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- (71) Applicant: **3M INNOVATIVE PROPERTIES COMPANY** [US/US]; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).
- (72) Inventors: **SCHEIBNER, John B.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **ENDLE, James P.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **ERICKSON, Ryan D.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **YORKGITIS, Elaine M.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

(74) Agent: **BLANK, Colene H.**, et al.; 3M Center, Office of Intellectual Property Counsel, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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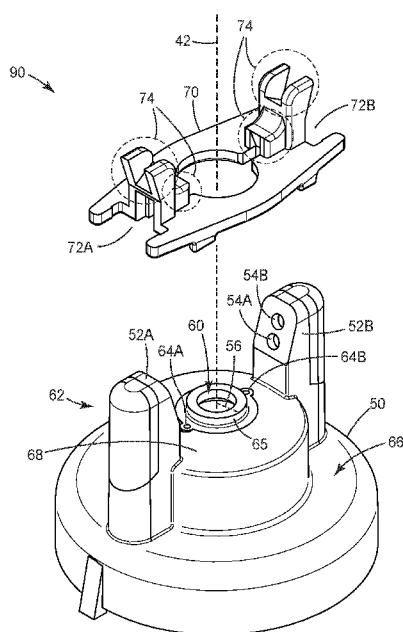


FIG. 2

(57) Abstract: An air guide (70) is disclosed that is configured to be disposed on a spraying apparatus that is configured to emit a plurality of air jets (52, 54, 64) to shape an atomized coating fluid stream of a coating material into a fan pattern along a spray axis (42). The air guide (70) comprises a first channel member (74) configured to shape a first air jet of the plurality of air jets to alter the fan pattern. The air guide may optionally comprise an integrated center air outlet comprising an outer center air guiding surface.

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AIR GUIDE FOR COATING FLUID DISPENSING GUN

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TECHNICAL FIELD

The disclosure relates generally to nozzle assemblies along with related systems and methods for a spraying apparatus. More particularly, the nozzle assemblies disclosed herein are for use in spray guns.

BACKGROUND

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Spray guns are devices that can project a stream of atomized coating fluid particles (or droplets) through the air and onto a substrate. A pressurized gas, such as air, is used to atomize and direct the coating fluid particles. High Volume Low Pressure (HVLP) spray guns, for example, may reduce overspray and material consumption and thus are preferred in a variety of commercial and industrial applications. Materials that may be applied with a spray gun include a wide variety of coating or similar media, including paints, primers, sealers, base coats, clearcoats, slurries, fine powders, and other sprayable coating fluids. Notable applications for spray guns include painting and texturizing architectural surfaces such as walls and ceilings, furniture (re)finishing, refinishing bathroom fixtures and kitchen appliances, applying cosmetics, and painting and repairing marine and automotive surfaces.

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One type of spray gun uses a gun platform connected with a compressed air source and coating fluid passageway in conjunction with a spray nozzle. The air and coating fluid are generally directed into respective flow channels and expelled from the gun through adjacent atomizing and shaping apertures, respectively. The air flows out of the atomizing apertures through a region of reduced pressure, which in turn assists in drawing out the coating fluid from the fluid tip and atomizing it to form a directed stream of coating fluid droplets. Spray guns commonly incorporate a pair of air horns. These air horns are positioned on opposite sides of the coating fluid stream as it leaves the spray nozzle and direct air jets from opposing directions to flatten the shape of the coating fluid stream, thereby modifying the spray pattern to a more desirable “fan” pattern.

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SUMMARY

This disclosure includes techniques for the design, manufacture, assembly, and use of nozzle assemblies and the various components thereof described in this specification for spraying apparatuses. An air cap for a spraying apparatus includes an air cap base. The spraying apparatus is configured to create a plurality of air jets that shape a coating fluid stream. The spraying apparatus may receive an air guide. The air guide includes a plurality of channel members. A set of the plurality of channel members is configured to channel air of air jets of the plurality of air jets.

A method for using a spraying apparatus includes receiving an air cap base by a distal portion of a barrel of the spraying apparatus. The air cap base includes a pair of diametrically opposed air horns that are configured to guide a plurality of air jets towards a spray axis of the barrel of the spraying apparatus. A first air guide is received by the air cap base in a first orientation. The first air guide includes a first plurality of channel members. A first set of channel members of the first plurality of channel members is configured to channel air of at least two air jets of the plurality of air jets. A surface is sprayed by the spraying apparatus with coating fluid that is dispensed between the air horns. The surface is sprayed in a first fan pattern as a result of the plurality of air jets. The spraying apparatus is adjusted to a first state.

Exemplary embodiments according to the present disclosure include, but are not limited to, the embodiments listed below, which may or may not be numbered for convenience. Several additional embodiments, not specifically enumerated in this section, are disclosed within the accompanying detailed description.

1. An air guide configured to be disposed on a spraying apparatus that is configured to emit a plurality of air jets to shape an atomized coating fluid stream of a coating material into a fan pattern along a spray axis, the air guide comprising a first channel member configured to shape a first air jet of the plurality of air jets to alter the fan pattern.

