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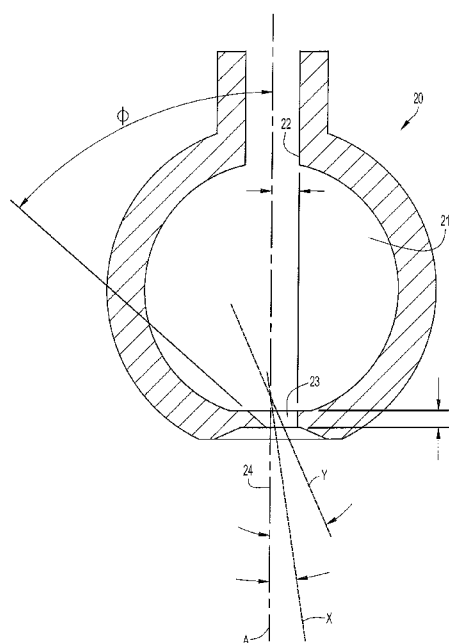


FIG.2

(57) Abstract: A fluidic nozzle of the scanner type has its outlet spray pattern skewed from its chamber axis (A) by an amount determined by the asymmetry of its outlet orifice (23, 33) about that axis. A spray assembly (70, 90) of such nozzles, such as a showerhead, can be designed using nozzles with selected pattern skew angles to achieve desired spray coverage. Indexing tabs (97) and slots (96) are used to angularly position the nozzles in the showerhead. A portion of each nozzle may be formed with the showerhead faceplate (71) as an integral piece.



FLUIDIC SCANNER NOZZLE AND SPRAY UNIT EMPLOYING SAME**CROSS REFERENCE TO RELATED APPLICATIONS**

[001] The present application is a non-provisional application of and claims priority to U.S. Provisional Application No. 62/330,930, entitled "Scanner Nozzle Aim Structure and Method, Aimed Scanner Nozzle Array and Method", filed May 3, 2016, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUNDTechnical Field

[002] The present invention pertains generally to methods and apparatus for fluidically generating desired fluid spray patterns, primarily liquid patterns sprayed in droplets to reliably wet a target area. In a more particular aspect, the invention pertains to enhancements to fluidic oscillator nozzles, their use in spray assemblies (e.g., showerheads) configured to generate a plurality of predeterminedly aimed three-dimensional oscillating sprays of fluid droplets from a plurality of fluidic scanner nozzles, and methods of fabricating such assemblies.

Discussion of the Prior Art

[003] It is known in the prior art to design fluidic oscillators as nozzles that generate spray patterns of liquid droplets resulting from a cyclically deflected liquid jet, as well as nozzle assemblies employing multiple such fluidic oscillators and methods of integrating the geometry of such fluidic oscillators into the nozzle structure. Examples of such designs are found in Applicant's commonly owned prior U.S. Patent Nos. 4122845 (Stouffer et al.), 6240945 (Srinath et al.), 6948244 (Crockett), 7111800 (Berning et al.), 7677480 (Russell et al.) and 8205812 (Hester et al.), and U.S. Pub. No. 2011/0233301 (Gopalan et al.), the disclosures in which are incorporated herein in their entireties to provide background and nomenclature reference and to enable persons of skill in the art to better understand the methods and apparatus of the present invention.

[004] FIGS. 1A and 1B of the accompanying drawings schematically illustrate the fluidic oscillator disclosed Applicant's U.S. Pat. No. 6,938,835 (Stouffer), the disclosure in which is incorporated herein in its entirety. That oscillator **10** is known as a scanner-type oscillator and generates a randomly sweeping three-dimensional

spray pattern to cover a substantially circular target area. This is achieved by forcing water under pressure through a cylindrical interaction/oscillation chamber **11** defined between longitudinally spaced upstream end member **12** and downstream end member **13** having respective axially aligned inlet **14** and outlet **15** apertures, or orifices, defined therethrough. More specifically, these inlet and outlet apertures are each symmetric about their own centroids, and symmetrically and concentrically disposed about the central longitudinal axis **A** of chamber **11**. The inlet aperture in the upstream end member **12** is configured to be coupled to a source **P+** of liquid (e.g., water) under pressure for issuing a jet of liquid into the oscillation chamber. The outlet orifice **15** in the downstream end member discharges a spray of the pressurized liquid to atmosphere and typically onto an area of a surface to be wetted. The cylindrical oscillation chamber **11** is configured to support the generation and volumetric oscillation of a toroidal vortex flow pattern. More specifically, a portion of the periphery of the liquid jet that does not exit through outlet orifice **15** is fed back upstream around the jet to form a three-dimensional vortical flow pattern (i.e., a doughnut or toroidal shaped vortical flow) axially centered about the chamber longitudinal axis **A**. Random perturbations in the flowing liquid cause the vortical flow in the toroid to become diametrically unstable such that the toroid transverse cross-section randomly increases along one angular section of the chamber and correspondingly decreases in the toroid section at the opposite side of the chamber. This is illustrated diagrammatically in FIG. 1A by the larger oval on one side of the liquid jet and the correspondingly smaller oval on the diametrically opposite side of the jet. In FIG. 1B the oval sizes are seen to have reversed position, indicating that the diameters of vortical flow at those locations of the toroid have reversed at some point in time. The jet flowing through the chamber will be deflected away from the larger diameter portion of the toroid and, when so deflected, will cause the spray pattern produced by the jet at outlet orifice **15** to be deflected accordingly. The randomly oscillating three-dimensional deflection of the jet in chamber **11** causes the resulting oscillating outlet jet to break up into a generally conical pattern of liquid droplets about a spray axis that is substantially coaxial with chamber axis **A**. More particularly, the outflowing jet is randomly deflected both transversely (i.e., radially) relative to the chamber axis **A** and angularly (i.e., tangentially) relative to that axis, and as a result of such deflection generates a spray pattern of droplets that covers a predetermined area of a target.

[005] Applicant's prior research and development in designing and manufacturing nozzle assemblies and components have resulted in several new structures and methods for generating fluid or liquid sprays having unique spray patterns of appropriately sized droplets which are projected toward a desired target area or in a pre-defined spray direction at a desired droplet velocity. These developments have, in turn, fostered customer requests for even more specialized nozzle assemblies and components to solve specific problems or provide creative spray patterns. For example, showerheads with applicant's fluidic oscillators have achieved some significant commercial success, partly because they provide pleasing sprays without requiring excessive flow rates.

[006] Many considerations go into the design of a functionally and aesthetically pleasing showerhead. For example, a showerhead typically includes a faceplate perforated to issue a plurality of water jets in a spray pattern that covers a predetermined large solid angle; part of the showerhead design process involves configuring the faceplate to provide a desired spray pattern. Further, in water conserving designs, less water is used to shower or wet a given area, and it is recognized that low flow showerheads can use water more efficiently by aerating the water stream. Further, some showerheads are designed to be adjustable to issue different spray patterns. Another consideration is the fact that hard water may result in calcium and magnesium deposits clogging the head, reducing the flow and changing the spray pattern. These design issues and many others are described in U.S. Patent 7,740,186 (Macan et al.) and the prior art cited therein.

[007] Rain can style showerheads have become increasingly popular because they provide the user with a gentle rain-like shower pattern of spray with the goal of drenching the user's entire body with just enough pressure to make it mildly invigorating. The desired sensation for users has been described as a "natural rainfall experience". A rain can shower head issues its gentle spray pattern from an array of outlets defined through a faceplate surface, and is traditionally mounted on a long gooseneck shower arm to provide an above-the-head position, but can also be configured for use on a traditional showerhead-supporting pipe nipple projecting from an elevated position on a wall. The rain can shower head typically has a front face that is larger than that of an ordinary shower head in order that the parallel streams issued from its respective outlets might provide maximum coverage. For example,

such a showerhead may have a six-inch-diameter face with forty (40) or more spray channels in an effort to provide the full-body drenching spray that simulates rainfall. The effect desired can be characterized as a relatively uniform spray originating from co-planar openings in a larger surface area than is provided by a typical showerhead.

[008] Stationary spray heads with fixed jets are the simplest of all spray heads, consisting essentially of a water chamber or manifold and one or more outlet orifices issuing respective jets directed to produce a constant single or multi-jet pattern. Stationary spray heads with adjustable outlet orifices are typically of a similar construction, except that it is possible to make some adjustment of the outlet opening size and/or the number of outlets utilized. However, such outlets in showerheads issue straight jets that continuously impact essentially the same location on a user's skin, often causing a stinging type discomfort. Rain can spray heads represent an effort to reduce this discomfort by enlarging the area emitting the sprays; however, the resulting spray is often too gentle for many users who enjoy a shower spray that produces a pleasant but not painful impact on the body without discomfort.

[009] Fluidic oscillators are known in the prior art for providing a wide range of liquid spray patterns by cyclically deflecting a liquid jet fluidically, i.e., without the use of mechanical moving parts. The absence of moving parts to effect jet deflection has the advantage of fluidic oscillators not being subject to the wear and tear that adversely affects the reliability and operation of pneumatic and reciprocating nozzles. Examples of fluidic oscillators may be found in many patents, including U.S. Pat. Nos. 3,185,166 (Horton & Bowles), 3,563,462 (Bauer), 4,052,002 (Stouffer & Bray), 4,151,955 (Stouffer), 4,157,161 (Bauer), 4,231,519 (Stouffer), 4,508,267 (Stouffer), 5,035,361 (Stouffer), 5,213,269 (Srinath), 5,971,301 (Stouffer), 6,186,409 (Srinath), 6,253,782 (Raghu) and 6,938,835 (Stouffer). The disclosures in these patents are incorporated herein for reference and background purposes regarding the various ways in which fluid jets can be fluidically deflected.

