94. The gas from gas outlets 47, 49, 51, 53, 55, 57 will impinge the lobes 96a-d of the filament 96. The impinging gas will provide an impulse to the filament 96 by momentum transfer and cause movement that ultimately results in an overlapping or non-overlapping pattern on substrate 33 (Fig. 6). After the filament 96 is impinged by the gas from gas outlets 47, 49, 51, 53, 55, 57, the lobes 96a-d of filament 96 may coalesce to form a more cylindrical shape that deposits on the moving substrate 33.

The number and/or shape of arms in outlet 94 may be modified to provide a different filament cross-sectional profile. For example and as shown in Fig. 11, a liquid material passage 98 may include a liquid material outlet 100 shaped to discharge a continuous trilobal filament 102 (Fig. 11A) having three arms or lobes 102a-c, each similar to arms 96a-d, that intersect at a core 101.

One advantage of the invention is to effectively increase the surface area of the discharged hollow filaments while retaining the same mass of liquid material per unit length, which conserves the amount of liquid material while permitting a larger width to be covered on the moving substrate. To that end, the surface area of the dispensed filament is increased by making the discharged filament hollow along its length. Hollow filaments have a greater outer diameter and surface area in comparison with a solid filament of comparable mass per unit length. When impinged by gas jets, the increase in the filament surface area may result in greater oscillation frequency and/or greater oscillation amplitude due to the increased momentum transfer from the gas jets to the filament, as compared with a solid core filament.

Alternatively, the filament may be shaped to include multiple lobes, as opposed to a smoothly curved outer surface. Shaped filaments have plural intersecting arms or lobes (e.g., plus-shaped), which may have a greater surface area, that are impinged by the gas jets to provide surfaces for momentum transfer. When impinged by gas jets, the change in filament shape may result in greater oscillation frequency and/or greater oscillation amplitude due to the increased momentum transfer from the gas jets to the filament, as compared with a solid core filament having a smoothly curved (e.g., cylindrical) cross-sectional profile without lobes or arms. Overlapping or non-overlapping patterns may be ultimately dispensed onto the substrate.

With reference to Figs. 12-14 in which like reference numerals refer to like features in Figs. 1-11 and in accordance with an alternative embodiment of the invention, a liquid material dispenser 110 includes a plurality of arc-shaped or C-shaped liquid material passages 112, 114, 116 that are arranged in a line across a dispenser body 119. Each of the liquid material passages 112, 114, 116 is similar or identical to liquid material passage 74 (Figs. 8 and 8A). Each of the liquid material passages 112, 114, 116 includes an arc-shaped or C-shaped outlet 113, 115, 117 formed by the intersection of the corresponding one of the liquid material passages 112, 114, 116 with a surface of a frustoconical discharge tip 118, 120, 122, respectively.

With reference to Fig. 14, liquid material passage 112 includes a discontinuity 124 defined in liquid material outlet 113 between the confronting ends of the C-shape. A plurality of, for example, four gas outlets 126, 128, 130, 132 surround the discharge outlet 113 and are each defined by the intersection of a corresponding one of a plurality of gas passages 136, 138, 140, 142 with an inclined surface 134 that is inclined in a direction toward the discharge tip 118. The liquid material outlet 113 is defined in a generally flat surface 144 at the end of discharge tip 118. Surface 144 is separated from surface 134 so that the liquid material outlet 113 is non-planar with the gas outlets 126, 128, 130, 132.

The gas outlets 126, 128, 130, 132 direct gas streams generally toward the discharged stream of liquid material and cooperate to transfer momentum to the hollow filament 18 (Fig. 8A) discharged from discharge outlet 113. The gas streams discharged from the gas outlets 126, 128, 130, 132 operate to move and attenuate the discharged stream of the liquid material that defines the hollow filament. The orientation of the gas streams is determined by the inclination angle of the corresponding one of the gas passages 136, 138, 140, 142 relative to the discharge outlet 113.

The other liquid material outlets 115, 117 are each surrounded by a set of gas outlets similar to gas outlets 126, 128, 130, 132. Consequently, the liquid material dispenser 110 is adapted to dispense a plurality of hollow filaments (Fig. 8A) such that each individual filament contacts the substrate 33 (Fig. 6) with a pattern. A person having ordinary skill in the art will understand the liquid material passages 112, 114, 116 and the liquid material outlets 115, 117, 119 thereof may be configured to have any of the configurations described herein.

With reference to Fig. 15 in which like reference numerals refer to like features in Figs. 1-14 and in accordance with another alternative embodiment of the invention, a liquid material dispenser 150 includes a plurality of substantially identical arc-shaped or C-shaped liquid material passages 152 that are arranged in a line across a dispenser body 154. Each of the liquid material passages 154 is similar or identical to liquid material passage 74 (Figs. 8 and 8A) and liquid material passages 112, 114, 116 (Figs. 12-14). Each of the liquid material passages 154 includes an arc-shaped or C-shaped outlet, similar or identical to outlet 113 (Fig. 14) and including a discontinuity, similar or identical to discontinuity 124 (Fig. 14).

With reference to Fig. 14, the line of liquid material passages 154 is flanked on opposite sides by a pair of slots 156, 158 extending along the length of the dispenser body 154. Slot 156 includes a plurality of gas outlets 160 that are arranged in pairs. A person having ordinary skill in the art will appreciate that other arrangements of gas outlets 160 may be used to generate gas streams that impinge the filament discharged from each of the liquid material passages 154. The impinging gas streams from each pair of gas outlets 160, which are directed generally toward the discharged stream of liquid material, cooperate with a similar pair of gas outlets (not shown but similar to gas outlets 160) in slot 158 to transfer momentum to the hollow filament 18 (Fig. 8A) discharged from the outlet of one of the liquid material passages 154. The gas streams discharged from the gas outlets 160 operate to move and attenuate the discharged stream of the liquid material that defines the hollow filament. A person having ordinary skill in the art will understand that the liquid material passages 154 and the outlets of the liquid material passages 154 may be configured to have any of the configurations described herein.

For purposes of this description, words such as "vertical", "horizontal", "bottom", "right", "left" and the like are applied in conjunction with the drawings for purposes of clarity and for purposes of defining a frame of reference. As is well known, dispensers for liquid materials, like hot melt adhesives, may be oriented in substantially any orientation, so these directional words should not be used to imply any particular absolute directions for a dispenser consistent with the invention.

Further details and embodiments of the invention will be described in the following examples and comparative examples.

<u>Example 1</u>

Hollow filaments of an adhesive were oscillated by a process consistent with the embodiment of the invention described with regard to Figs. 1-6. The frequency of the oscillating hollow filament after striking the substrate was measured as a function of fiber hollowness. Fiber hollowness was determined from the flow rate of gas injected into the filament center.

Hollow filaments were formed using an annular liquid material outlet surrounding a coaxial gas discharge outlet and then steered by gas streams by an apparatus similar to dispenser 10 (Fig. 1) to define an oscillating pattern. The filaments were formed from a ZEROPACK® hot melt adhesive commercially available from HB Fuller (St. Paul, Minnesota) and using thirteen (13) standard liters per minute (SLM) of non-heated gas discharged for oscillating the filament. The adhesive was discharged at fifty-four (54) grams per minute at a temperature of 150°C (head & hose) through an annular ring outlet of a dispensing die and a flow of nitrogen was injected through a central hole into the center of the dispensed adhesive to form the hollow fibers. A modified standard Controlled Fiberization (CF®) applicator nozzle, commercially available from Nordson Corporation, was mated with the dispensing die in which the cone was removed to allow it to fit on the die and to define a clearance opening for the discharge tip. The diameter of the gas passage was 0.022" and the radial dimension of the annular liquid material passage was 0.040" with an inner diameter of 0.050" and an outer diameter of 0.090". The axial dimension of the annular liquid material passage was 0.140".

Fig. 16 graphically shows the measured results in which it is apparent that the frequency of oscillation of the controlled pattern traced by the hollow filament after discharge increases with increasing fiber hollowness. Increases in the hollowness were provided by concomitant increases in the flow rate of nitrogen to the fiber center, while holding all other variables constant. The period, p, is determined by counting the number of discrete swirls per second in the dispensed pattern formed after the hollow filament 29 lands on the substrate 33, as indicated in Fig. 17 and as illustrated for purposes of description with an overlapping pattern. The frequency is then determined from the period. Each oscillation cycle is measured between repeating features in the pattern traced on the substrate. The width, w, of the pattern traced by the oscillating hollow filament on the substrate may also be measured.

The gas-filled core of the hollow filament was observed to be retained after discharge despite the momentum transferred to the hollow filament from the impinging gas streams. The hollow filament, which was impinged by the gas streams immediately after discharge and before the molten hot melt adhesive constituting the annular sidewall of the hollow filament had experienced significant cooling or solidification, was not collapsed by the gas impingement.

Example 2 and Comparative Example 1

Multi-lobed, plus-shaped filaments of an adhesive were oscillated by a process consistent with the embodiment of the invention described with regard to Fig. 10. The dispensed adhesive had a viscosity of 4,500 centipoise (cps). For the frequency measurement, the filament was impinged by gas jets from four gas passages arranged about the adhesive outlet. For the width measurement, the filament was impinged by gas jets from eight gas passages arranged about the adhesive outlet. The filament was dispensed at a throughput of about 33 grams per minute from a height of about 30 mm above the recipient substrate and with the substrate moving at about 5 feet per minute. The swirl gas pressure was varied to acquire the data shown in Figs. 14 and 15.

With reference to Figs. 18 and 19, the frequency and width of the pattern of the oscillating filament, which has an appearance similar to that of filament 96 shown in Fig. 10A after discharge from the dispenser, after striking the substrate was measured as a function of swirl gas pressure and compared with the pattern traced by a comparable solid filament having a circular cross-sectional profile. As is apparent from Fig. 18, a frequency curve 200 for the plus-shaped filament exhibits a greater oscillation frequency at all swirl gas pressures than a frequency curve 202 representing the oscillation frequency for the comparable solid, circular filament. Similarly, a width curve 204 for the plus-shaped filament exhibits a greater width for swirl gas pressures greater than about 1 psi than a width curve 206 representing the oscillation width for the comparable solid, circular filament. The oscillation frequency for the plus-shaped filament impinged by eight gas jets was similar to that of the solid, circular filament.

The filament lobes were observed to be retained when impinged by the gas streams after discharge despite the transferred momentum from the impinging gas streams. The lobes, which were impinged by the gas streams immediately after discharge and before the molten hot melt adhesive in the lobes had experienced significant cooling or solidification, were not significantly deformed by the gas impingement.

Example 3 and Comparative Example 2

Hollow filaments of an adhesive were oscillated by a process consistent with the embodiment of the invention described with regard to Figs. 7-9. The dispensed adhesive had a viscosity of 4,500 centipoise (cps) and the filament was impinged by process gas from four gas passages arranged about the adhesive outlet.