2. The air guide of Embodiment 1, wherein the first channel member comprises a control surface configured to alter the trajectory of the first air jet.

3. The air guide of any of Embodiments 1 to 2, wherein the first channel member comprises a guidance wall configured to concentrate the first air jet.

4. The air guide of any of Embodiments 2 to 3 further comprising an air cap base upon which the air guide is configured to be received.

5. The air guide of Embodiment 4 wherein the air cap base is configured to be received by a distal portion of a spraying apparatus.

6. The air guide of any of Embodiments 4-5 wherein the air cap base comprises:

a center air orifice comprising a first orifice axis that is substantially parallel with the spray axis; and

a first air horn extending substantially parallel to the spray axis and comprising an air passageway that feeds a first shaping air orifice, wherein the first shaping air orifice is configured to emit a first shaping air jet along a first shaping axis towards the spray axis;

wherein a shaping plane is defined as a common plane passing through the spray axis and the first shaping axis.

7. The air guide of any of Embodiments 4-5 wherein the air cap base comprises:

a center air orifice comprising a first orifice axis that is substantially parallel with the spray axis; and

a first auxiliary air orifice configured to emit a first auxiliary air jet along a first auxiliary axis;

wherein a shaping plane is defined as a common plane passing through the spray axis and the first auxiliary axis.

8. The air guide of any of Embodiments 4-5 wherein the air cap base comprises:

a center air orifice comprising a first orifice axis that is substantially parallel with the spray axis;

a first air horn extending substantially parallel to the spray axis and

comprising an air passageway that feeds a first shaping air orifice, wherein the first shaping air orifice is configured to emit a first shaping air jet along a first shaping axis towards the spray axis; and

a first auxiliary air orifice configured to emit a first auxiliary air jet along a first auxiliary axis;
wherein a shaping plane is defined as a common plane passing through the spray axis, the first shaping axis, and the first auxiliary axis.

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9. The air guide of any of Embodiments 6 or 8 wherein the air cap base comprises:

a second air horn opposite the first air horn, extending substantially parallel to the spray axis and comprising an air passageway that feeds a second shaping air orifice, wherein the second shaping air orifice is configured to emit a second shaping air jet along a second shaping axis towards the spray axis;

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wherein the shaping plane further passes through the second shaping axis.

10. The air guide of any of Embodiments 7 or 8 wherein the air cap base comprises:

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a second auxiliary air orifice configured to emit a second auxiliary air jet along a second auxiliary axis;

wherein the shaping plane further passes through the second auxiliary axis.

11. The air guide of Embodiment 8 wherein the air cap base comprises:

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a second air horn opposite the first air horn, extending substantially parallel to the spray axis and comprising an air passageway that feeds a second shaping air orifice, wherein the second shaping air orifice is configured to emit a second shaping air jet along a second shaping axis towards the spray axis; and

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a second auxiliary air orifice configured to emit a second auxiliary air jet along a second auxiliary axis;

wherein the shaping plane further passes through the second shaping axis and the second auxiliary axis.

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12. The air guide of any of Embodiments 6, 8, or 9 wherein the first air jet is the first shaping air jet.

13. The air guide of any of Embodiments 7, 8, or 10 wherein the first air jet is the first auxiliary air jet.

5 14. The air guide of any of Embodiments 9 or 11 comprising a second channel member configured to shape a second air jet, wherein the second air jet is the second shaping air jet.

10 15. The air guide of any of Embodiments 10 or 11 comprising a second channel member configured to shape a second air jet wherein the second air jet is the second auxiliary air jet.

16. The air guide of any of Embodiments 1-3 comprising a second channel member configured to shape a second air jet.

15 17. The air guide of any of Embodiments 4-13 comprising a second channel member configured to shape a second air jet.

20 18. The air guide of any of Embodiments 14, 15, or 17, wherein the second channel member comprises a control surface configured to alter the trajectory of the second air jet.

19. The air guide of Embodiment 16 wherein the second channel member comprises a control surface configured to alter the trajectory of the second air jet.

25 20. The air guide of any of Embodiments 14, 15, 17, or 18, wherein the second channel member comprises a guidance wall configured to concentrate the second air jet.

21. The air guide of any of Embodiments 16 or 19, wherein the second channel member comprises a guidance wall configured to concentrate the second air jet.

30 22. The air guide of any of Embodiments 4-15, 17-18, or 20, wherein the air guide is integral with the air cap base.

23. The air guide of any of Embodiments 1-21 wherein the air guide is a unitary structure.

24. The air guide of Embodiment 23 wherein the air guide is constructed of an injection molded polymeric material.

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25. The air guide of Embodiment 3 wherein the guidance wall of the first channel member is opposed by an opposing guidance wall, such that the first channel member is configured to concentrate the first air jet in two locations.

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26. The air guide of any of Embodiments 20 or 21 wherein the guidance wall of the second channel member is opposed by an opposing guidance wall, such that the second channel member is configured to concentrate the second air jet in two locations.