[0010] Fluidic oscillators, as described in these and other patents, are capable of issuing an oscillating jet that breaks up into a spray of droplets which are much more like rainfall than the water-drilling static spray from a standard showerhead. Unfortunately, it is not a trivial matter to replace several nozzles generating static jets

with plural fluidic oscillators. Typical rain can showerhead assemblies have a plurality of nozzles fed via a bowl-shaped water chamber or manifold with a central flow inlet which is configured with a pivoting ball joint so that the shower head assembly can be aimed. In such cases, because of the nature of the inlet, the flow inside the manifold becomes highly turbulent, with the result that flow to each outlet orifice differs from the flow to adjacent outlet orifices, and flow to any individual outlet orifice is variable over time. Fluidic scanner nozzle inserts are also sensitive to such turbulence, as well as to problems pertaining to sealing each insert in the housing. Therefore, a traditional showerhead incorporating the above-described fluidic elements likely may not spray as intended because turbulent inlet or manifold flow disrupts the operation of fluidic oscillators.

[0011] In U.S. Pub. No. 2011/0233301 (Gopalan et al., cited above) there is disclosed a rain can type showerhead having a manifold for delivering received water under pressure to an array of multiple fluidic oscillator inserts in a faceplate. Although that showerhead is quite satisfactory for most purposes, neither that showerhead nor any of those described in the other above-cited patents provides arrays of fluidic scanner nozzles in a single molded piece having varying aim angles to permit predetermined contouring of overall combined spray patterns. There is also no disclosed approach to reliably providing larger coverage areas and more uniform coverage across the target area. Finally, there is no practical way disclosed in the prior art of making the egress orifice throat side of the multi-nozzle scanner array in one piece.

Terminology

[0012] It is to be understood that, unless otherwise stated or contextually evident, as used herein:

The terms “axial”, “axially”, “longitudinal”, “longitudinally”, etc., refer to dimensions extending parallel to the longitudinal axis of an interaction chamber in a fluidic device.

The terms “radial”, “lateral”, “transverse”, etc., refer to dimensions extending perpendicularly from the interaction chamber axis.

The terms “angle”, “angular”, “rotationally”, etc., unless otherwise stated, refer to angular dimensions relative to the interaction chamber axis.

The terms “up”, “down”, “upper”, “lower”, “upward”, “downward”, “top” and “bottom” are used herein for convenience only in describing parts and their positions as they appear in the drawings and are not to be construed as limiting positions and orientations parts of the inventions and parts thereof.

The term “centroid” as used herein refers to the geometric center of a two dimensional object such as an orifice.

SUMMARY OF THE INVENTION

[0013] Fluidic scanner nozzles of the present invention overcome the difficulties described above by providing outlet orifice configurations that permit nozzle designers to achieve differently and selectively aimed scanning sprays that have particular utility in fluidic showerheads. The geometries of the scanner nozzles and their methods of manufacture permit use of a minimum of parts and provide for economical and effective sealing between parts. More specifically, plural scanner nozzles, or parts thereof, may be molded in simple open and close tooling as one piece in a scanner array with the individual nozzles configured to have their respective spray configurations predeterminedly aimed to effect a desired overall spray pattern from the array. Still more specifically, the outlet orifice or “throat” portions of the scanner nozzles in the array are molded with appropriate aiming configurations as one piece. The nozzle aim angle variations across the array allows for nozzle assemblies capable of reliably generating sprays with larger coverage areas and more uniform droplet coverage across a target area. The particular advantage of this method of aiming or yawing the sprays is that, when molding the scanner array, a very simple shutoff, perpendicular to the draw of the mold, is maintained over all scanners in the array. This is also an advantage, though not as great, when making even a single aimed scanner nozzle outlet orifice geometry.

[0014] According to the present invention an asymmetrical or off-axis outlet orifice or throat is provided to predeterminedly direct or aim the generally conical scanner nozzle output spray. In one disclosed embodiment the divergence angle from the nozzle chamber axis of the centerline of the generally conical outlet spray pattern is about one-third of the maximum angle between the asymmetric outlet orifice and chamber axis.

[0015] In accordance with an aspect of the present invention, a scanner nozzle inlet orifice is symmetrically defined about the chamber axis, but its outlet orifice is not to thereby define an “aiming” aperture or throat. The required asymmetry of the outlet aperture may result from it being asymmetrical about its centroid with the centroid disposed on the chamber axis, or by being symmetrical about its centroid but with the centroid transversely displaced from the chamber axis, or both.

[0016] In accordance with the present invention, outlet parts of an array of fluidic scanner nozzles may be molded in a single molded piece whereby different individual scanner nozzles can have different respective aim angles. The aim angle variation across the array allows for nozzle assemblies capable of reliably generating sprays with larger coverage areas and more uniform sprayed fluid droplet coverage across a target area.

[0017] In accordance with one aspect of the present invention, the fluidic scanner oscillator of the type described above in connection with FIGS. 1A and 1B is modified such that its outlet orifice is asymmetric relative to the chamber axis. This asymmetry may be the result of the orifice perimeter being asymmetric about its own centroid while disposed on or about the chamber axis, or the orifice centroid being transversely displaced from the chamber axis, or both. In the preferred embodiment the asymmetry is provided by the perimeter of the orifice being asymmetric about the orifice centroid. In any case, the asymmetry causes the transversely and angularly deflected outlet jet to be redirected to an extent determined by the particular asymmetry. As a consequence, the axis of the generally conical scanning spray pattern is skewed, or yawed, from the chamber axis, thereby permitting the spray to be aimed as desired by the orifice geometry. The scanner oscillator of the invention includes an interaction chamber that can have any of a variety of configurations to produce the desired spray pattern and, in a preferred embodiment, is generally spherical or formed from two spherical segments joined at their bases. Also in the preferred embodiment, the asymmetric outlet orifice periphery takes the form of an axially short (i.e., short relative to the axial length of the chamber) frustum converging in a downstream direction.

[0018] In accordance with another aspect of the invention a plurality of the modified scanner oscillator nozzles are deployed in an array in a spray unit, such as a showerhead. The designed aim angles of the nozzles and their positions in the array

permit the spray unit designer to preselect desired overall spray patterns. A given spray pattern provided by the array of the aimed scanner nozzles can be produced by fewer nozzles than the number of openings required for a conventional spray head that issues parallel static streams. As a result, the spray head with the aimed scanner nozzles may be smaller than conventional spray heads and, since fewer nozzles are used, the amount of water required to cover a given target is less.

[0019] In another aspect of the invention a fluidic scanner nozzle comprises an interaction chamber defined longitudinally between upstream and downstream walls and surrounded transversely. The upstream wall has an inlet opening defined therein for receiving pressurized liquid and delivering it as a jet into the chamber along a chamber longitudinal axis. The downstream wall has an outlet orifice defined therein for issuing a liquid spray from the chamber into ambient environment surrounding the nozzle. To permit aiming or skewing the outlet spray pattern from the chamber axis, the outlet orifice may have a perimeter that is asymmetrically disposed relative to the chamber axis. The inlet opening and outlet orifice may be at least partially longitudinally aligned along the chamber axis, and the outlet orifice may have a generally frustoconical configuration converging outwardly from the chamber and disposed asymmetrically about the chamber axis.

[0020] The improved fluidic scanner oscillator described above has utility in a wide variety of applications and may be used as an individual oscillator or as a combination of oscillators. The spray producing assembly of oscillators described above is not limited to showerheads; rather, it can be used to provide designed sprays for any type of sprayer application.

[0021] The above and still further features and advantages of the present invention will become apparent upon consideration of the definitions, descriptions and descriptive figures of specific embodiments thereof set forth herein. In the detailed description below, like reference numerals in the various figures are utilized to designate like components and elements, and like terms are used to refer to similar or corresponding elements in the several embodiments. While these descriptions go into specific details of the invention, it should be understood that variations may and do exist and would be apparent to those skilled in the art in view of the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1A is a schematic illustration of a prior art fluidic scanner-type oscillator representing one condition during its operation.

[0023] FIG. 1B is a schematic illustration of the oscillator of FIG. 1A representing another condition during its operation.

[0024] FIG. 2 is a schematic illustration in longitudinal section of illustrating operation of a fluidic scanner oscillator of the present invention.

[0025] FIG. 3 is a perspective view in longitudinal section of one fluidic scanner oscillator embodiment of the present invention FIG. 2.

[0026] FIG. 4A is a top view in plan of the bottom portion of another embodiment of the scanner oscillator of the present invention.

[0027] FIG. 4B is a view in longitudinal section of the scanner oscillator of FIG. 4A.

[0028] FIG. 5A is a top view in plan of the bottom portion of another embodiment of the scanner oscillator of the present invention.

[0029] FIG. 5B is a view in longitudinal section of the scanner oscillator of FIG. 5A.

[0030] FIG. 6A is a top view in plan of the bottom portion of yet another embodiment of the scanner oscillator of the present invention.

[0031] FIG. 6B is a view in longitudinal section of the scanner oscillator of FIG. 6A.

[0032] FIG. 7 is a view in perspective from below of a showerhead of the present invention.

[0033] FIG. 8 is an exploded view in longitudinal section of an embodiment of the showerhead of FIG. 7 employing fluidic scanner oscillators of the present invention partially molded into the showerhead faceplate.

[0034] FIG. 9 is a partial perspective view from below in longitudinal section of the showerhead faceplate of FIG. 8 showing a bottom portion of a fluidic scanner oscillator of the invention molded into the faceplate.

[0035] FIG. 10A is a top view in plan of the bottom portion of still another embodiment of the fluidic scanner oscillator of the present invention.

[0036] FIG. 10B is a view in longitudinal section of the fluidic scanner oscillator of FIG. 10A.

[0037] FIG. 11A is a top view in plan of the bottom portion of a further embodiment of the fluidic scanner oscillator of the present invention.

[0038] FIG. 11B is a view in longitudinal section of the fluidic scanner oscillator of FIG. 11A\

[0039] FIG. 12A is a top view in plan of the bottom portion of still a further embodiment of the fluidic scanner oscillator of the present invention.

[0040] FIG. 13 is an exploded view in longitudinal section of another embodiment of the showerhead of the present invention employing fluidic scanner oscillators of the type illustrated in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0041] Specific dimensions set forth below are by way of example for particular embodiments to assist in an understanding of the illustrated structure; these dimensions are not to be construed as limiting the scope of the invention.