With reference to Fig. 20, the frequency of the pattern of the oscillating hollow filament, after striking the substrate was measured as a function of swirl gas pressure and compared with the frequency of a pattern traced by a comparable solid filament having a circular cross-sectional profile. As is apparent from Fig. 20, a frequency curve 208 for a hollow filament formed using the liquid/gas outlet arrangement of Fig. 8 and a frequency curve 210 for a hollow filament formed using the liquid/gas outlet arrangement of Fig. 9 each exhibits a greater oscillation frequency at all swirl gas pressures than a frequency curve 212 representing the oscillation frequency for the comparable solid, circular filament. In addition, a hollow filament formed using the liquid/gas outlet arrangement of Fig. 7 had an oscillation frequency similar to frequency curve 212 at the measured swirl gas velocities.

The gas-filled core of the hollow filament was observed to form passively by gas entrained from the ambient environment and be retained despite the momentum transferred to the hollow filament from the impinging gas streams. The hollow filament, which was impinged by the gas streams immediately after discharge and before the molten hot melt adhesive constituting the annular sidewall of the hollow filament had experienced significant cooling or solidification, formed while influenced by the gas impingement and, after forming, was not collapsed by the gas impingement.

While the present invention has been illustrated by a description of various preferred embodiments and while these embodiments have been described in considerable detail in order to describe the best mode of practicing the invention, it is not the intention of applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications within the spirit and scope of the invention will readily appear to those skilled in the art. The invention itself should only be defined by the appended claims, wherein we claim:

An applicator for dispensing at least one hollow filament of a liquid material, comprising:

a dispenser body including a first liquid material passage communicating with a first liquid material outlet and a plurality of first gas outlets positioned near said first liquid material outlet, said first liquid material passage configured to discharge a first stream of the liquid material from said first liquid material outlet as a first hollow filament, and each of said first gas outlets configured to emit a corresponding one of a first plurality of streams of a first gas that impinges the first hollow filament after discharge from said first liquid material outlet to cause movement of the first hollow filament.

2. The applicator of claim 1 wherein said first liquid material outlet is configured to introduce a stream of a second gas into an open core of the first stream of the liquid material to form the first hollow filament.

3. The applicator of claim 1 wherein said first liquid material outlet is annular and includes an outer perimeter and an inner perimeter, and said first gas outlets are arranged radially outside of said outer perimeter and angled generally tangentially relative to said outer perimeter.

4. The applicator of claim 3 wherein said dispenser body further includes a second gas outlet arranged radially inside said inner perimeter of said first liquid material outlet, said second gas outlet configured to discharge a stream of a second gas into an open core of the first stream of the liquid material to form the first hollow filament.

The applicator of claim 1 wherein said first liquid material outlet has an open planar geometrical shape with end points separated by a discontinuity to define a communication path for a second gas from an ambient environment surrounding the stream of the liquid material into an open core of the first stream of the liquid material to form the first hollow filament.

6. The applicator of claim 1 wherein said dispenser body includes a removable nozzle carrying said gas outlets.

7. The applicator of claim 6 wherein said dispenser body includes a discharge tip, said first liquid material passage intersects said discharge tip to define said first liquid material outlet, and said nozzle includes a clearance opening through which said discharge tip protrudes.

8. The applicator of claim 1 wherein said dispenser body includes a second liquid material passage communicating with a second liquid material outlet and a plurality of second gas outlets positioned near said second liquid material outlet, said second liquid material passage configured to discharge a second stream of the liquid material from said second liquid material outlet as a second hollow filament, and each of said second gas outlets configured to emit a corresponding one of a second plurality of streams of the first gas that impinges the hollow filament after discharge from said second liquid material outlet to cause movement of the second hollow filament.

An applicator for dispensing a liquid material to form at least one filament having a plurality of lobes, the applicator comprising:

a dispenser body including a first liquid material passage with a first liquid material outlet configured to discharge a first stream of the liquid material and a plurality of first gas outlets positioned about said first liquid material outlet, said first liquid material outlet shaped to produce the lobes of a first filament as the first stream of the liquid material is discharged, and each of said first gas outlets emits a corresponding one of a first plurality of gas streams that impinge the lobes of the first filament after discharge from said first liquid material outlet to cause movement of the first filament.

10. The applicator of claim 9 wherein said dispenser body includes a removable nozzle carrying said gas outlets.

11. The applicator of claim 10 wherein said dispenser body includes a discharge tip, said liquid material passage intersects said discharge tip to define said liquid material outlet, and said nozzle includes a clearance opening through which said discharge tip protrudes.

12. The applicator of claim 9 wherein said dispenser body includes second liquid material passage with a second liquid material outlet configured to discharge a second stream of the liquid material and a plurality of second gas outlets positioned about said second liquid material outlet, said second liquid material outlet shaped to produce the lobes of a second filament as the second stream of the liquid material is discharged, and each of said second gas outlets emits a corresponding one of a second plurality of gas streams that impinge the

lobes of the second filament after discharge from said second liquid material outlet to cause movement of the second filament.

13. A method of forming a hollow filament of a liquid material, comprising:

extruding a stream of the liquid material;

introducing a gas into an open core of the stream as the stream is being extruded to form the hollow filament; and

impinging the hollow filament with a plurality of gas jets to cause movement of the hollow filament.

14. The method of claim 13 wherein introducing the gas into the open core of the stream further comprises:

injecting a stream of the gas into the open core.

15. The method of claim 13 wherein introducing the gas into the open core of the stream further comprises:

transferring the gas from an ambient environment surrounding the stream into the open core.

16. The method of claim 13 further comprising:

moving a substrate relative to the hollow filament so that the hollow filament deposits with a desired pattern on the moving substrate.

17. The method of claim 16 wherein said desired pattern is selected from the group consisting of overlapping patterns and non-overlapping patterns.

18. The method of claim 13 wherein impinging the continuous hollow filament with the plurality of gas jets further comprises:

increasing the amplitude of the movement of the hollow filament.

19. The method of claim 13 wherein impinging the continuous hollow filament with the plurality of gas jets further comprises:

increasing the frequency of the movement of the hollow filament.

20. The method of claim 13 wherein impinging the continuous hollow filament with the plurality of gas jets further comprises:

impinging the continuous hollow filament generally tangentially with the plurality of gas jets.

21. A method of forming a continuous filament of a liquid material, comprising:

extruding a stream of the liquid material with continuous filament having a plurality of lobes; and

impinging the lobes of the filament with a plurality of gas jets to cause movement of the filament.

22. The method of claim 21 wherein the filament moves with a periodicity to provide a controlled pattern.

23. The method of claim 21 further comprising:

moving a substrate relative to the filament so that the filament deposits with a desired pattern on the moving substrate.

24. The method of claim 23 wherein said desired pattern is selected from the group consisting of overlapping patterns and non-overlapping patterns.

25. The method of claim 21 wherein impinging the lobes of the filament with the plurality of gas jets further comprises:

increasing the amplitude of the movement of the filament.

26. The method of claim 21 wherein impinging the lobes of the filament with the plurality of gas jets further comprises:

increasing the frequency of the movement of the filament.

27. The method of claim 21 wherein impinging the lobes of the filament with the plurality of gas jets further comprises:

impinging the lobes of the filament generally tangentially with the plurality of gas jets.