27. A method of using a spraying apparatus comprising

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operating a spraying apparatus to cause the spraying apparatus to emit an atomized stream of a coating material and a plurality of air jets to shape the atomized stream into a fan pattern along a spray axis, the plurality of air jets comprising a first air jet; and
shaping the first air jet with a first channel member to alter the fan pattern.

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28. The method of Embodiment 27, wherein the first channel member comprises a control surface configured to alter the trajectory of the first air jet, the method comprising altering the trajectory of the first air jet to alter the fan pattern.

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29. The method of any of Embodiments 27-28, wherein the first channel member comprises a guidance wall configured to concentrate the first air jet, the method comprising concentrating the first air jet to alter the fan pattern.

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30. The method of any of Embodiments 27-29 wherein the plurality of air jets comprises a second air jet, the method comprising shaping the second air jet with a second channel member to alter the fan pattern.

31. The method of Embodiment 30, wherein the second channel member comprises a control surface configured to alter the trajectory of the second air jet, the method comprising altering the trajectory of the second air jet to alter the fan pattern.

5 32. The method of any of Embodiments 30-31, wherein the second channel member comprises a guidance wall configured to concentrate the second air jet, the method comprising concentrating the second air jet to alter the fan pattern.

10 33. The method of Embodiment 29 wherein the guidance wall of the first channel member is opposed by an opposing guidance wall, such that the first channel member is configured to concentrate the first air jet in two locations, the method comprising concentrating the first air jet to alter the fan pattern.

15 34. The method of Embodiment 32 wherein the guidance wall of the second channel member is opposed by an opposing guidance wall, such that the second channel member is configured to concentrate the second air jet in two locations, the method comprising concentrating the second air jet to alter the fan pattern.

20 35. The air guide of any of Embodiments 1-21 or 23-26 comprising a center air orifice comprising an outer center air guiding surface.

25 36. The air guide of Embodiment 35 comprising an inner center air guiding surface and a transition located between the inner center air guiding surface and the outer center air guiding surface.

37. A spraying apparatus comprising an air guide according to any of Embodiments 35 or 36 wherein the liquid spray gun nozzle comprises a fluid tip comprising a distal end and an exterior center air guiding surface.

30 38. The spraying apparatus of Embodiment 37 wherein the outer center air guiding surface comprises an axially outermost edge, wherein a fluid tip position F is defined as a distance along the spray axis from the axially outermost edge of the outer center air guiding surface and the distal end of the fluid tip, wherein the fluid tip position F is a

positive value when the distal end of the fluid tip is recessed within the axially outermost edge of the outer center air guiding surface.

5 39. The spraying apparatus of any of Embodiments 37 or 38 wherein a transition position T is defined as a distance along the spray axis from the distal end of the fluid tip to the transition between the inner center air guiding surface and the outer center air guiding surface, wherein the transition position T is a positive value when the transition between the inner center air guiding surface and the outer center air guiding surface is recessed behind the distal end of the fluid tip.

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40. The spraying apparatus of any of Embodiments 37-39 wherein a center air annulus area A is defined as the annular area between the outer center air guiding surface of the air guide and the exterior center air guiding surface of the fluid tip when viewed along the spray axis.

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41. A method of providing an air guide for a spraying apparatus to tailor a spraying apparatus for a given application, the method comprising:

selecting an air guide according to any of Embodiments 35 or 36 to fit a spraying apparatus comprising a fluid tip comprising a distal end and an exterior center air guiding surface; and
assembling the air guide to the spraying apparatus.

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42. The method of Embodiment 41 wherein the outer center air guiding surface comprises an axially outermost edge, wherein a fluid tip position F is defined as a distance along the spray axis from the axially outermost edge of the outer center air guiding surface and the distal end of the fluid tip, wherein the fluid tip position F is a positive value when the
10 distal end of the fluid tip is recessed within the axially outermost edge of the outer center air guiding surface, wherein selecting the air guide comprises selecting the air guide to result in a particular fluid tip position F.

43. The method of any of Embodiments 41 or 42 wherein a transition position T is
15 defined as a distance along the spray axis from the distal end of the fluid tip to the transition between the inner center air guiding surface and the outer center air guiding surface, wherein the transition position T is a positive value when the transition between the inner center air guiding surface and the outer center air guiding surface is recessed behind the distal end of the fluid tip, wherein selecting the air guide comprises selecting
20 the air guide to result in a particular transition position T.

44. The method of any of Embodiments 41-43 wherein a center air annulus area A is defined as the annular area between the outer center air guiding surface of the air guide and the exterior center air guiding surface of the fluid tip, wherein selecting the air guide
25 comprises selecting the air guide to result in a particular center air annulus area A.

45. The method of any of Embodiments 41-44 wherein selecting the air guide comprises selecting from among a set of different air guides, wherein each air guide in the set of different air guides is configured to tailor the spraying apparatus for a different
30 application.