[0042] Referring specifically to FIG. 2 of the accompanying drawings, a fluidic scanner oscillator **20** comprises an interaction chamber **21** of substantially spherical configuration and having a longitudinal axis **A**. An inlet lumen **22** is disposed preferably concentrically about axis **A** and is typically connected to a source of pressurized liquid to deliver a jet of the liquid into the upstream end of the chamber. Substantially diametrically opposed to the inlet lumen is an outlet orifice or aperture **23** for issuing the liquid jet to the surrounding ambient environment through a short annular collar region **24** defined as a recess in the outer surface of the chamber wall and diverging from orifice **23**.

[0043] The periphery of outlet orifice **23** is configured as an irregular conical frustum converging in a downstream direction from the downstream end of the chamber with chamber axis **A** passing therethrough. The terminus of outlet orifice **23** is an angularly continuous edge of negligible axial length, as opposed to a lumen or passage having finite axial length. The convergence angle of the perimeter of orifice **23** varies angularly (i.e., as a function of perimetric location) such that it is asymmetrically disposed about its own centroid and about axis **A**. In the illustrated embodiment the maximum convergence angle ϕ of orifice **23** relative to axis **A** is approximately 49° and shown to the left of the axis in FIG. 2; the convergence angle is at a minimum, on the order of 1°, at the diametrically opposed location to the right of the axis in the drawing.

[0044] As described above in connection with the scanning oscillator shown in FIGS. 1A and 1B, a portion of the periphery of the liquid jet that does not exit through outlet orifice **23** is fed back upstream alongside the jet to form a three-dimensional vortical flow pattern (i.e., a doughnut or toroidal shaped vortical flow) axially centered about the chamber axis **A**. Random perturbations in the flowing liquid cause the vortical flow in the toroid to become diametrically unstable such that the toroid transverse cross-section randomly increases along different angular sections thereof and correspondingly decreases in the toroid sections at correspondingly opposite sides of the chamber. The jet flowing through the chamber and toroid will be deflected away from the larger diameter portion of the toroid and, when so deflected, will cause the spray pattern produced by the jet at outlet orifice **23** to be deflected accordingly. The randomly oscillating deflection of the jet in chamber **21** causes the resulting oscillating outlet jet to break up into a generally conical pattern of liquid droplets about a spray axis that, in the absence of the asymmetry of outlet orifice **23**, would be substantially coaxial with chamber axis **A**. However, as a result of the orifice asymmetry, the axis **X** of the scanning spray pattern egressing from chamber **20** is skewed (i.e., the spray pattern experiences yaw) relative to axis **A** by an angle θ determined by the orifice configuration and transverse position relative to axis **A**. Moreover, the conical spray pattern becomes asymmetrical as indicated by the nominal boundary line **Y** of the deflected spray pattern shown in the drawing.

[0045] It should be noted that obtaining selected aiming is sensitive to the axial length of the outlet orifice relative to its transverse dimension. If the throat length is too short, the spray aim angle will not be achieved reliably. If the throat angle is too long, then the cone angle of the output spray will be reduced. Also, the entrance angle of the scanner outlet orifice in the particular example illustrated in FIG. 2 (i.e., $49^\circ + 1^\circ = 50^\circ$) must be considered: if the entrance angle is too small, then the cone angle of the spray will be reduced; if the entrance angle is too large, then the desired aim angle of the output spray may not be achieved. As examples of dimensions in embodiments successfully tested, axial lengths of the outlet throats ranged from 0.010 inch to 0.020 inch, and diameters of the downstream throat ends ranged from 0.039 inch to 0.044 inch. In order to effect different skew or aiming angles, the angle of the asymmetrically converging throat wall relative to the chamber axis varied along its periphery between 19° and 31° in one embodiment, between 49° and 1° in

another embodiment, between 13° and 37° in a further embodiment, and between 1° and 14° in still a further embodiment.

[0046] The ability to redirect the spray pattern axis **X** as a function of the asymmetry of outlet orifice **23** permits the spray pattern to be aimed as desired. More particularly, in a spray head having a flat front face at which the outlets of a plurality of scanner oscillators are coplanar, differently aimed coplanar oscillators can be positioned by the designer to achieve a wide variety of combined spray patterns and overall spray coverage.

[0047] The oscillator **30** illustrated in FIG.3 is functionally the same as oscillator **20** of FIG. 2 and is made in two parts, a top part **35** and bottom part **36**, to define a generally spherical interaction chamber in two respective halves joined at their bases. Top part **35** includes an inlet connector **37** extending upstream from its top in which liquid inlet lumen or passage **32** to chamber **31** is defined. A hemispherical downward-facing surface of top part **35** defines the upper half of interaction chamber **31** and is bounded perimetrically by a depending cylindrical wall **39**. An annular flange **38** projects radially outward from wall **39**.

[0048] Bottom part **36** has a hemispherical upward-facing surface defining the lower half of chamber **31** and has the oscillator's asymmetrical outlet orifice **33** and surrounding collar region **34** defined therethrough. The wall **40** of bottom part **36** includes an annular ledge **41** surrounding the rim of the lower half of chamber **31**. At the radial outer extremity of ledge **41** the wall **40** extends upwardly as a cylindrical section **42**, radially spaced from the chamber. The resulting annular space is configured for receiving depending cylindrical wall **39** of top part **35**. With top part **35** and bottom part **36** thusly joined, the bottom edge of wall **39** abuts ledge **41**. Similarly, the annular upper edge of wall section **42** abuts the bottom surface of ledge **41**, and the circumferential inner surface of wall section **42** abuts the circumferential outer surface of wall **39**. These abutting surfaces facilitate sealing between parts **35** and **36**, either by tight fit abutment, the use of one or more grommets, silicone sealant or the like, or any combination thereof. The bottom surface **47** of wall section **42** projects radially outward from wall **40** and serves as a support flange for the assembly as described in connection with the showerhead of FIG. 13. An indexing or positioning tab **43** extends a short distance radially outward at a predetermined angular location on the periphery of wall section **42**. Tab **43**

permits oscillator **30** to be positioned in a predetermined angular orientation in a showerhead, or the like, as described hereinbelow in relation to FIG. 13.

[0049] The bottom hemispherical parts of fluidic scanner oscillators **45**, **55** and **65**, each of the general type illustrated in FIGS. 2 and 3, are illustrated in FIGS. 4A & 4B, 5A and & 5B and 6A & 6B, respectively. Each oscillator is molded into a sprayer unit **44**, only a downstream portion of which is shown in these drawings, the planar bottom surface **50** of which is the face of the sprayer. Oscillator nozzles **45**, **55** and **65** are substantially identical except for the configurations of their respective outlet orifices which are asymmetrically (or symmetrically for no skewing or yaw) contoured as described above to effect different aiming directions. Specifically, the outlet orifice in oscillator **45** is asymmetrically configured relative to the oscillator axis identically to the outlet orifice **23** in FIG. 2, such that the aim angle of the outlet spray is deflected downward to the right. The outlet orifice in oscillator **55** is symmetrical about the oscillator axis so that there is no deflection of the spray pattern axis from the oscillator axis. The outlet orifice in oscillator **65** is asymmetrically configured relative to the oscillator axis such that the aim angle of the outlet spray is deflected downward to the left.

[0050] It will be appreciated that any number of oscillators can be thusly combined in a sprayer with their aim angles selected to effect a desired overall spray pattern. As an example, a showerhead **70** employing plural fluidic scanner nozzles of the present invention is illustrated in FIGS. 7, 8 and 9. Showerhead **70** comprises a faceplate **71** having a substantially planar front surface and with multiple spray openings **72** defined therein, each opening configured to issue a spray pattern from a respective fluidic scanner nozzle. The fluidic scanner nozzles are preferably arrayed in the circular faceplate **71** at different radial distances from the plate center to cooperate with the aiming angles of the scanner nozzles so that the resultant spray from the showerhead provides a widely distributed and uniform distribution of water droplets.

[0051] The bottom parts **75** of fluidic scanner nozzles of the type illustrated in FIGS. 4A, 4B and 5A, 5B and 6A, 6B are molded as part of faceplate **71** and extend therethrough. In assembling the showerhead the top parts **76** of these nozzles, which are substantially similar to the nozzle top parts **35** in FIG. 3 without the positioning tabs **43**, are placed in the faceplate **71** from above to join with and

communicate with respective bottom parts **75**. The faceplate is then placed in the showerhead housing **77** and secured and sealed therein by screws (not shown) extending through appropriate bores **79** defined through housing and into threaded bores **78** defined in the faceplate. Pressurized water is received via a showerhead inlet fitting **80** which is preferably made of a metal such as brass, or of plastic or the like, and is adapted to engage a fitting such as a standard ½-inch pipe fitting. The received water is delivered to the various oscillator nozzles via respective inlet connectors **81** formed as a portion of the upper parts **76** of the nozzles and which are configured similarly to connector **37** in FIG. 3. In this regard, when faceplate **71** is sealed in housing **77** there is an open volume or space above the faceplate that receives the pressurized water and serves as a manifold from which the turbulently flowing water is distributed to the connectors **81**. Alternatively, housing **77** may be provided with fittings integrally formed therein to receive respective connectors **81**.

[0052] Instead of molding the bottom part of the fluidic nozzles as part of a showerhead faceplate, a plurality of fluidic scanner nozzles **85A**, **85B**, **85C** of the type illustrated in FIG. 3 may be disposed as respective nozzle units in an appropriately configured faceplate **91** of a showerhead **90** as illustrated in FIG. 13. The bottom parts of three such nozzles are illustrated in FIGS. 10A & 10B, 11A & 11B and 12A & 12B, each shown to have a respective aim angle as described in connection with the embodiments illustrated in FIGS. 4A & 4B, 5A & 5B and 6A & 6B. The faceplate **91** has a plurality of bores **92** defined therethrough for receiving respective scanner nozzles **85**. Each bore **92** includes an upper cylindrical section **93** of a relatively large diameter and a lower cylindrical section **94** of relatively smaller diameter, the demarcation between the sections being defined by an annular shoulder **95**. Each nozzle **85** includes an annular support flange **98**, configured similarly to support flange **47** of FIG. 3, and arranged to abut shoulder **95** when a scanner nozzle is fully longitudinally inserted into a respective bore **92**. In this position the bottom portion of the scanner nozzle extends into the lower section **94** of the bore with the upper part of the nozzle residing in the upper bore section **93**.