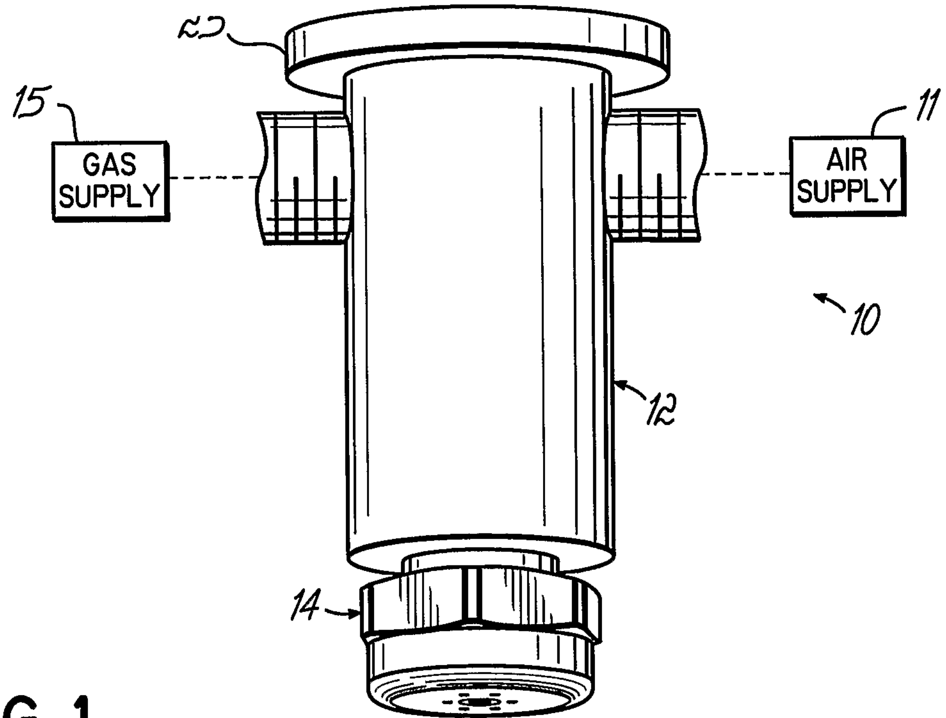

22
15
GAS SUPPLY
11
AIR SUPPLY
10
12
14

FIG. 1

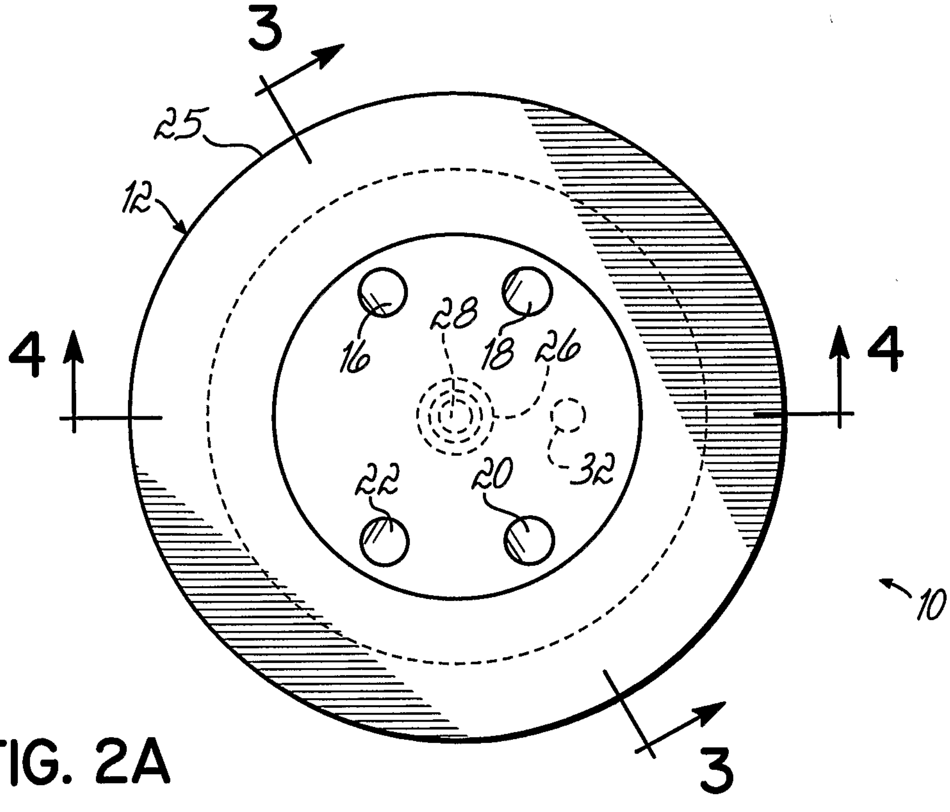

3
25
12
4
16
28
18
26
32
22
20
4
10
3

FIG. 2A

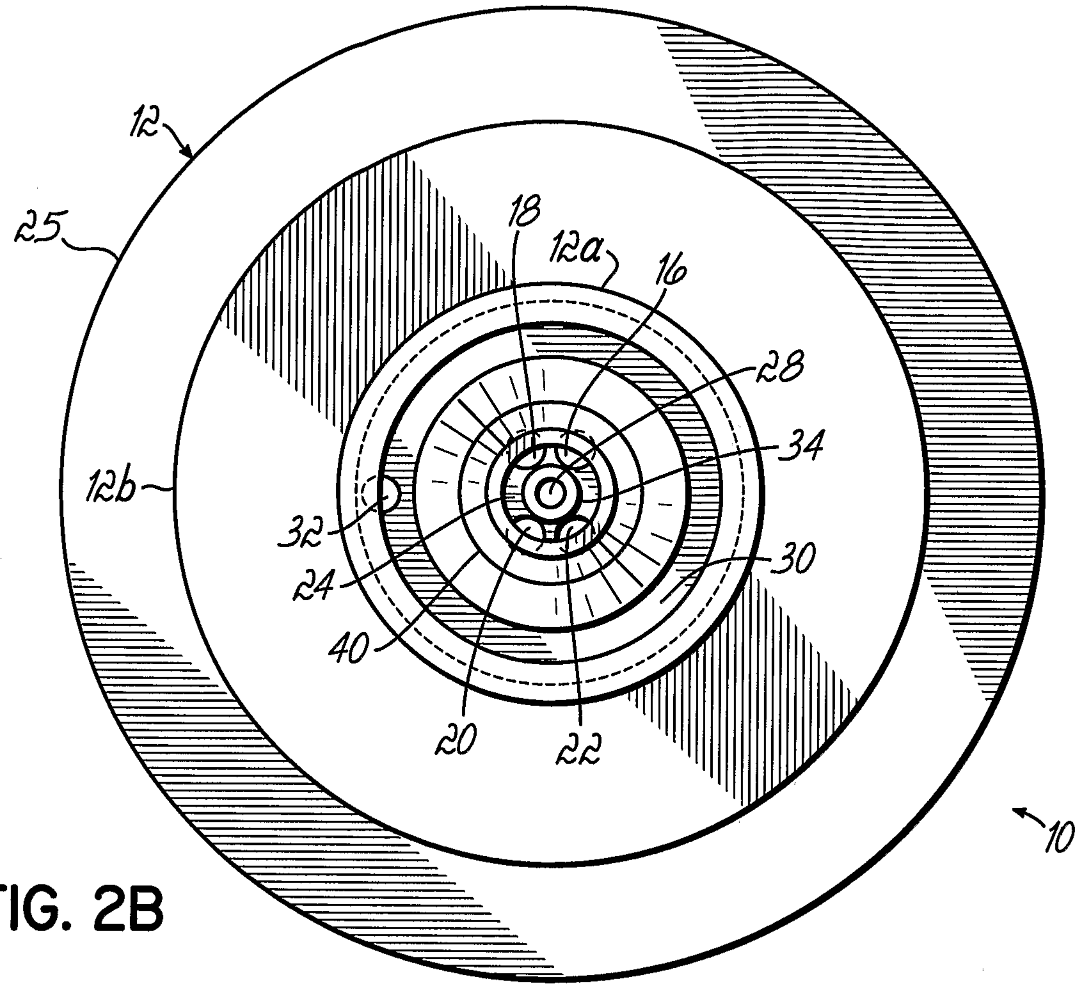


FIG. 2B

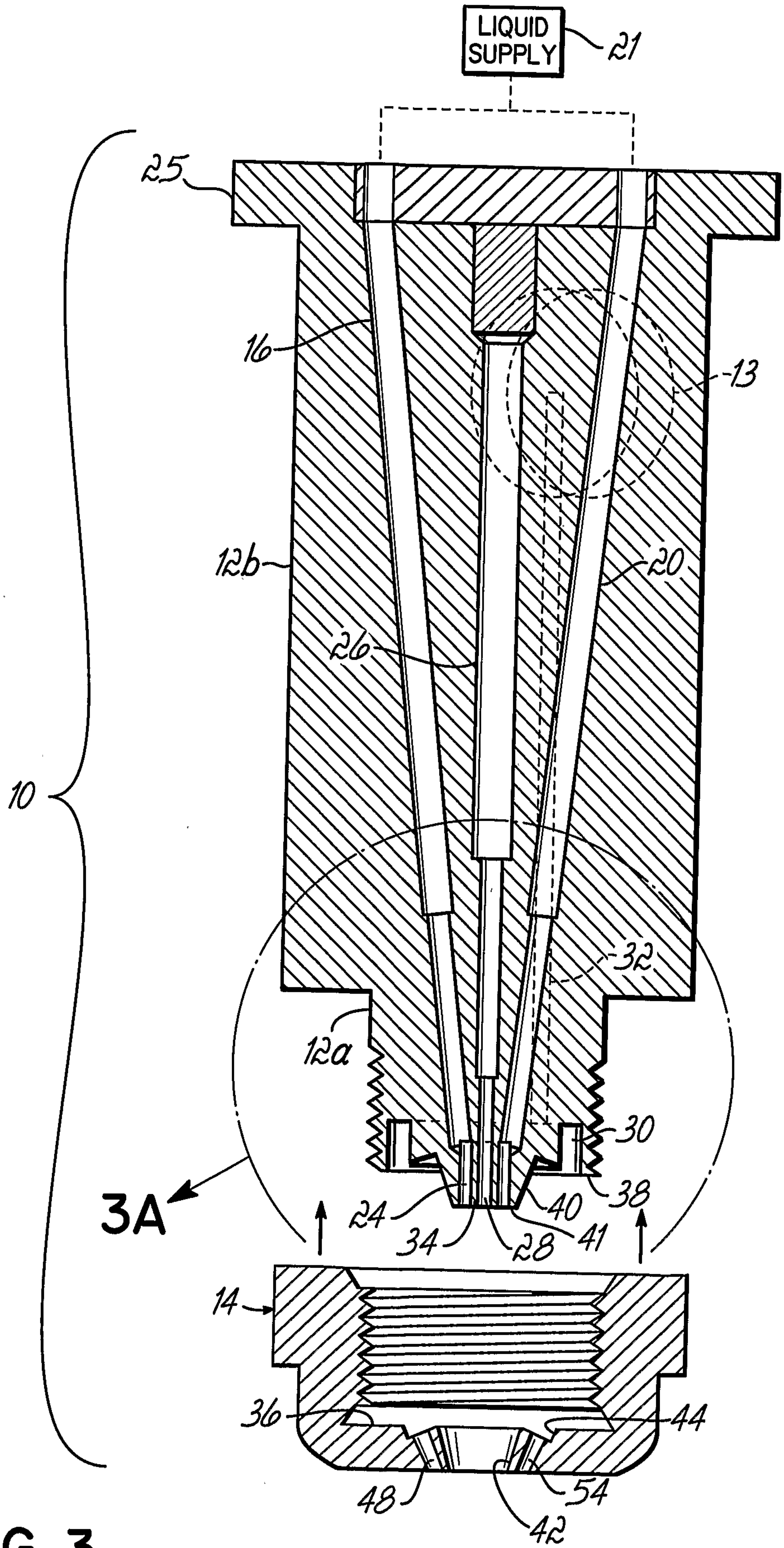
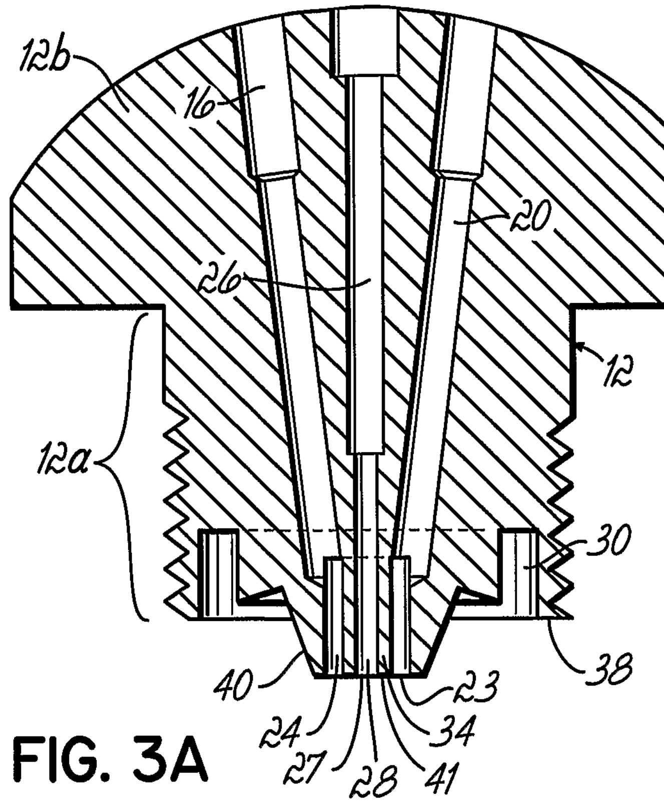

LIQUID SUPPLY
21
25
16
13
12b
20
26
10
32
12a
30
3A
24
40
38
34
28
41
14
36
44
48
54
42

FIG. 3


12b
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20
26
12
12a
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38
23
24
34
27
28
41