46. The method of any of Embodiments 27-32 comprising shaping a center air flow with an outer center air guiding surface, wherein the outer center air guiding surface and the first channel member are positioned on an air guide.

5 The words “preferred” and “preferably” refer to embodiments described herein that may afford certain benefits, under certain circumstances. However, other embodiments may also be preferred, under the same or other circumstances. Furthermore, the recitation of one or more preferred embodiments does not imply that other embodiments are not useful, and is not intended to exclude other embodiments from the scope of the invention.

10 As used herein and in the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a” or “the” component may include one or more of the components and equivalents thereof known to those skilled in the art. Further, the term “and/or” means one or all of the listed elements or a combination of any two or more of the listed elements.

15 As used herein, the term “substantially parallel” means within +/- 10 degrees of parallel.

 It is noted that the terms “comprises” and variations thereof do not have a limiting meaning where these terms appear in the accompanying description. Moreover, “a,” “an,” “the,” “at least one,” and “one or more” are used interchangeably herein.

20 Relative terms such as left, right, forward, rearward, top, bottom, side, upper, lower, horizontal, vertical, and the like may be used herein and, if so, are from the perspective observed in the particular figure. These terms are used only to simplify the description, however, and not to limit the scope of the invention in any way.

 Reference throughout this specification to “one embodiment,” “certain
25 embodiments,” “one or more embodiments” or “an embodiment” means that a particular feature, structure, material, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. Thus, the appearances of the phrases such as “in one or more embodiments,” “in certain embodiments,” “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily
30 referring to the same embodiment of the invention. Furthermore, the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments.

The above summary is not intended to describe each embodiment or every implementation of the reservoirs and associated vent assemblies described herein. Rather, a more complete understanding of the invention will become apparent and appreciated by reference to the following Description of Illustrative Embodiments and claims in view of the accompanying figures of the drawing.

These and other aspects of the invention will be apparent from the detailed description below. In no event, however, should the above summaries be construed as limitations on the claimed subject matter, which subject matter is defined solely by the attached claims, as may be amended during prosecution.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view of an example spraying apparatus including an air cap showing the rear and side surfaces of the assembly;

FIG. 2 depicts an exploded perspective view of an example air cap with an exemplary air guide and air cap base;

FIGS. 3 and 4 depict a perspective view and a top view of an exemplary air cap, respectively;

FIG. 5 is a cross-section view taken at 5-5 of FIG. 4;

FIGS. 6A and 6B are partial detailed cross-section views of one side of example air caps taken along cuts akin to the cross-section of FIG. 5;

FIG. 7A is a view through a shaping air orifice as viewed along 7A-7A of FIG. 6A;

FIG. 7B is a view through a shaping air orifice as viewed along 7B-7B of FIG. 6B;

FIG. 7C is a view through an auxiliary air orifice as viewed along 7C-7C of FIG.

6A;

FIG. 7D is a view through an auxiliary air orifice as viewed along 7D-7D of FIG.

6B;

FIGS. 8 and 9 depict a top view and a perspective view of an adjustable air guide, respectively;

FIG. 10 depicts a perspective view of an exemplary air guide;

FIG. 11 depicts a perspective view of an alternative configuration of an exemplary air guide;

FIG. 12 depicts a cross-section view of an alternative configuration of an exemplary air guide;

FIGS. 13 and 14 are additional perspective views of the exemplary air guide depicted in FIG. 10;

FIG. 15 is a top view of the exemplary air guide depicted in FIGS. 13 and 14;

FIG. 16 is a bottom view (slightly tilted) of the exemplary air guide depicted in
5 FIGS. 13 and 14;

FIG. 17 is a cross-section view taken at 17-17 of FIG. 15;

FIG. 18 is a cross-section view of an air cap comprising an air guide taken at a cross-section akin to the cross section of FIG. 17, wherein a common plane is depicted as coplanar with the cut of the cross-section;

10 FIG. 19 depicts a method of using an air guide to operate a spraying apparatus;

FIG. 20 is a schematic view of an air jet that is concentrated at one location;

FIG. 21 is a schematic view of an air jet that is concentrated in two opposing locations;

FIG. 22 is a schematic view of an air jet whose trajectory is altered;

15 FIG. 23 is a table describing various exemplary fan pattern profile types;

FIG. 24 is a table describing fan patterns observed from Comparative Examples according to the present disclosure;

FIG. 25 is a table describing fan patterns observed from Examples according to the present disclosure;

20 FIGS. 26A-26C are Schlieren images obtained from Comparative Examples according to the present disclosure;

FIGS. 27A-27C are Schlieren images obtained from Examples according to the present disclosure;

FIGS. 28A-28C are Schlieren images obtained from Comparative Examples
25 according to the present disclosure depicting a location of air jet intersection;

FIGS. 29A-29C are Schlieren images obtained from Examples according to the present disclosure depicting a location of air jet intersection;

FIG. 30 is a table describing the locations of air jet intersection depicted in FIGS. 22A-23C;