[0053] One or more longitudinally extending indexing slots **96** are defined at different angular positions in the boundary wall of lower section **94** and are configured to longitudinally receive and angularly engage a indexing or positioning tab **97** extending radially from the outer wall of the bottom section of each scanner nozzle

85. Positioning tabs **97** are configured substantially the same as positioning tab **43** described in connection with FIG. 3. Insertion of a scanner nozzle **85** into any bore **92** is prevented unless the nozzle positioning tab **97** is angularly aligned and engaged with one of the indexing slots **96** defined in that bore. This permits a nozzle having a specific aim axis direction to have its location in the showerhead nozzle array predetermined, permits specific design and preselection of the overall pattern of the showerhead spray. In other words, oscillator nozzles having specific aim angles and be inserted into the faceplate in specific angular orientations to effect a desired three-dimensional combined outlet spray pattern for the showerhead.

[0054] This scanner nozzle configuration and showerhead assembly and method of the present invention provide some significant advantages, including:

1. The simplicity of the scanner nozzle member geometry, which includes an essentially spherical interaction region with coaxial, opposed inlet lumen (i.e., power nozzle) and outlet orifice or throat, allows for simplified construction of scanner fluidic arrays.
 - a. All of the scanner nozzle throats with the downstream half of the interaction regions can be molded in one piece of the showerhead. In this embodiment, the power nozzle and upstream half of the interaction region are molded individually for each nozzle. The component count is equal to the number of fluidic nozzles plus one, which greater than in some prior fluidic showerheads, but the components are much simpler to design, mold, and assemble.
 - b. All of the scanner throats with the downstream half of the interaction regions can be molded in one piece of the showerhead and all of the power nozzles and upstream half of the interaction regions can be molded in one other piece of the showerhead. In this scenario, component count for the fluidics is two, no matter how many fluidics are included. This embodiment also allows each showerhead to be designed and built to whatever scanner fluidic geometry is best suited rather than using more or less standard components that are typical in prior fluidic showerheads.

- i. To facilitate the alignment of a large number of fluidic nozzles in the assembly, one of the components may be molded out of a flexible material to allow it to conform to the other hard plastic component.
 - ii. To facilitate the alignment of a large number of fluidics in the assembly of the present invention and to allow aiming or bending of the fluidics into various aim angles, both of the components may be molded out of a flexible material to allow them to conform to each other and to a hard face or backing plate that holds prescribed aim angles.
2. The economy inherent in the manufacturing process for making the scanner nozzles and the showerhead nozzle assembly (i.e., the essentially spherical interaction region coaxial opposed inlet and outlet) provide the option of economically molding the downstream parts of the interaction regions in the one piece of the showerhead assembly. Since the inlet lumen and upstream half of the interaction region are molded individually for each fluidic, the assembly of the showerhead is simplified and the components are much simpler to design and mold.

[0055] As described, the bottom parts of showerhead nozzles may be molded together economically in a single molding operation, and this rapid and economical fabrication method provides a showerhead or nozzle assembly that reliably generates sprays covering large coverage areas with uniform coverage across target area. The method and structure of the present invention thus provides a practical way to make the throat sides of the distinct scanner inserts in a scanner array in a single molded piece in commercially available “open and close” tooling, by providing arrays with selected aiming features molded into the throats of each scanner insert.

[0056] The scanner fluidic nozzle geometry of the present invention does not require a large surface seal as is required in prior fluidic nozzles; rather the nozzle of the present invention is molded in two parts that are joined by a very simple cylindrical seal which is much more robust than a large surface seal.

[0057] As noted herein, although the invention has been disclosed with primary application for a showerhead, the principles are equally applicable for and sprayer unit requiring area coverage of liquid spray.

[0058] Having described preferred embodiments of new and improved fluidic scanner nozzles and sprayer assemblies employing same, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. It is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the present invention as defined by the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. A fluidic scanner nozzle comprising:
an interaction chamber (21, 31) defined longitudinally between an upstream end and a downstream end and having a longitudinal chamber axis (A);
said upstream end having an inlet opening (22, 32) for receiving pressurized fluid and delivering the pressurized liquid as a jet into said chamber along said chamber axis;
said downstream end having an outlet orifice (23, 33) for issuing a generally conical outlet spray of liquid droplets from said chamber into ambient environment;
wherein said outlet orifice is asymmetric relative to said chamber axis to thereby skew the direction of the liquid outlet spray relative to the chamber axis.
2. The scanner nozzle of claim 1 wherein said outlet orifice is asymmetric about its centroid.
3. The scanner nozzle of claim wherein said outlet converges in a downstream direction at an angle of convergence that varies with perimetric location about the orifice.
4. The scanner nozzle of claim 1 wherein the centroid of the outlet orifice is transversely offset from the chamber axis.
5. The scanner nozzle of claim 1 wherein said outlet orifice is configured as an irregular conical frustum converging in a downstream direction.
6. The scanner nozzle of claim 1 wherein said upstream and downstream ends are configured as generally spherical segments having respective bases at which said segments are joined.
7. The scanner nozzle of claim 1 comprising first (35) and second (36) members secured and sealed together to define said interaction chamber therebetween, said first member including said upstream wall and a first open end longitudinally opposite inlet opening, said second member including said downstream wall and a second

open end longitudinally opposite said outlet orifice, and wherein said first and second members are joined at said first and second open ends.

8. The scanner nozzle of claim 7 wherein said second member is defined in and through a plate (71) of a sprayer (70) in which a plurality of said second members (75) of a respective plurality of scanner nozzles are formed integrally therein in an array.

9. The scanner nozzle of claim 8 wherein said plate is a front plate of a shower head.

10. The scanner nozzle of claim 7 wherein the nozzle (85) is disposed in a first bore (92) defined through a plate (91) of a sprayer (90) along with a plurality of said nozzles (85) disposed in respective additional bores (92) defined through the plate, wherein said second member includes an angular positioning tab (97) projecting radially outward therefrom at a predetermined angular location about the chamber axis, and wherein said plate has at least one indexing slot (96) defined longitudinally at the periphery of said first bore and arranged to receive and rotationally engage said positioning tab with said nozzle in an angular position determined by the angular location of said indexing slot.

11. A nozzle assembly configured as a showerhead (70, 90) comprising a faceplate (71, 91) configured to receive a plurality of inserted fluidic scanning spray nozzles (85) of the type that issue a scanning liquid jet that provides a generally conical spray pattern of liquid droplets, the assembly comprising:

a nozzle assembly housing (77) having an inlet configured to receive pressurized liquid from a liquid supply and an interior manifold configured to provide the pressurized liquid to the plurality of spray nozzles;

wherein each of said spray nozzles comprises an outlet orifice (23, 33) and an interaction chamber (21, 31) having a longitudinal axis (A) in which the liquid jet is continuously deflected in three dimensions about the chamber axis to provide said conical spray pattern from said outlet orifice;

wherein at least one of said nozzles has said outlet orifice asymmetric relative to said chamber axis to thereby skew the direction of the liquid outlet spray pattern relative to the chamber axis.

12. The nozzle assembly of claim 11 wherein:

the faceplate (71) is a plastic molded piece having a front surface that is substantially planar;

the outlet orifices of said plurality of nozzles terminate proximate said front surface; and

portions (75) of each of said nozzles including said outlet orifices are formed integrally with said faceplate.

13. The nozzle assembly of claim 11 wherein said outlet orifice is asymmetric by virtue of it being asymmetric about its centroid.

14. The nozzle assembly of claim 11 wherein said outlet orifice is asymmetric by virtue of its centroid being transversely offset from said chamber axis.

15. The nozzle assembly of claim 11 wherein each of said nozzles comprises:

First (35) and second (36) members secured and sealed together to define said interaction chamber therebetween, said first member including an inlet opening (32) defined therein and a first open end longitudinally opposite said inlet opening, said second member including said outlet orifice and a second open end longitudinally opposite said outlet orifice, and wherein said first and second members are joined at said first and second open ends.

16. The nozzle assembly of claim 15 wherein each nozzle is disposed in a respective bore (94) defined through said faceplate, wherein said second member includes an angular positioning tab (97) projecting radially outward therefrom at a predetermined angular location about the chamber axis, and wherein said faceplate has at least one indexing slot (96) defined longitudinally at the periphery of at least one of said bores and arranged to receive and rotationally engage said positioning tab with the nozzle in an angular position in that bore determined by the angular location of said indexing slot.

17. The nozzle assembly of claim 11 wherein the outlet orifices of each of said nozzles terminate in a common plane.
18. The nozzle assembly of claim 11 wherein more than one of said nozzles has said outlet orifice asymmetric relative to said chamber axis to thereby skew the direction of their liquid outlet spray patterns relative to their chamber axes.
19. A method of aiming a liquid spray pattern issued from a fluidic scanner nozzle of the type having an interaction chamber in which a liquid jet is deflected in three dimensions relative to a longitudinal chamber axis such that the jet, upon issuing from a chamber outlet orifice, forms said spray pattern in a substantially conical configuration of liquid droplets about a spray axis, said method comprising the step of:
- positioning said outlet orifice asymmetrically relative to said chamber axis to skew the spray axis relative to the chamber axis.
20. The method of claim 19 wherein the step of positioning comprises configuring said outlet orifice asymmetrically relative to its centroid.