FIG. 3A

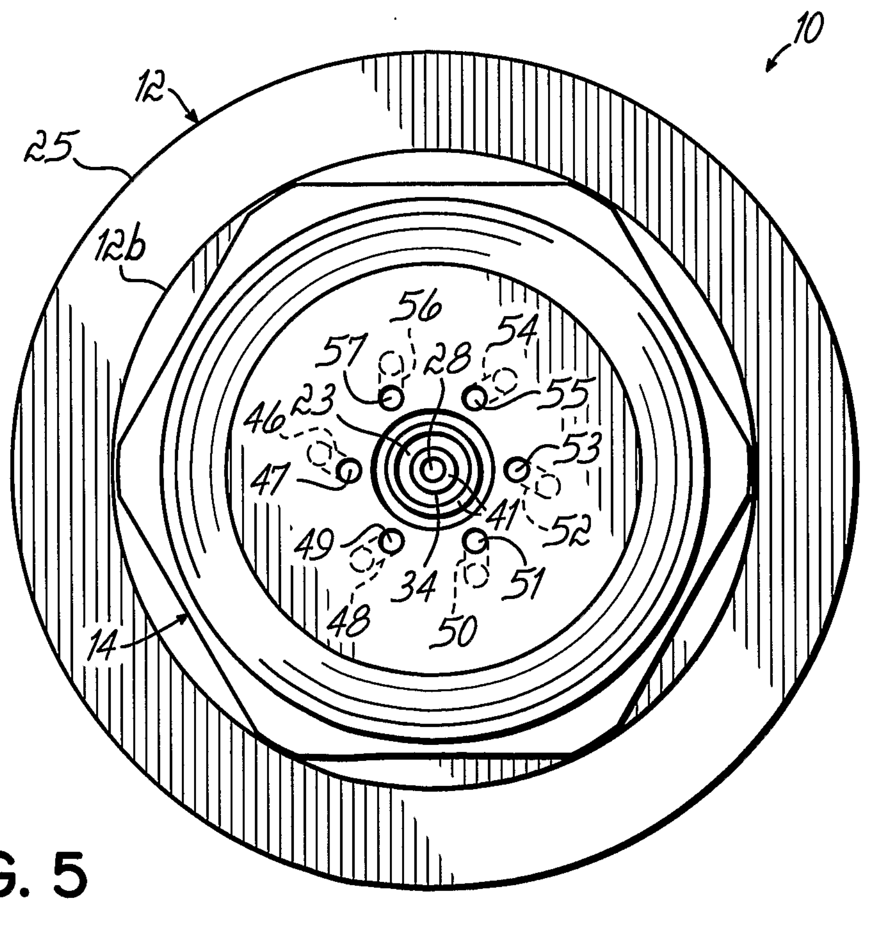

10
12
25
12b
56
57
28
54
55
23
46
53
47
41
52
49
34
51
48
50
14

FIG. 5

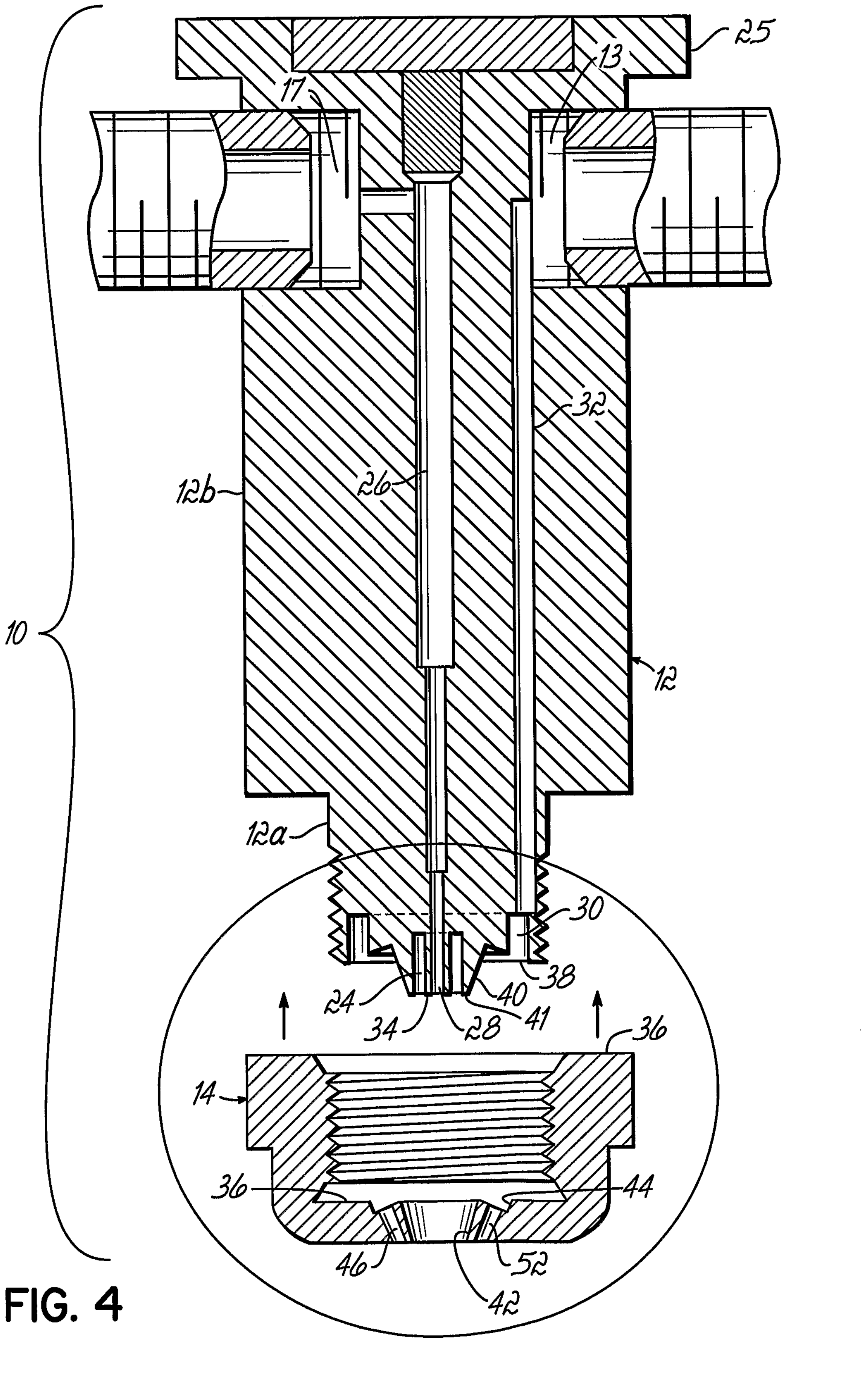


FIG. 4

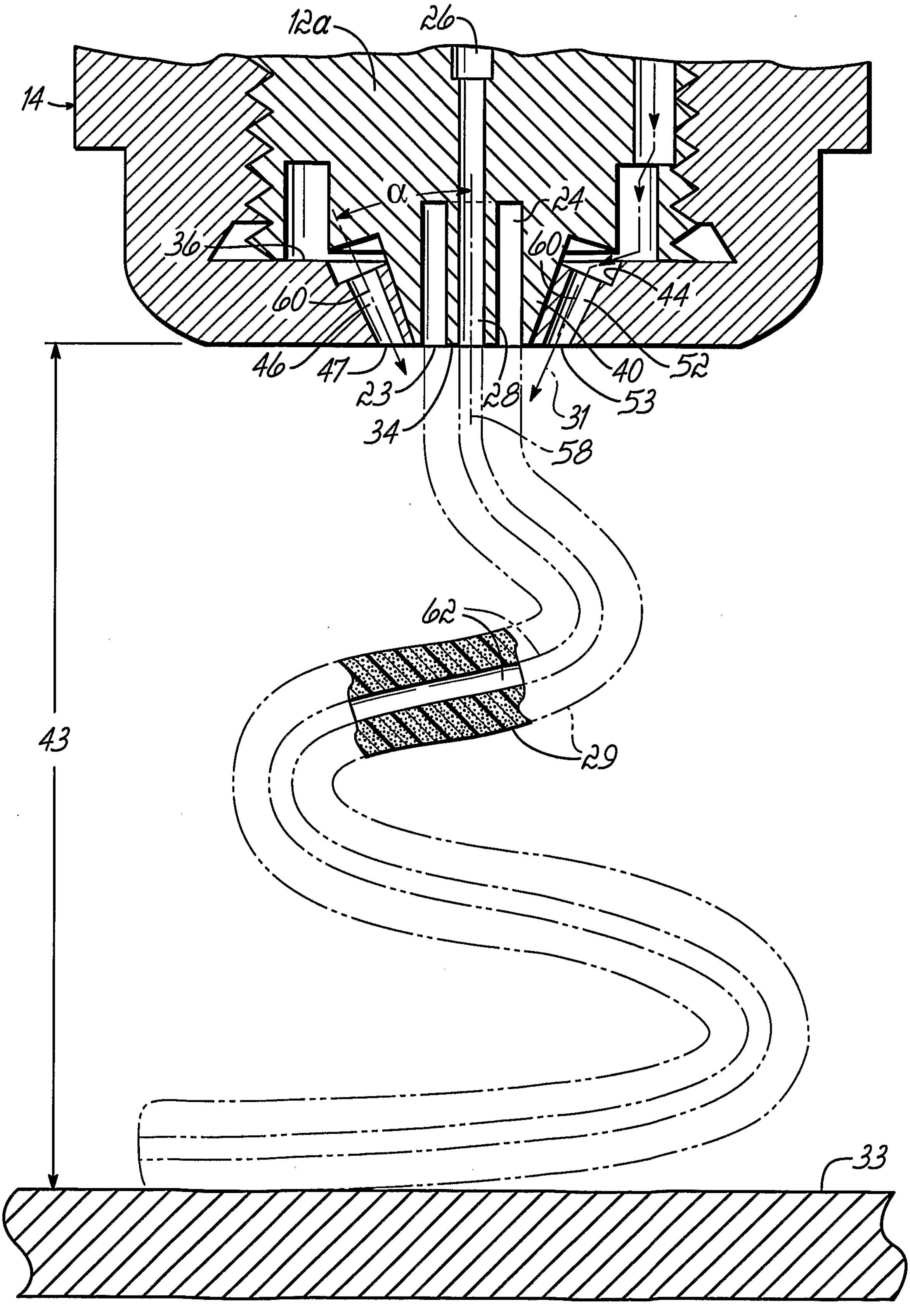


FIG. 6

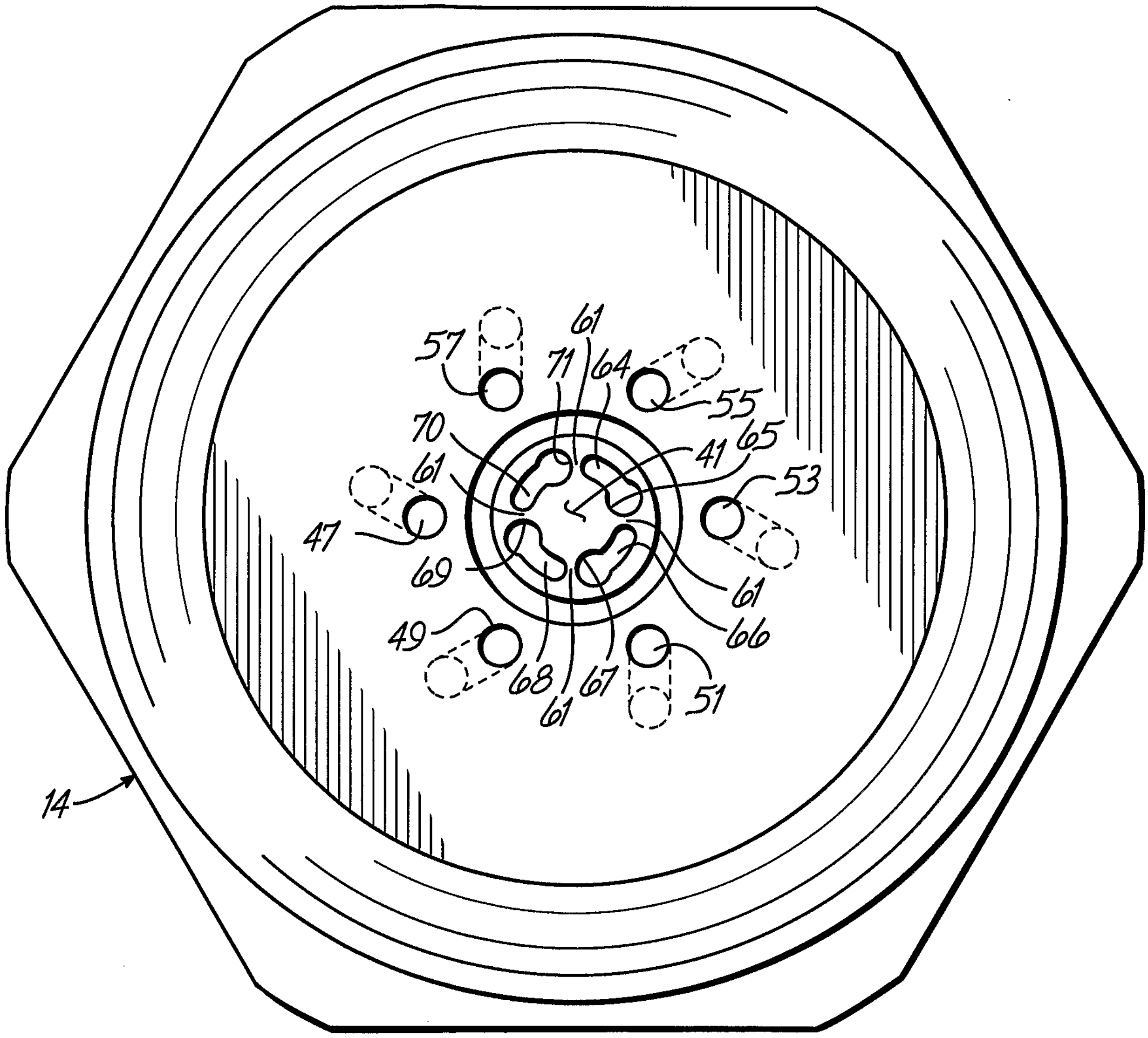


FIG. 7