30 FIG. 31 is a plot showing absolute changes in the jet intersection positions described in the Table of FIG. 30;

FIG. 32 is a plot showing percent-wise changes in jet intersection positions described in the Table of FIG. 30;

FIG. 33 depicts an exploded perspective view of an example air cap with an exemplary air guide and air cap base;

FIG. 34 depicts a perspective view of an exemplary air cap with an exemplary air guide included therewith;

5 FIG. 35 is depicts a perspective view of an exemplary air guide;

FIG. 36 is a cross-section view of the exemplary air guide of FIG. 35, taken along a cross-section akin to that depicted in FIG. 17;

FIG. 37 is a cross-section view of an exemplary air cap comprising an exemplary air guide, taken along a cross-section akin to that depicted in FIG. 5;

10 FIG. 37A is a detailed view of the cross-section of FIG. 37; and

FIG. 38 depicts a method of selecting an air guide to operate a spraying apparatus.

DETAILED DESCRIPTION

15 The features and techniques described herein are useful for types of spraying apparatus, which include spray guns and spray gun platforms. A spraying apparatus can utilize an air cap base and an air guide. The air cap base may connect to a distal portion of the spraying apparatus in such a way that a central aperture of the air cap base aligns with a fluid tip of the spraying apparatus. The air cap base has numerous ports or orifices that are configured to direct numerous streams of air (e.g., air jets) towards a coating fluid stream exiting the fluid tip. The coating fluid stream exiting the fluid tip may be surrounded by a center air flow that acts to break the coating fluid stream into small droplets (i.e., to atomize the coating fluid) that are in turn propelled toward a target surface to be coated by the droplets. The air jets may alter the direction or shape of all or portions of the atomized coating fluid stream to realize desired spraying results on the surface to be coated. The air guide may be connected to a distal portion of the air cap base. The air guide comprises one or more channel members that are configured to channel air of the air jets.

25 A spraying apparatus can be used to apply a material (e.g., primer, paint, clearcoat, slurry, fine powder) to a surface in a coating fluid stream. In some examples, two diametrically opposed air horns of the air cap base may direct streams of air towards the atomized coating fluid stream to shape the stream. In these examples, the shaped coating fluid stream may contact the target surface in a general ovaloid shape (or, for example, the

geometric shape of a rectangle with semicircles at a pair of opposite sides of the rectangle), said shape hereinafter referred to as a “fan pattern.” It can be advantageous to maintain a steady shape within the fan pattern (e.g., a pattern with a consistent width of a central portion of the general ovaloid shape of the fan pattern) with an even density of material between ends of the fan pattern. In some examples, it can be advantageous to concentrate a sprayed material more heavily at a center point of a long axis of the fan pattern, with the material of the pattern gradually becoming less concentrated toward the poles of the long axis (e.g., where there are no abrupt changes in paint concentration along the general ovaloid shape). This may result in a sprayed material being concentrated relatively more lightly at far ends of the fan pattern (e.g., at the semicircle ends of a general rectangle shape at the center of the fan pattern). Example fan patterns are described and depicted in FIG. 23.

In certain examples, a spraying apparatus may not utilize an air guide. In such examples, the only way to achieve a satisfactory fan pattern may be to precisely adjust a number of controls on the spraying apparatus while articulating the spraying apparatus at a steady distance and angle from the surface to be coated. For example, the amount of air sent to (e.g., corresponding to the relative air pressure within the air passages of) the shaping air orifices, the auxiliary air orifices, or the central aperture may all be adjusted using various controls. The controls may adjust the pressure and/or relative air flow used in projecting and shaping the atomized coating fluid stream into the fan pattern. A slight adjustment may result in an uneven fan pattern, a fan pattern with uneven density, a change in transfer efficiency (e.g., the proportion of sprayed material which ends up on the target surface at the intended location), or another issue which may increase the difficulty in using the spraying apparatus to apply the coating material evenly. A spraying apparatus may require a different adjustment for each coating material being applied (for example, due to differing viscosities or tendencies to break up into droplets), requiring regular adjustments. Thusly necessitating regular adjustments may increase chances for error in the spraying process.

Aspects of the disclosure relate to one or more channel members of an air guide that are configured to channel air jets emitted from the spraying apparatus. The channel members may improve the fan pattern of a spraying apparatus that uses an air guide. The channel members may improve the fan pattern by making the resulting fan pattern less sensitive to changes in spraying apparatus pressures and /or control adjustments. In some

examples, channel members may make the fan pattern less sensitive by reducing the correlation between the fan pattern and the inlet pressure of the spraying apparatus. Alternatively, an air guide may be made with a specific set of channel members for a specific application (e.g., applying a certain coating fluid onto a certain surface), such that a single spraying apparatus can be adjusted from a first application to a second application with little or nothing more than switching from a first air guide to a second air guide. Structure and function of channel members is described in further detail elsewhere in the disclosure.