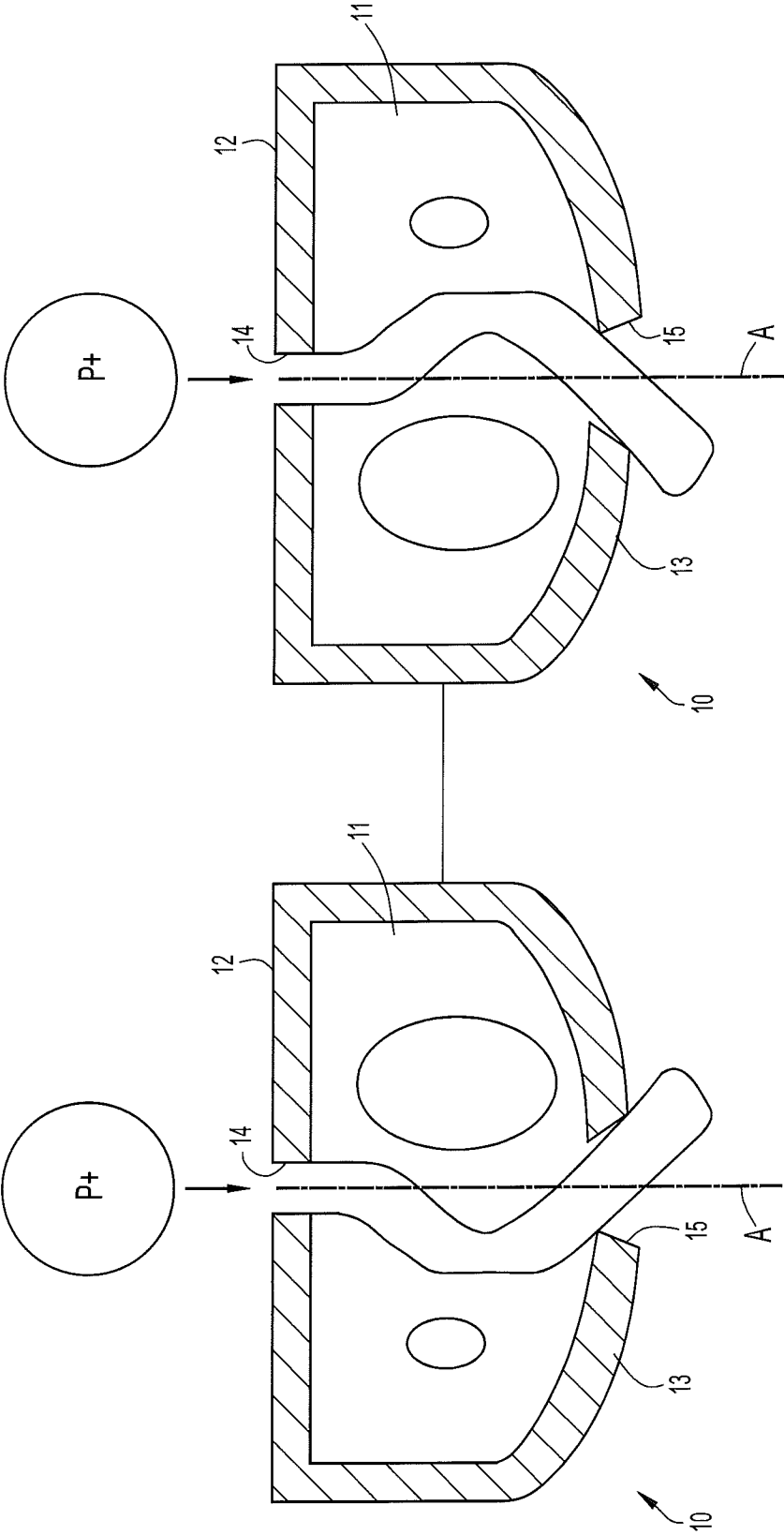


FIG.1B
PRIOR ART

FIG.1A
PRIOR ART

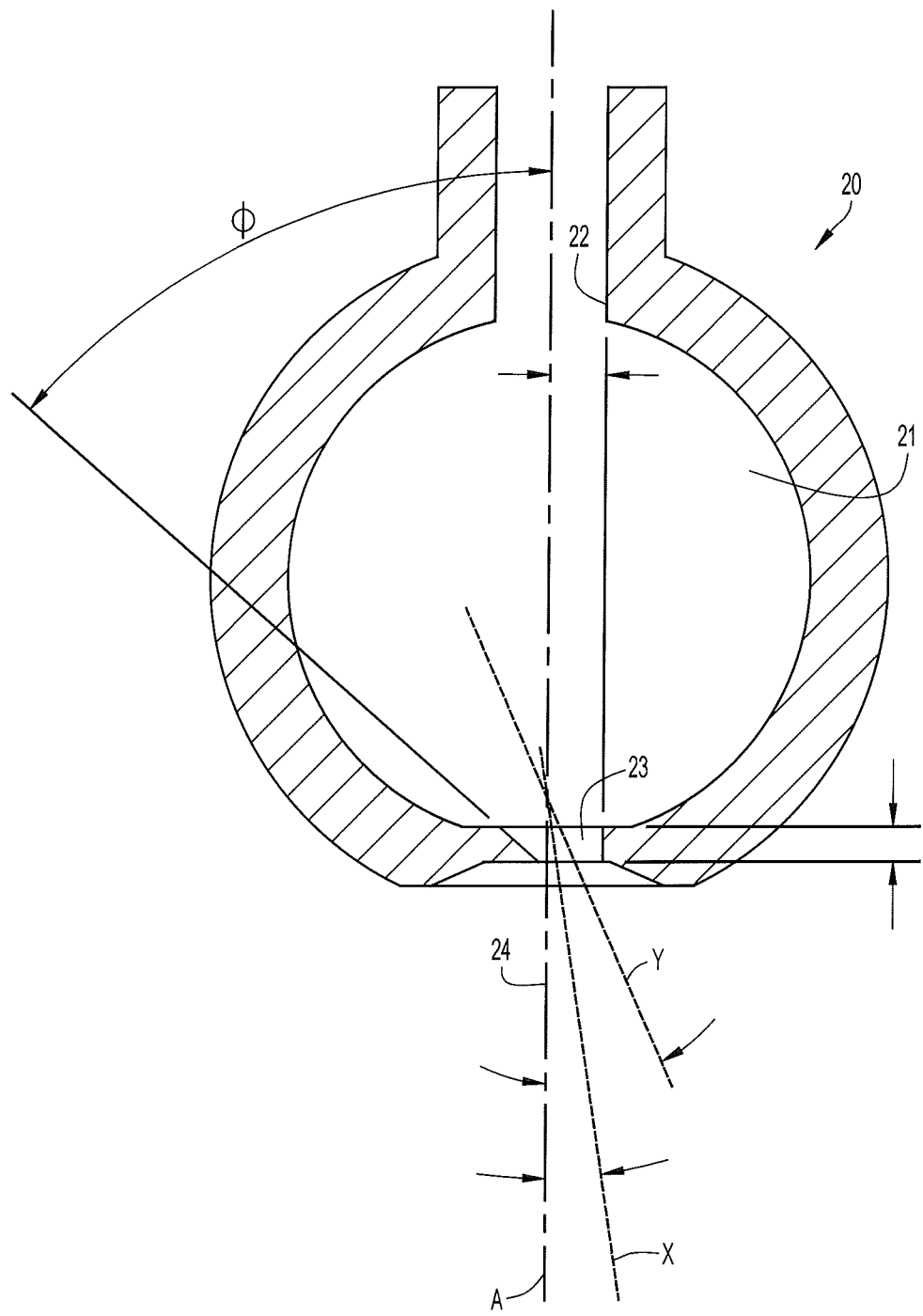


FIG.2

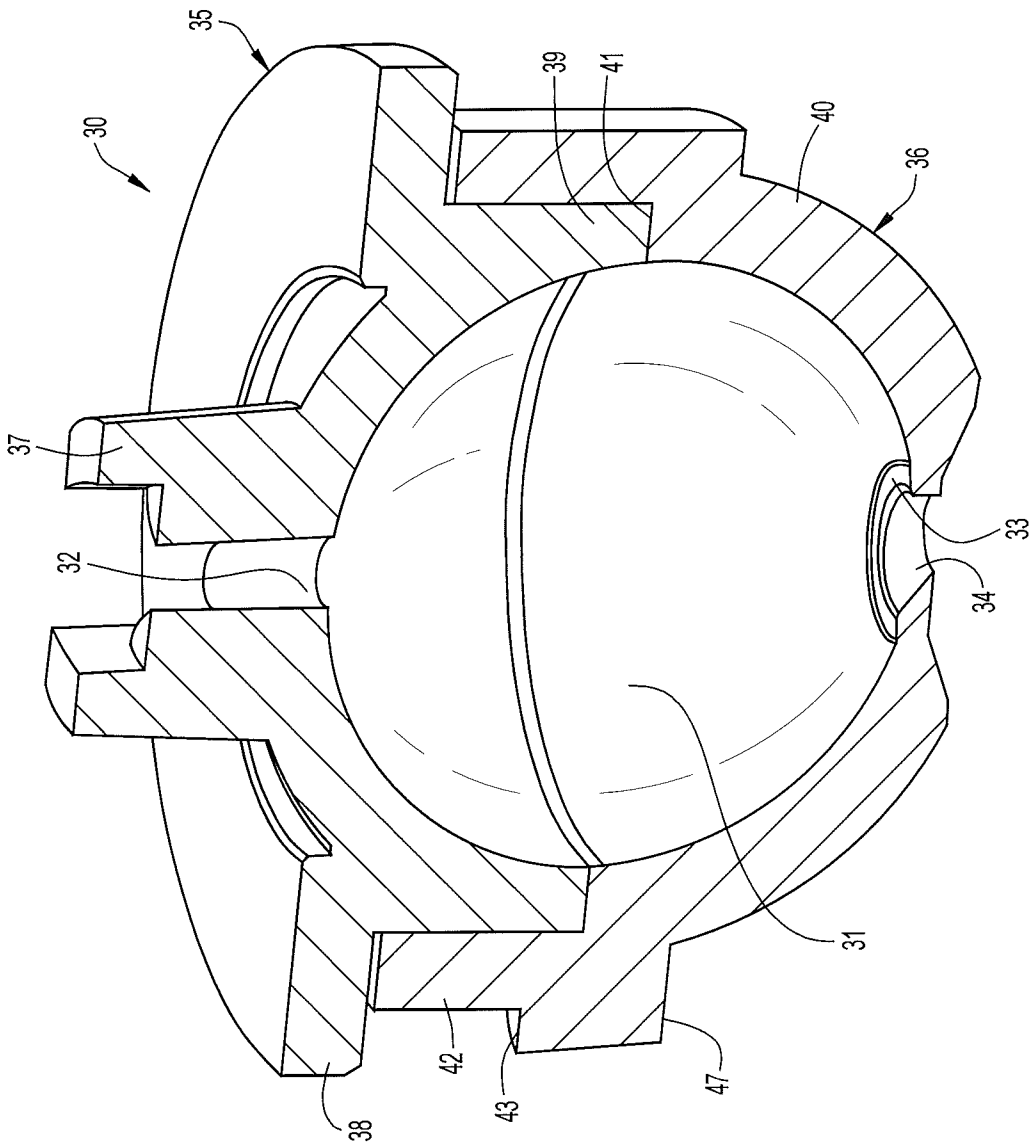


FIG.3

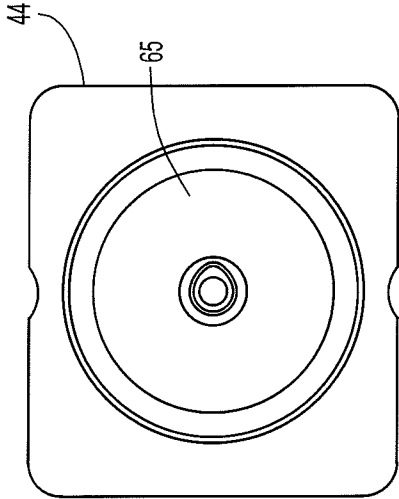


FIG. 4A

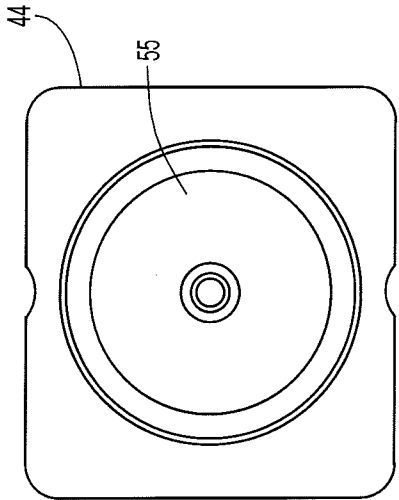


FIG. 5A

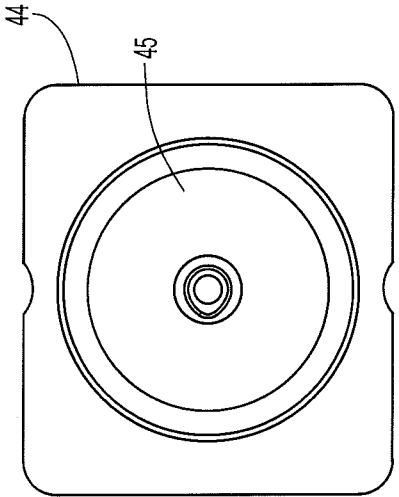


FIG. 6A

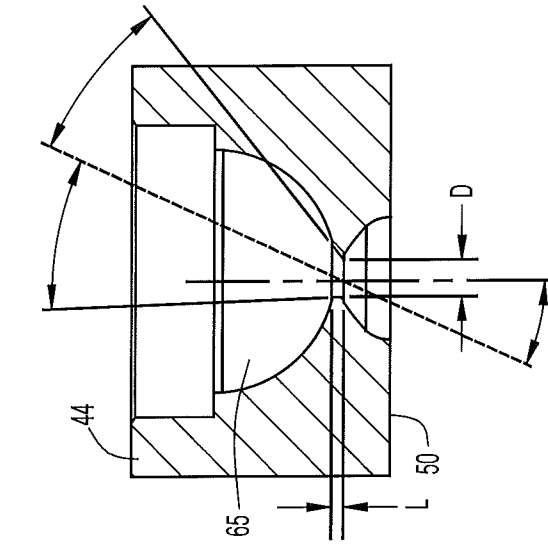


FIG. 4B

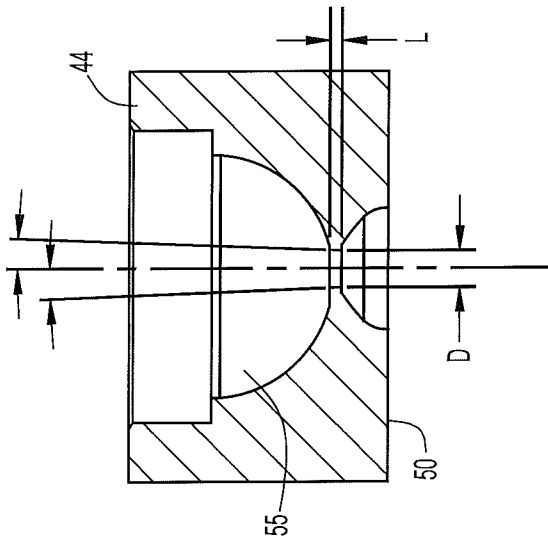


FIG. 5B

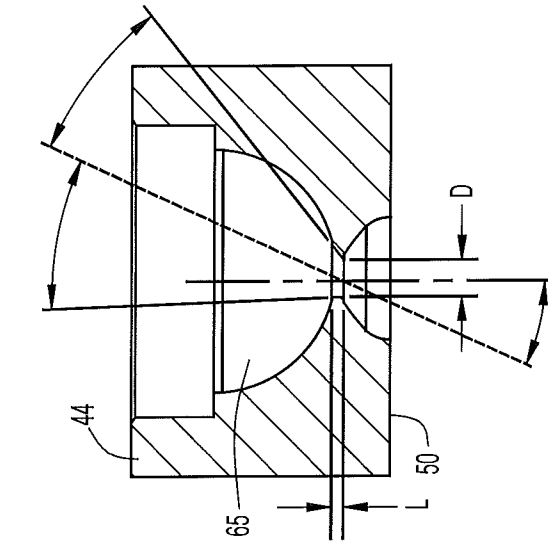


FIG. 6B

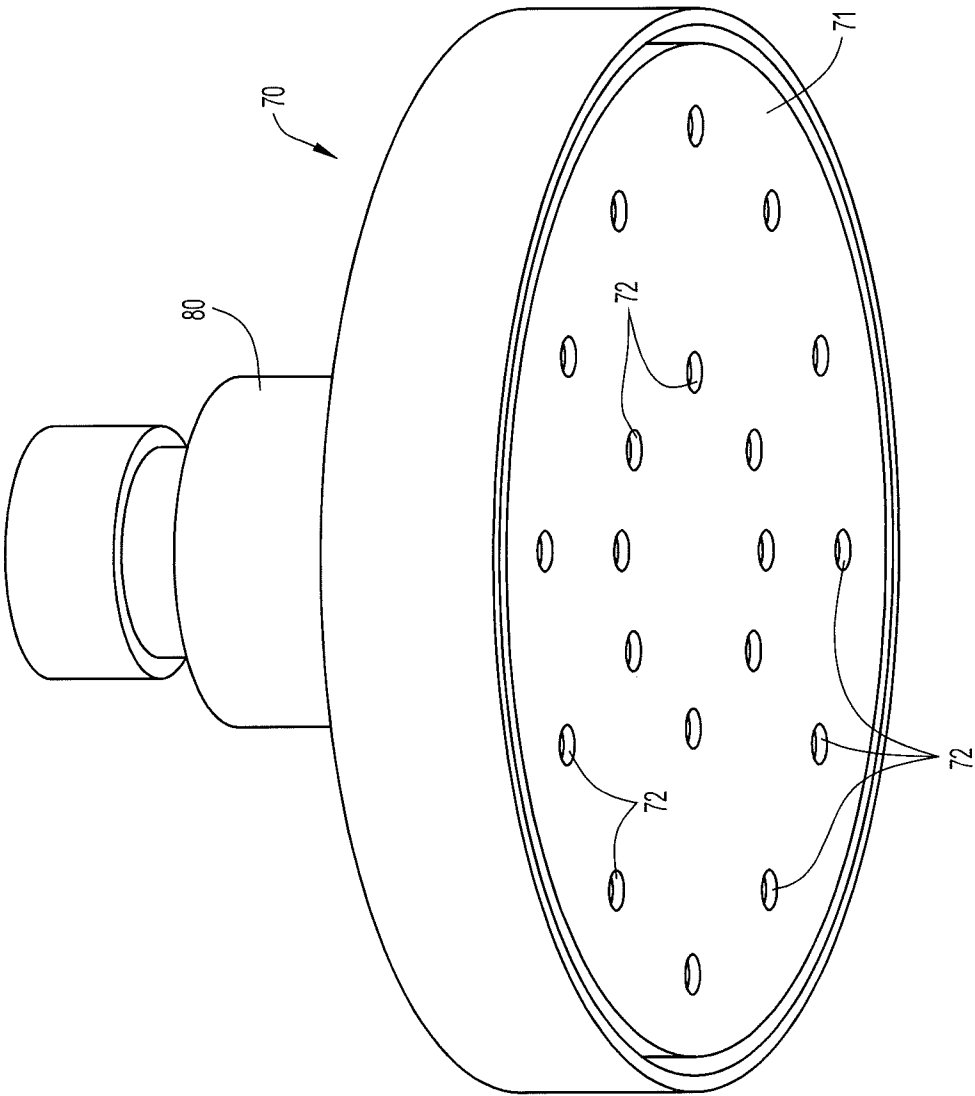


FIG. 7

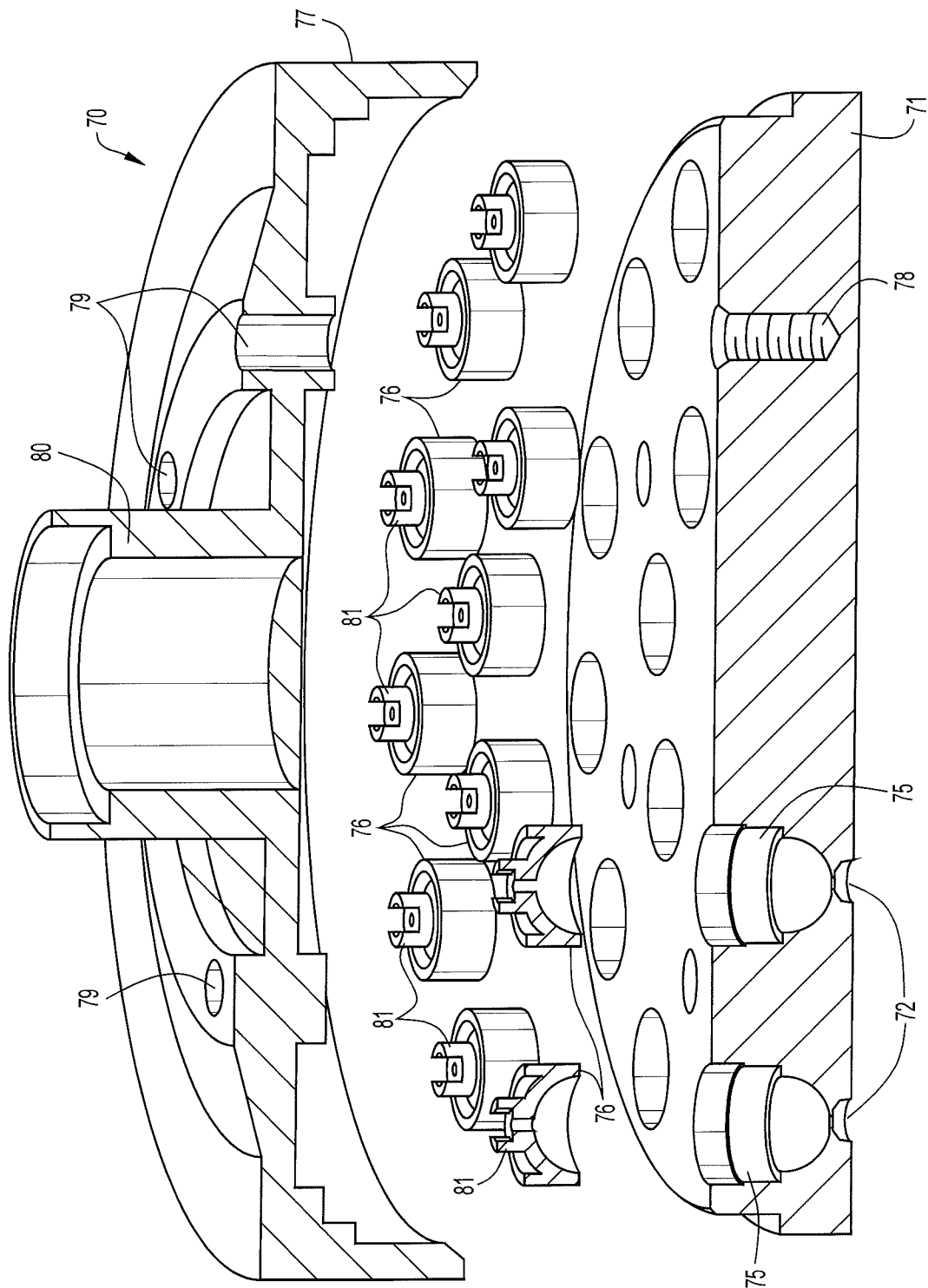


FIG. 8

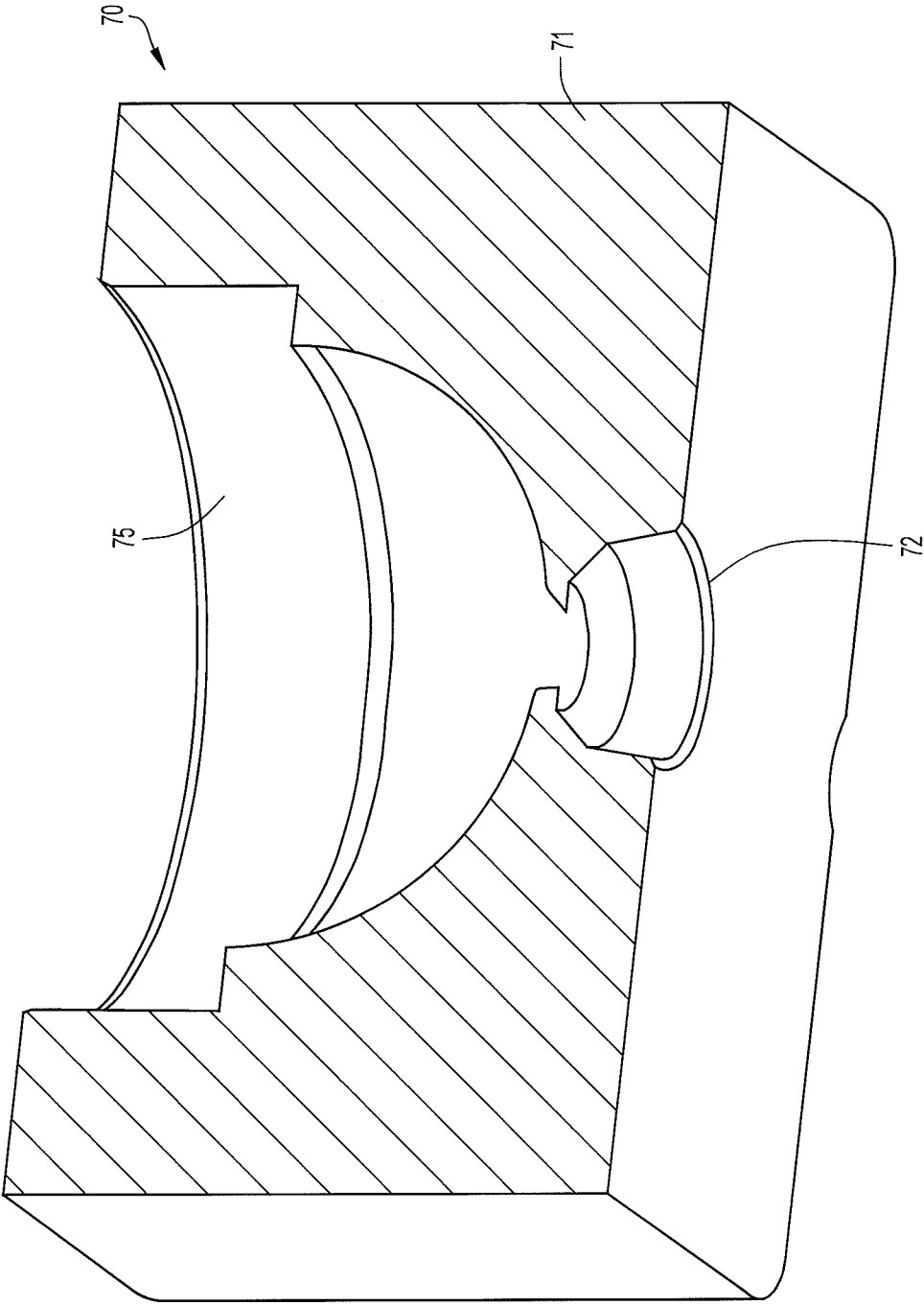


FIG.9

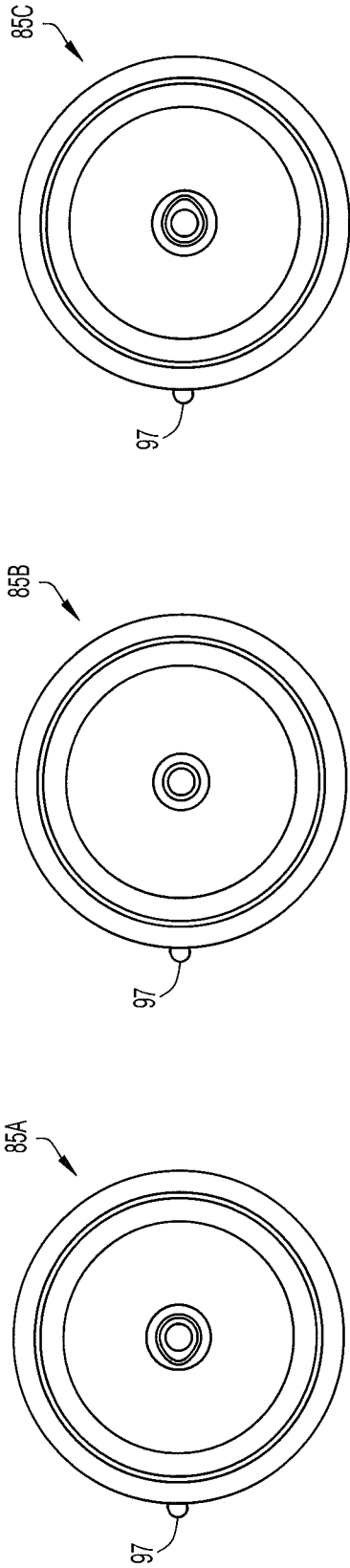


FIG.12A

FIG.11A

FIG.10A

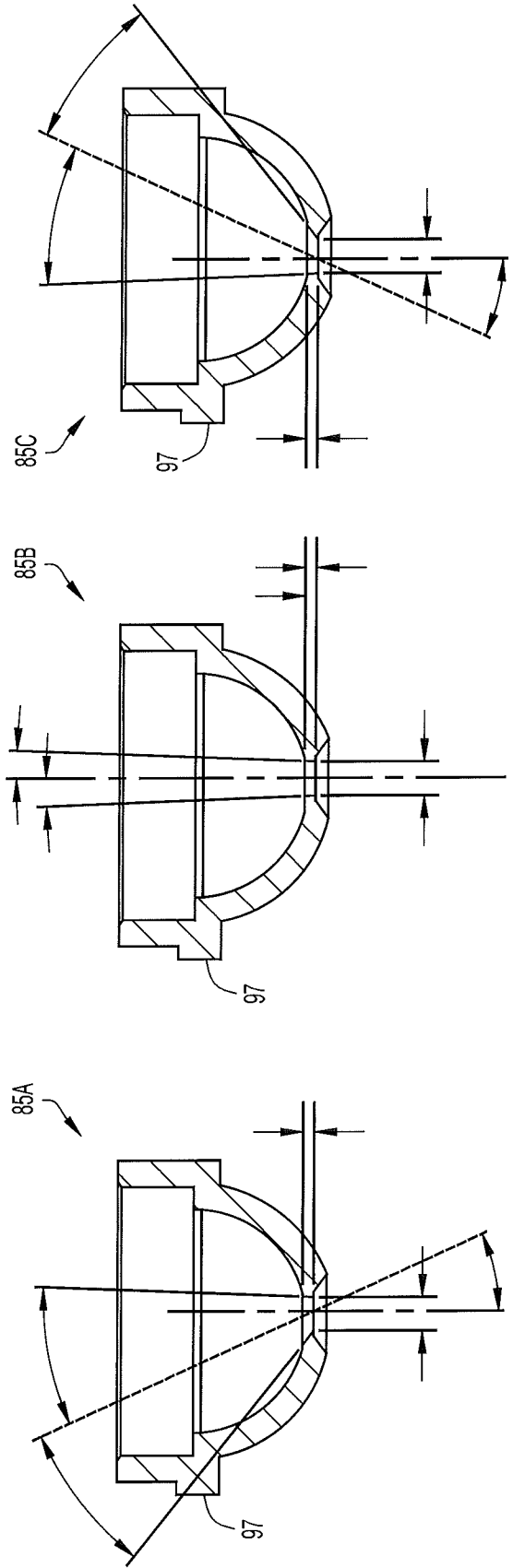


FIG.12B

FIG.11B

FIG.10B

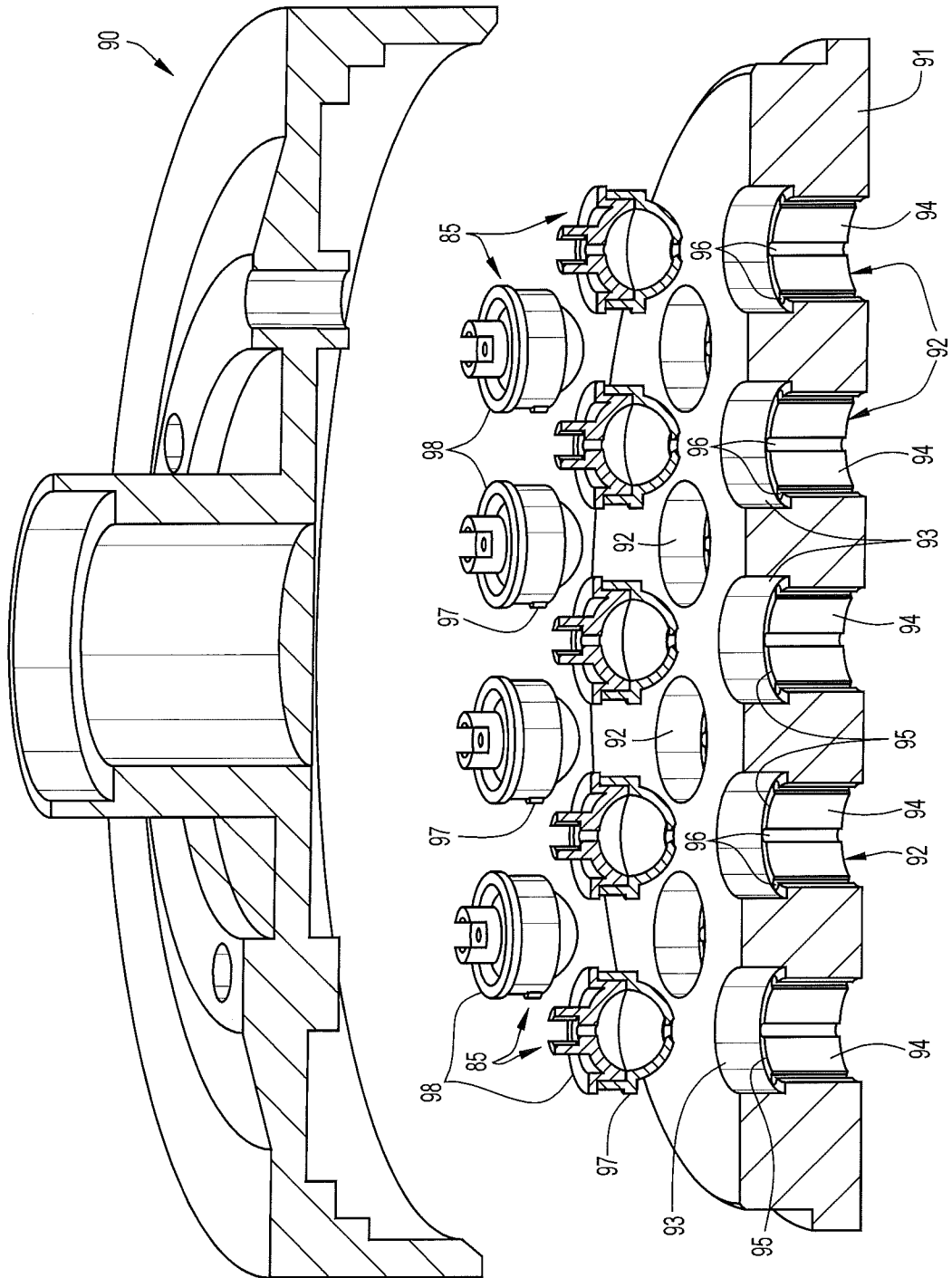


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/30813

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-10 drawn to a fluidic scanner nozzle having an interaction chamber with an inlet opening for receiving pressurized fluid and delivering the pressurized liquid as a jet into said chamber along said chamber axis, and an outlet orifice that is asymmetric relative to said chamber axis to thereby skew the direction of the liquid outlet spray relative to the chamber axis.