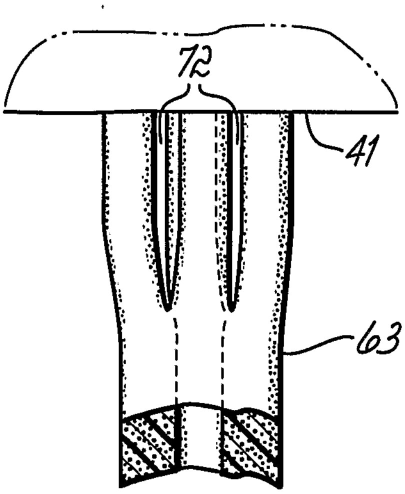


FIG. 7A

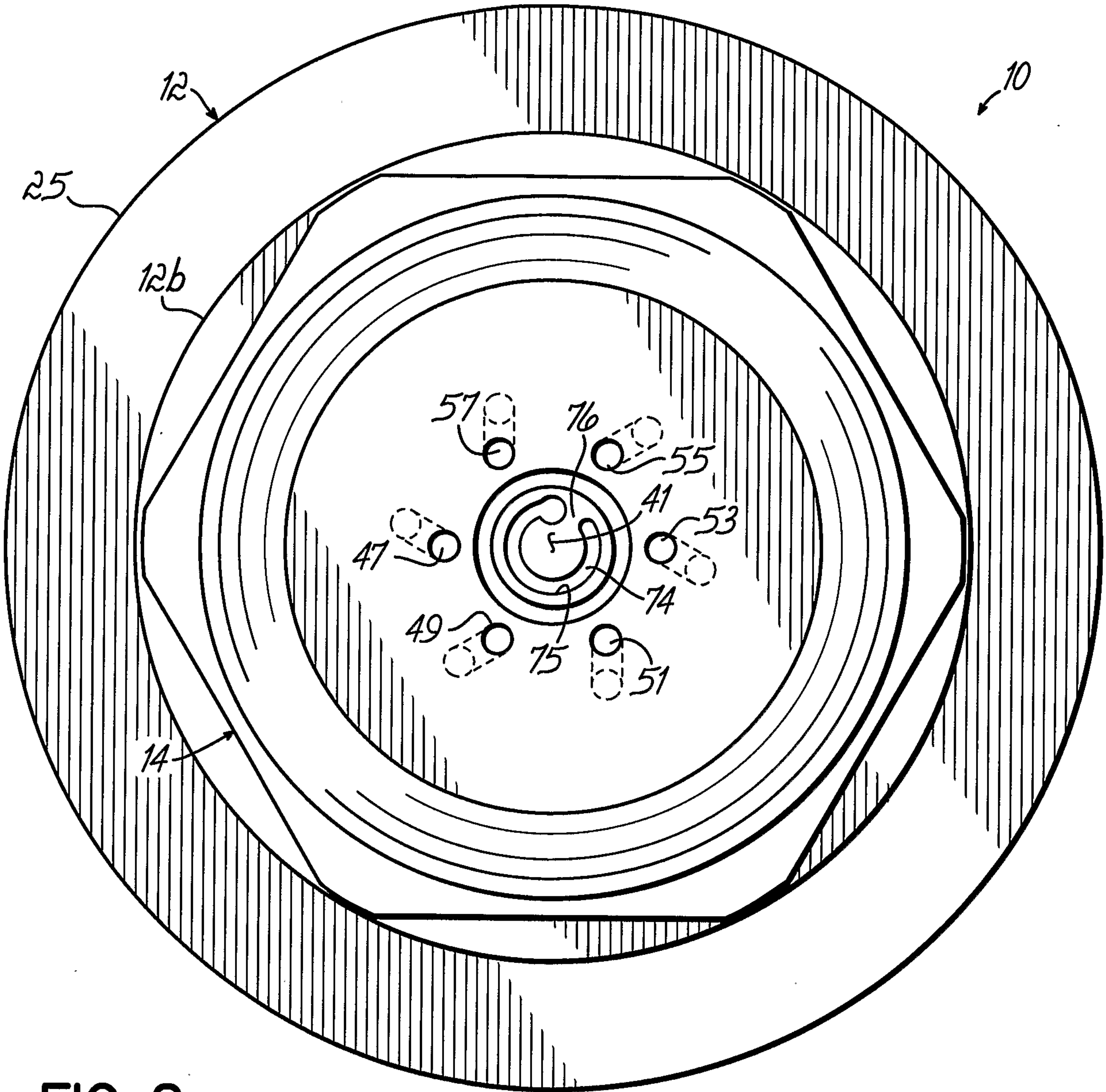


FIG. 8

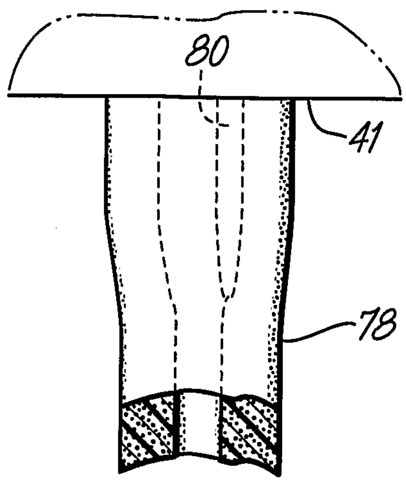


FIG. 8A

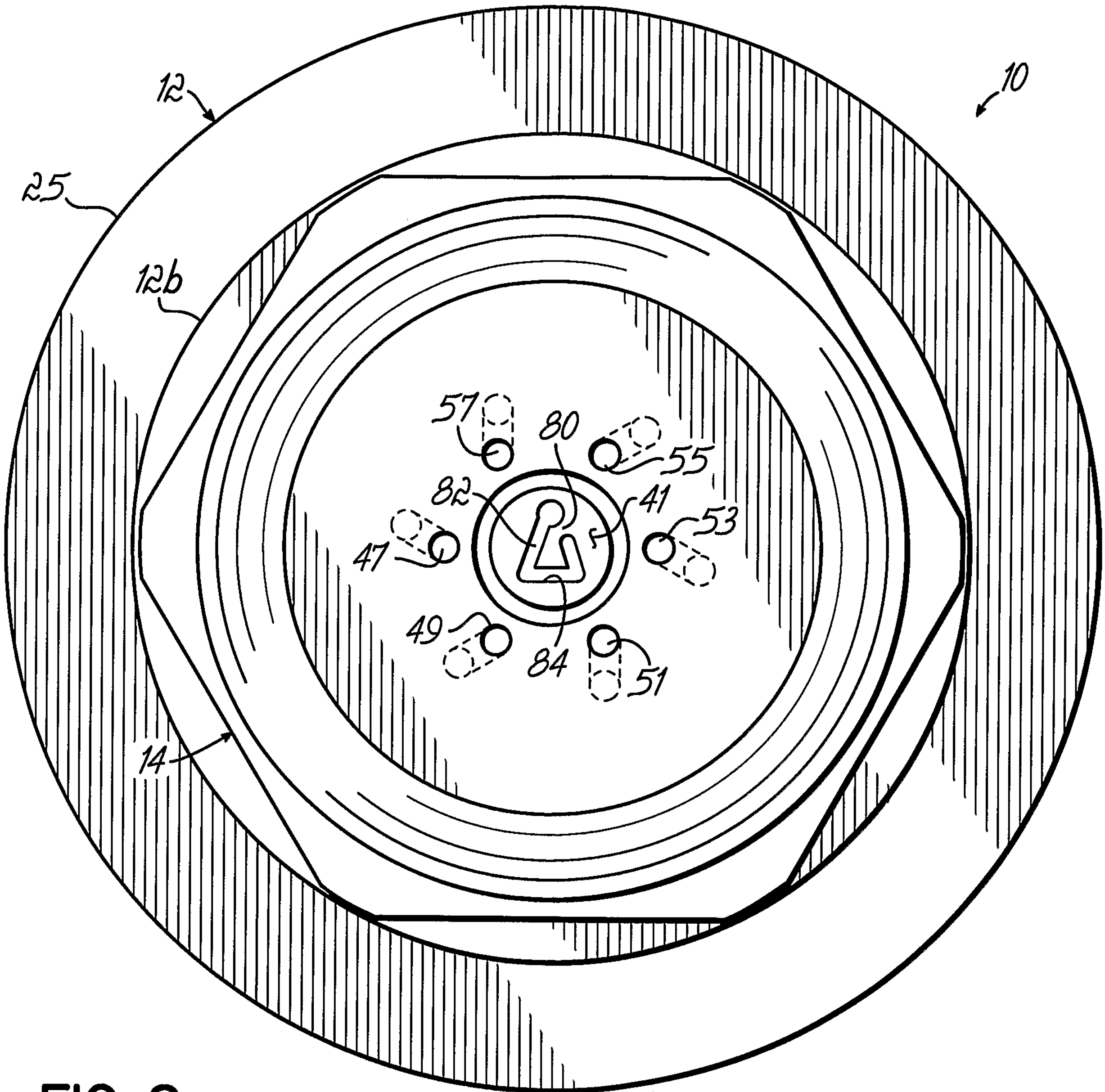


FIG. 9

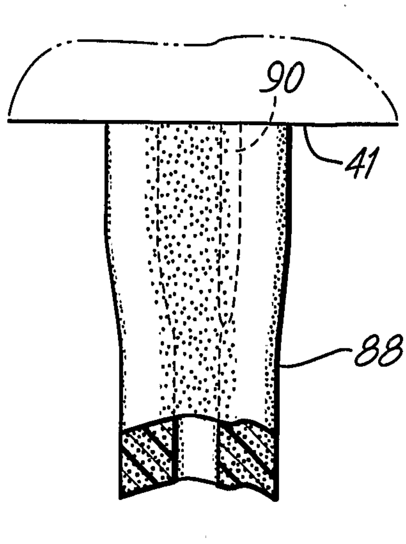


FIG. 9A

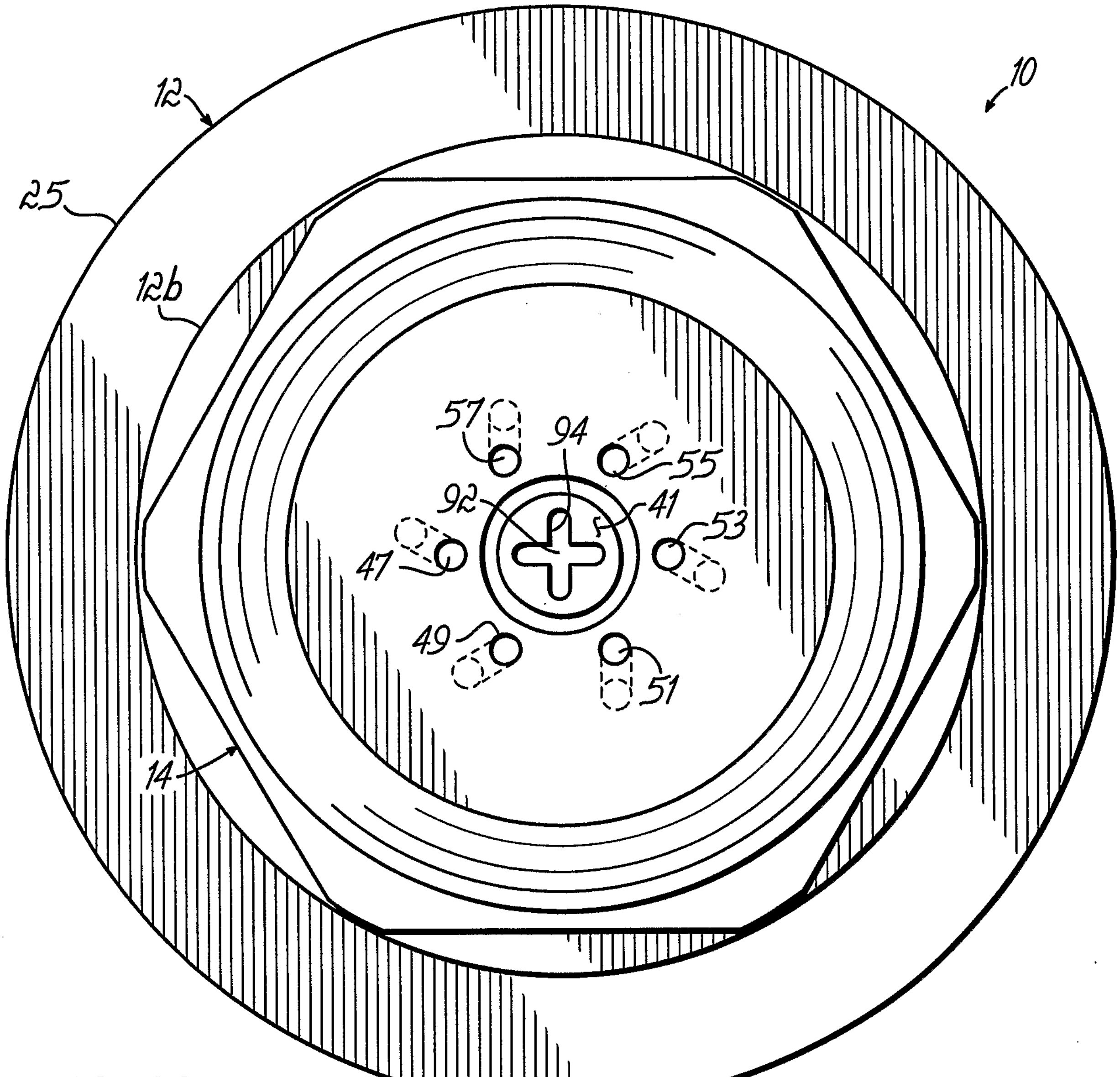