Air guides may be interchangeably attached to a spraying apparatus. In this way, a first air guide may be attached to a spraying apparatus to adjust the spraying apparatus for a first coating material, and after the first coating material is applied, the first air guide may be removed and a second air guide may be attached to the same spraying apparatus to configure said spraying apparatus for a second coating material. The spraying apparatus may be configured for the second material with minimal or no other spraying apparatus adjustments.

In some examples, a spraying apparatus may be constructed partially, mostly, or entirely out of metal. Using metal for the construction of a spraying apparatus may extend the lifespan of the spraying apparatus. However, a metal spraying apparatus may be relatively expensive. As a result of being relatively expensive, a user may not wish to purchase many different configurations, and may not wish to discard such apparatus after only a relatively few uses. Therefore, such relatively expensive spraying apparatus is likely to be pre-configured to be merely adequate for executing a wide variety of spraying applications, while not being optimized to excel at any one particular application.

Typically, a spraying apparatus needs to be broken down and cleaned after each use. The paint industry is trending increasingly towards waterborne paints. Waterborne paints tend to be relatively viscous and can be difficult to remove from parts, and a small amount of residual paint within a spraying apparatus may lead to the spraying apparatus being unreliable (until being cleaned of the residue). The unreliability may stem in part from partial or total blockage of air or coating fluid orifices, improper working of soiled moving parts in the spraying apparatus, and/or the potential for paint residue to contaminate the next job by generating nibs and/or altering the desired paint color. The latter issue may be especially problematic when switching between widely varying paint colors (e.g., from black to white, or vice versa). Further, waterborne paints may coagulate

relatively quickly, meaning that a spraying apparatus must be cleaned relatively quickly after use. For example, an operator who forgets to clean a metal spraying apparatus for a night after utilizing waterborne paints may find it extremely difficult to suitably clean the next morning.

5 As such, in some examples, a spraying apparatus may be constructed partially, mostly, or entirely out of plastic. For example, the nozzle portions of a spraying apparatus may be removable and constructed of relatively inexpensive plastic, while a spray gun platform may be constructed of more expensive and/or durable materials. A plastic spraying apparatus (or portions thereof) may cost far less than comparative parts of a
10 metal spraying apparatus and may be disposed of after a single use or after a relatively small number of uses compared to the life of a more durable spraying apparatus body. Disposal after a single use may eliminate or greatly reduce the difficulty of cleaning a spraying apparatus to remove residual spraying materials such as waterborne paints. For example, even if an operator plans on reusing a plastic spraying apparatus, the ability for
15 said operator to economically dispose of a dirty plastic spraying apparatus (or portions thereof) the morning after failing to clean it the previous night may provide time and monetary benefits. However, in some examples, being as metal may often be manufactured with tighter tolerances than plastic, a plastic spraying apparatus may be less capable of providing a desirable fan pattern with as much consistency or accuracy as a
20 metal spraying apparatus.

Aspects of the disclosure relate to an air guide comprising one or more channel members that are configured to channel air of an air jet of the spraying apparatus that assists in defining the fan pattern. Providing further ability to channel air of air jets using one or more channel members may allow a plastic spraying apparatus that utilizes air
25 guides to provide a desirable fan pattern with as much consistency as or greater consistency than a respective metal spraying apparatus. Further, given an allowably short lifespan of an air guide and/or air cap base, an air guide and/or air cap base may be designed specifically for a single application or relatively few applications (e.g., spraying a single paint with shaping air orifices and/or auxiliary air orifices as specified by a
30 manufacturer), with tolerances and features specifically configured for said single or relatively few applications. Designing an air cap base and/or air guide for a single application or relatively few applications may increase the consistency with which a spraying apparatus can achieve a desired fan pattern. Alternatively, a more durable air

guide may be constructed according to the present disclosure that may, for example, be constructed of metal and/or otherwise built to last the useful life of the spraying apparatus

Construction of Spraying Apparatus / Spray Nozzle

5 An example spraying apparatus 10 is depicted in FIG. 1. The spraying apparatus 10 includes a spray gun platform 36 operatively coupled to a spraying apparatus barrel 38. The barrel 38 may define a spray axis 42, said axis hereinafter referred to as a spray axis 42 or longitudinal axis 42 of the spraying apparatus 10. The barrel 38 may be configured to receive an air cap 40 at a distal portion 44 of the barrel 38. Optionally, the barrel 38 is releasably connected to the spray gun platform 36, allowing the former to be conveniently
10 detached and cleaned. In one example, the barrel 38 is made from plastic and may be readily discarded or recycled at the end of a spraying operation.

Extending outwardly from the top of the barrel 38 is a fluid inlet 12 that can be operatively connected to a coating fluid container (not shown). The spraying apparatus 10, as shown, is a gravity-fed spray gun in which the coating fluid container is located above
15 the spray gun platform 36 to facilitate the flow of coating fluid into the spray gun platform 36. The fluid inlet 12 can be connected to a coating fluid source (not shown). The coating fluid source may be fed by gravity (e.g., a gravity-fed spray gun), by suction, or by positive pressure. In high volume applications, the fluid inlet 12 can be connected to a hose that conveys coating fluid from an external pressurized pot. Other types of coating
20 fluid containers and their modes of use as would be known by one skilled in the art are also contemplated and compatible with aspects of this disclosure.