Group II: Claims 11-20 drawn to a nozzle assembly configured as a showerhead or a method of aiming a liquid spray pattern from a nozzle having an interaction chamber in which the liquid jet is deflected in three dimensions about the chamber axis to provide a conical spray pattern from an outlet orifice, wherein the outlet orifice is asymmetric relative to said chamber axis to thereby skew the direction of the liquid outlet spray pattern relative to the chamber axis.

-*See extra sheet*-

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/30813

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B05B 1/34 (2017.01)

CPC - B05B 1/3405

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	US 2006/0108442 A1 (RUSSELL et al) 25 May 2006 (25.05.2006), entire document, especially Figs 9C and 11-14B, para [0034], [0081], [0085], and [0086]	1 and 4 --- 2, 3, and 5 --- 6-10, 15, and 16
X --- Y --- A	CN 204620233 U (KYLIN SANITARY TECHNOLOGY) 09 September 2015 (09.09.2015), entire document, especially Figs 1-4, para [0009], [0015], [0017], and [0018]	11, 14, and 17-19 --- 12, 13, and 20 --- 6-10, 15, and 16
Y --- A	US 2007/0158477 A1 (WU et al) 12 July 2007 (12.07.2007), entire document, especially Abstract and Figs 1, 3a, 3b, and 3c	2, 3, 5, 12, 13, and 20 --- 6-10, 15, and 16