FIG. 10

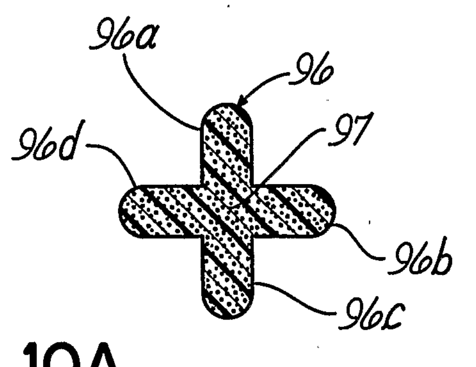


FIG. 10A

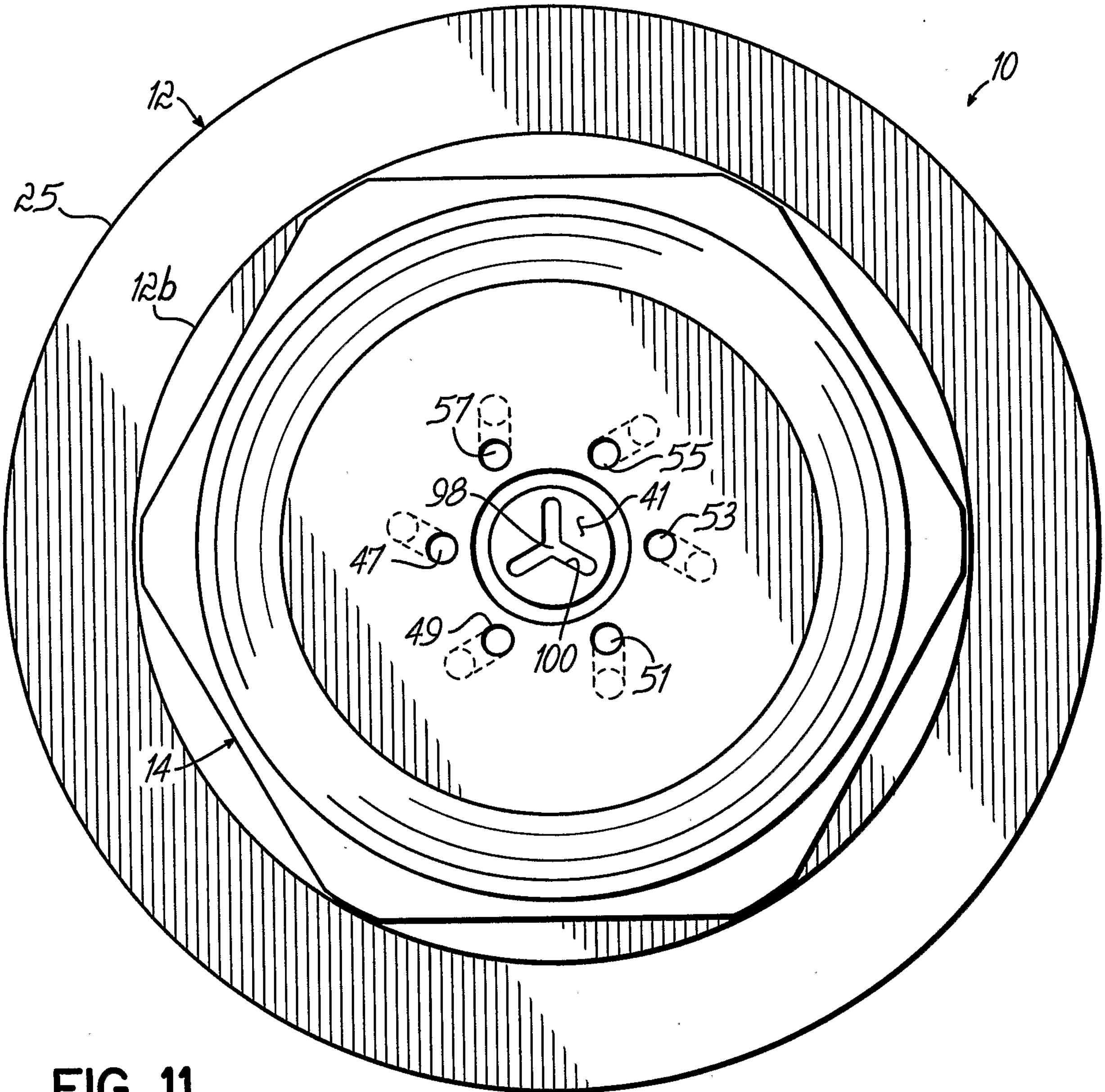


FIG. 11

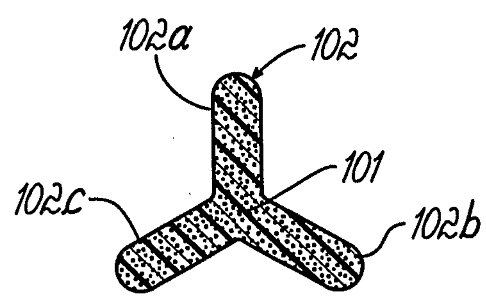


FIG. 11A

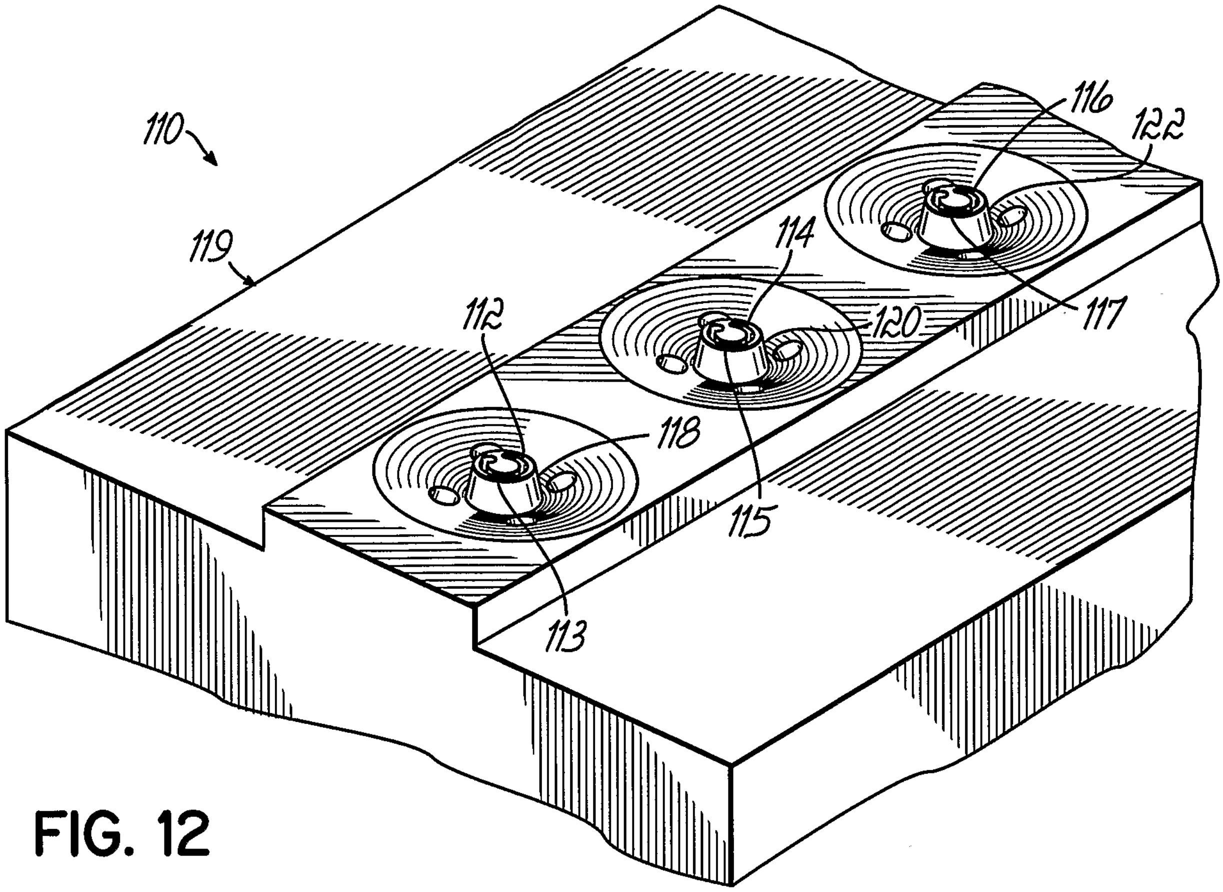
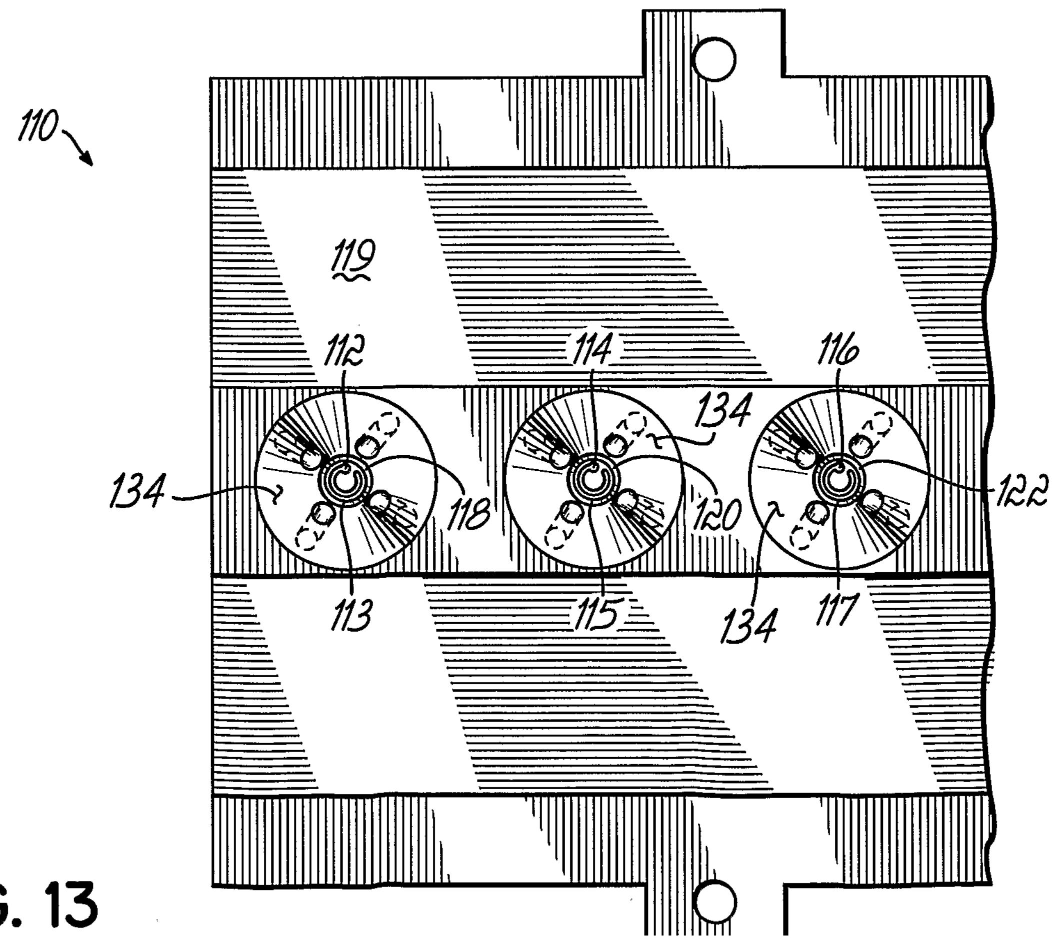

110
119
112
114
116
122
120
118
117
115