The coating fluid connection may comprise a quick-connect coupler as described, for example, in U.S. patent application number 62/430388, entitled "Paint Spray Gun Coating Liquid Connector," the disclosure of which is herein incorporated by reference in
25 its entirety. Other coating fluid connectors are possible. For example, the coating fluid connector may comprise connections, or features of connections, described in U.S. Provisional Pat. Appl. Nos. 62/279,300 ("Modular spray gun lid assemblies and methods of design and use"); 62/279,619 ("Wide-mouthed fluid connector for hand-held spray guns"); 62/279,537 ("Button-lock fluid connector for hand-held spray guns"); 62/322,492
30 ("Connector systems for hand-held spray guns"); and/or in U.S. Pat. Pub. Nos. 2013/0221130 A1 ("Spraygun with built-in quick-fit connector"); 2004/0016825 A1 ("Mixing cup adapting assembly"); 2015/0090614 A1 ("Apparatus for spraying liquids, and adapters and liquid reservoirs suitable for use therewith"); 2006/0065761 A1 ("Easy

clean spray gun”); 2016/0052003 A1 (“Liquid Spray gun, spray gun platform, and spray head assembly”); and/or 2015/0028131 (“Spray gun having internal boost passageway”), the disclosures of which are hereby incorporated by reference in their entireties.

5 In FIG. 1, the fluid inlet 12 is itself incorporated into the barrel 38 to avoid directing the coating fluid through the spray gun platform 36. Since the coating fluid to be sprayed does not pass through the spray gun platform 36, cleaning of the spray gun platform 36 is rendered unnecessary (except perhaps wiping the tip of the fluid needle in
10 embodiments where the fluid needle is housed in the spray gun body), saving operator time and labor. In some examples, the fluid needle can be housed within (and therefore removable along with) the barrel 38, thereby reducing or eliminating the need to clean the spraying apparatus body. As a further advantage, the spraying apparatus 36 can be quickly converted over to dispense a different coating fluid, if desired, by swapping out the barrel 38 with another that is (or can be) outfitted with a different coating fluid container that
15 may already be loaded with a different material and a different air guide to adjust the spraying apparatus 10 for the material, such swapping being possible conveniently, without leaving the location in which spraying is being carried out.

The connection at the spray gun interface 22 between the barrel 38 and the spray gun platform 36 enables fluid communication between respective interior cavities and can be achieved using attachment mechanisms known in the art. In the depicted example, the
20 spray gun platform 36 includes mating connection features that mechanically interlock to the barrel 38 at the spray gun interface 22, thus providing a releasable connection in which an air-tight seal can be achieved between interior chambers of these components. The mechanism shown in the appended figures is akin to the connection achieved via one or more lever elements as described, for example, in U.S. patent 8,590,809 B2 to Escoto, Jr.
25 et al. In some examples, the connection between the barrel 38 and the spray gun platform 36 can be of the nature described in U.S. patent application number 62/430383, entitled “Spray Gun and Nozzle Assembly Attachment,” the disclosure of which is herein incorporated by reference in its entirety. In other examples, the connection between the barrel 38 and the spray gun platform 36 may be carried out by other means, such as, for
30 example, a threaded collar, by manually operable means for releasably mounting as described in U.S. patent number 6,971,590 B2 to Blette et al., or by releasable mounts as described in U.S. patent publication number 2006/0065761 A1 to Joseph et al., the disclosures of which are herein incorporated by reference in their entirety. In other

examples not shown herein, the barrel 38 is integral with (or at least not readily removable from) the spray gun body.

5 In some examples, the spray gun platform 36 and barrel 38 are interconnected by a mechanical interlock. To this end, the former includes a pair of flexible connection tabs 20 having respective openings 14. As the spray gun platform 36 and barrel 38 are mutually engaged, the connection tabs 20 may flex outwardly to snap over matching retaining projections 18 located on the barrel 38. To facilitate this process, the operator can also (or alternatively) pinch buttons 16 radially in toward the spray axis 42 of the barrel 38 to depress the projections 18. The mating engagement between the openings 14 and the
10 retaining projections 18 prevents the barrel 38 from becoming inadvertently detached. Alternatively, or in combination, other mechanisms can be used, such as bayonet-type fixtures, clamps, collars, and threaded connections.

Referring again to FIG. 1, the spray gun platform 36 includes a frame 24. A pistol-grip handle 28 and trigger 26 are connected to the frame 24. Extending outwardly from the
15 bottom of the handle 28 is a threaded inlet port 34 for connection to a suitable source of pressurized gas, the gas typically being air. As used herein, "pressurized gas" refers to gas under greater than atmospheric pressure. Optionally, and as shown, the trigger 26 is pivotally connected to the frame 24 and biased in its forward-most position. While holding the handle 28, an operator can depress the trigger 26 to dispense the coating fluid from the
20 spraying apparatus 10.