A	US 2008/0073451 A1 (BRADBURY et al) 27 March 2008 (27.03.2008), entire document, especially Abstract	6-10, 15, and 16
A	US 2010/0072307 A1 (HESTER et al) 25 March 2010 (25.03.2010), entire document, especially Abstract	6-10, 15, and 16
X, P --- Y	US 2016/0228885 A1 (KYLIN SANITARY TECHNOLOGY) 11 August 2016 (11.08.2016), entire document, especially Figs 1-4, para [0009], [0015], [0017], and [0018]	11, 14, and 17-19 --- 12, 13, and 20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

20 September 2017

Date of mailing of the international search report

02 OCT 2017

Name and mailing address of the ISA/US

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Facsimile No. 571-273-8300

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/30813

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	US 2016/0318045 A1 (DELTA FAUCET COMPANY) 03 November 2016 (03.11.2016), entire document	1-20

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/30813

-*Box III.2 - Observations where unity of invention is lacking*-

The inventions listed as group I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Group I requires the special technical feature of an inlet opening for receiving pressurized fluid and delivering the pressurized liquid as a jet into said chamber along said chamber axis, not required by group II.

Group II requires the special technical feature of an interaction chamber in which the liquid jet is deflected in three dimensions about the chamber axis, not required by group I.

The only feature shared by groups I and II that would otherwise unify the groups, is an outlet orifice is asymmetric relative to said chamber axis to thereby skew the direction of the liquid outlet spray pattern relative to the chamber axis. However this technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by US 20080073451 A1 to Bradbury et al. (hereinafter Bradbury).

Bradbury teaches a nozzle (nozzle 10, Figs 1-3) with an outlet orifice (outlet 18 channel 40, Figs 1-3) that is asymmetric relative to said chamber axis (para [0025], nozzle 10 shown in FIG. 3 is asymmetric about a major axis A-A) to thereby skew the direction of the liquid outlet spray pattern relative to the chamber axis (non-uniform spray pattern, Abstract; asymmetric pattern, para [0032]).

As the common technical feature was known in the art at the time of the invention, this cannot be considered a common technical feature that would otherwise unify the groups.

Therefore, Groups I and II lack unity under PCT Rule 13.