113

FIG. 12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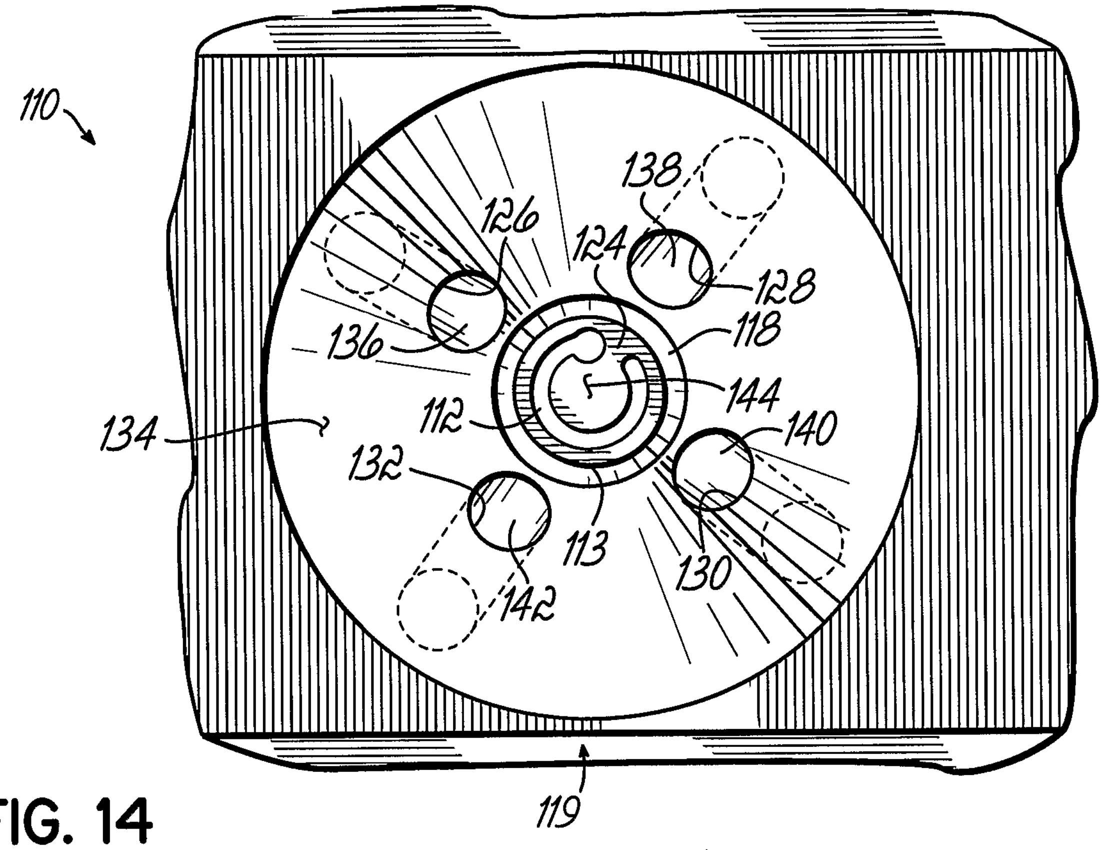
117

FIG. 13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142
119

FIG. 14

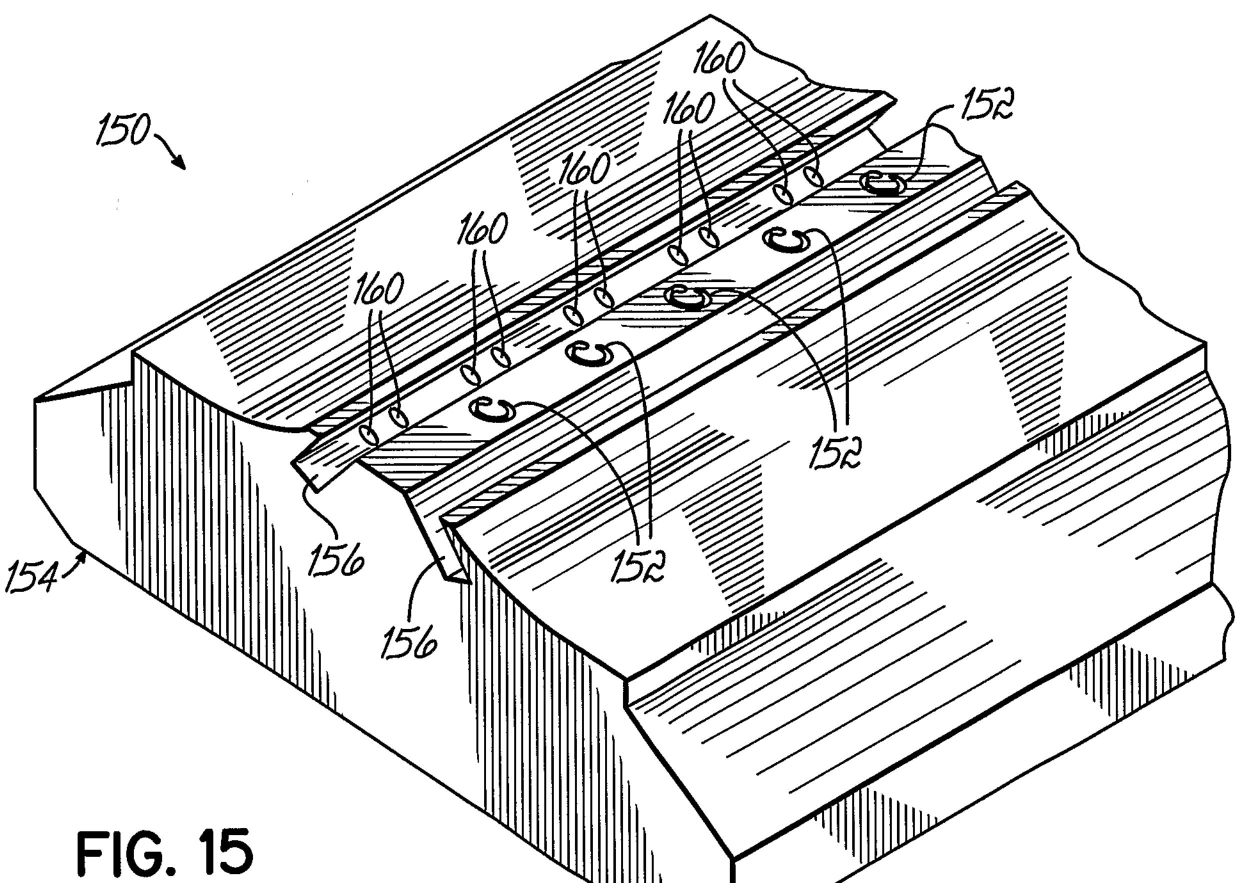
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FIG. 15

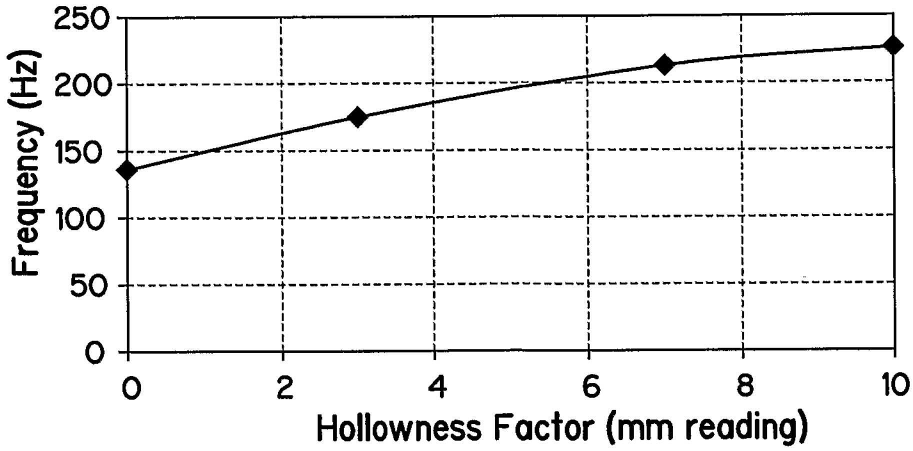

FIG. 16

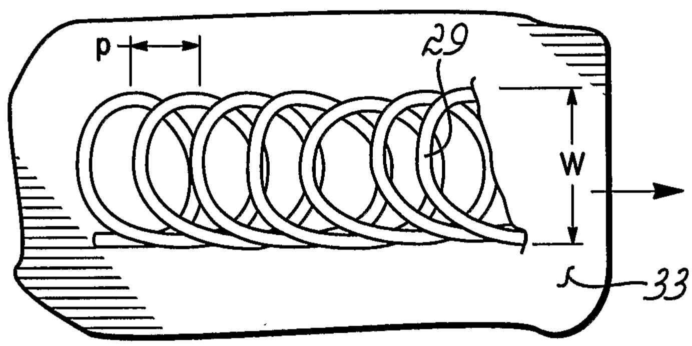

FIG. 17

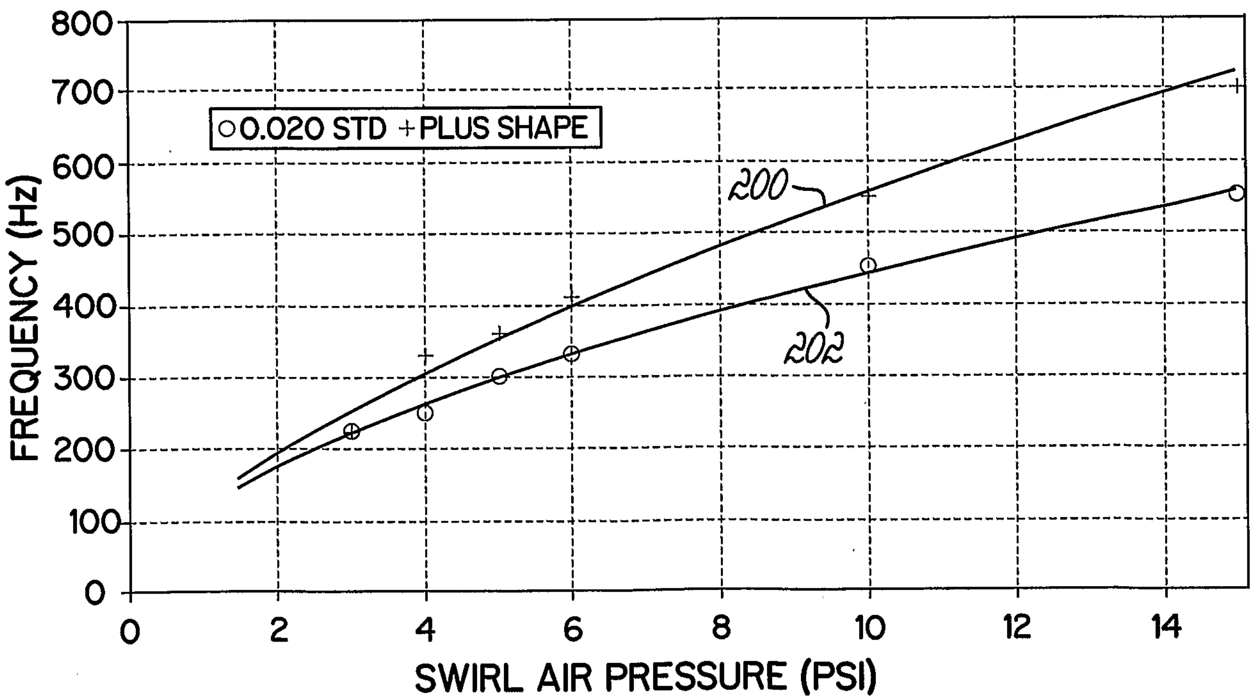

FIG. 18

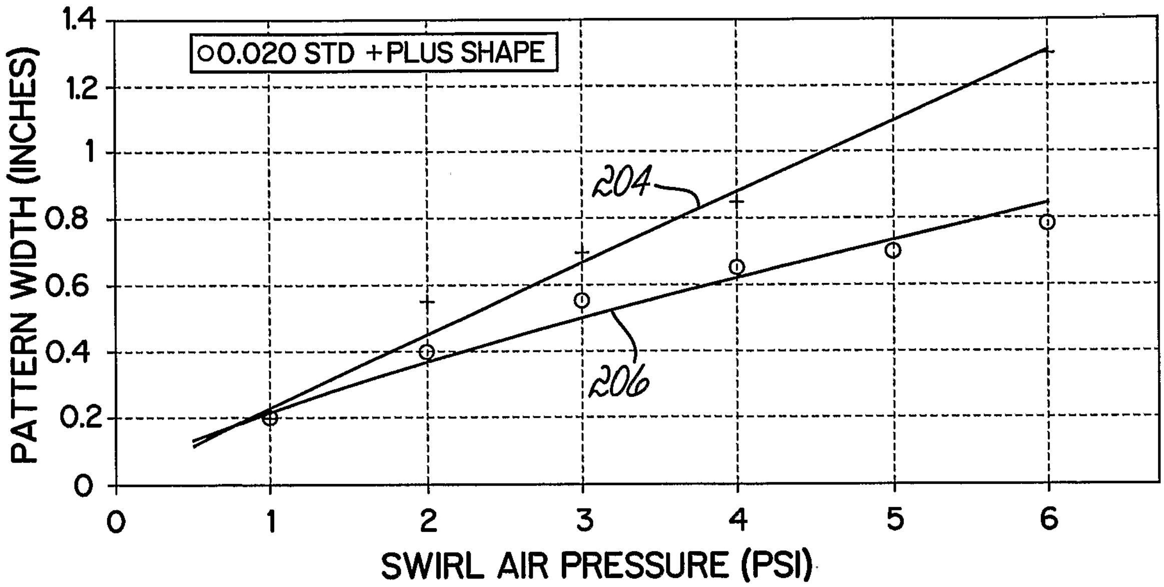
○0.020 STD +PLUS SHAPE
PATTERN WIDTH (INCHES)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
SWIRL AIR PRESSURE (PSI)
204
206

FIG. 19

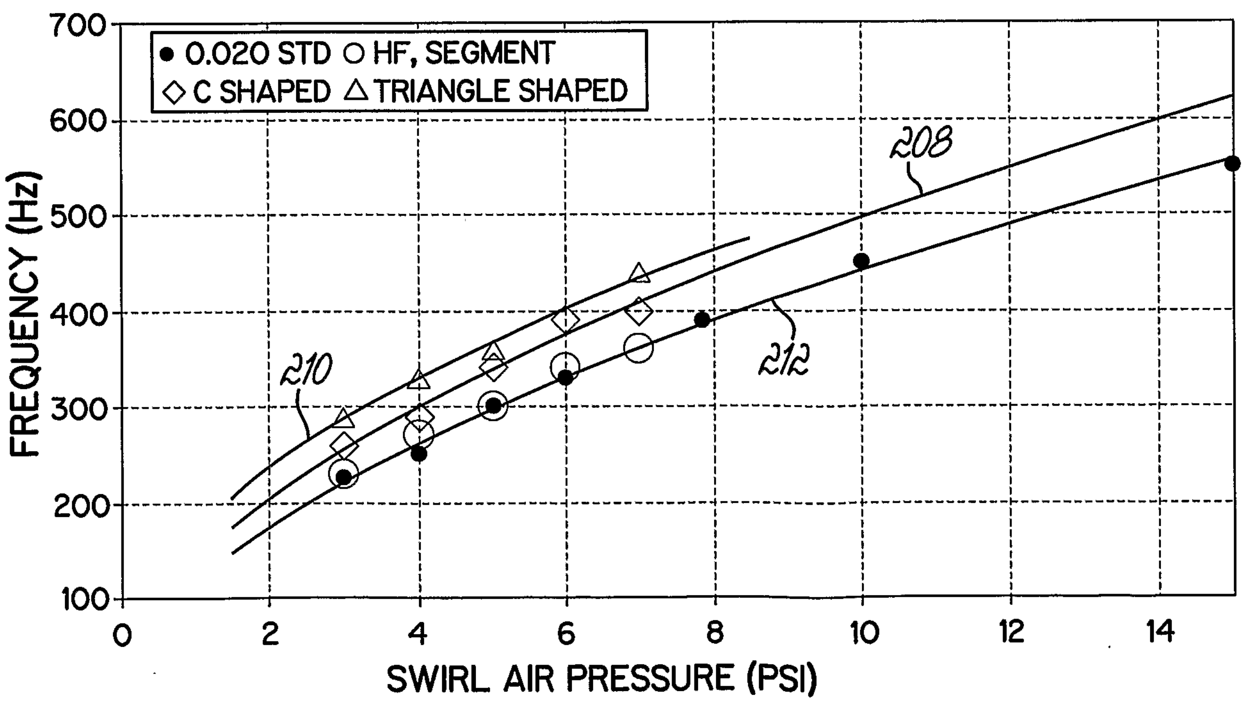
● 0.020 STD ○ HF, SEGMENT
◇ C SHAPED △ TRIANGLE SHAPED
FREQUENCY (Hz)
700
600
500
400
300
200
100
0
2
4
6
8
10
12
14
SWIRL AIR PRESSURE (PSI)
208
210
212

FIG. 20