A threaded air inlet port 34 on the spray gun typically connects with a regulator 35 that is adjustable to change gun inlet pressure. A regulator 35 sets a pressure of air sourced to the spray gun when the trigger 26 is fully actuated (e.g., fully depressed into handle 28). In some instances, a gauge on the regulator 35 may not be relied upon by an operator
25 because of malfunction, paint soiling, or personal preference, and an operator may adjust a regulator 35 based on sound (e.g., the sound made by the set pressure of the spraying apparatus 10 when the trigger is fully actuated) rather than a depicted pressure. As such, it is advantageous to configure the spraying apparatus to create a preferred fan pattern with as broad a range of inlet pressures as possible (as precise inlet pressures may be difficult
30 or impossible to achieve with a broken or otherwise impaired regulator 35). In addition, while relying on a gauge, some operators prefer to set their spray guns at lower pressures while other operators prefer to set their spray guns at higher pressures. As discussed

herein, an air guide may notably increase a range of inlet pressures within which a given spraying apparatus 10 may create a preferred fan pattern.

Optionally, a fluid needle control 32 and fan control 30 can be positioned on the frame 24 (for example, on the rear of the gun as shown) to adjust the pressure of gas
5 flowing from the spray gun platform 36 into the barrel 38, as would be understood by one skilled in the art. The fluid needle control 32 can be adjusted to limit the travel distance of a fluid needle associated with a needle valve (not visible) located within the spraying apparatus 10. The travel of the fluid needle can affect both coating fluid flow and center
10 air flow (atomization air). Specifically, the fluid needle adjustor 32 may adjust/open a valve that lets air into the spraying apparatus, such that an operator can increase/decrease the amount of air that enters the spraying apparatus. In the depicted example, the fan control 30 is a rotatable knob that allows an operator to control air flow to a pair of air
15 horns used to adjust the spray pattern geometry. Specifically, the fan control 30 may adjust the proportion of the total air that is sent to the center air orifice versus being sent to the air horns.

Air Cap / Air Cap Base

Advantageously, and as discussed herein, the provided air cap 40 can result in the fan pattern being less sensitive to changes in the inlet air pressure of the gun. Moreover,
20 the need for a fan control 30 may be reduced or eliminated in some examples. As such, in these examples, a spraying apparatus may not include a fan control 30 and the associated components to operate the fan control 30. Eliminating the fan control 30 and associated components may allow for a more streamlined internal passageway for air, thereby
25 significantly reducing pressure losses due to air flow inefficiencies within the spray gun body.

FIG. 2 depicts an exploded perspective view of an example air cap with an example air cap base 50 and an example air guide 70. The air cap base 50 comprises a pair of air horns 52A-B (collectively “air horns 52”), a plurality of shaping air orifices 54A-B (collectively “shaping air orifices 54”), a plurality of auxiliary air orifices 64A-B
30 (collectively “auxiliary air orifices 64”), and a center air orifice 60. The center air orifice 60 may be in a distal surface 68 of the air cap base 50. In some examples, the center air orifice 60 is slightly raised from the distal surface 68, resulting in an outer wall 65 of the

center air orifice 60. The center air orifice 60 may have a radius 56 and a hole axis that are substantially or entirely co-linear with a spray axis 42 of the spraying apparatus 10.

5 The air cap base 50 is configured to be received by a distal portion 44 of the barrel 38 of the spraying apparatus 10, as shown in FIG. 1. The air cap base 50 may connect to the distal portion 44 of the barrel 38 of the spraying apparatus 10 by any means known to one skilled in the art. For example, the air cap base 50 may be internally threaded (not depicted) to mate with the distal portion 44 of the barrel 38 of the spraying apparatus 10, or the air cap base 50 may connect with the distal portion 44 of the barrel 38 of the spraying apparatus 10 with a mechanical interlock that utilizes tabs or other structures as described above. Alternatively, the air cap base may be retained against the barrel in a conventional manner, such as by an external threaded retaining ring. In some
10 embodiments, the air cap base is retained as described in U.S. patent application number 62/430393, entitled "Spray Gun Air Cap Retention Means," the disclosure of which is hereby incorporated by reference in its entirety.

15 The two air horns 52 may be arranged diametrically opposed from each other (e.g., mirrored across the spray axis 42) as depicted in the example air cap base 50 of FIG. 2. The air horns 52 may extend distally away from the base 66 of the air cap base 50. When the air cap base 50 is received by the barrel 38 of the spraying apparatus 10, the air horns 52 extend distally away from the spraying apparatus 10. Arranging the air horns 52 as depicted in FIG. 2 may result in more reliable fan patterns. In other examples (not
20 depicted), the air cap base 50 may contain additional air horns 52 or air horns 52 in other configurations. The air horns 52 may be partially or entirely hollow as to allow respective air passageways through the respective air horns 52 as discussed herein. The air passageways, shown in more detail in FIG. 5, may terminate at respective shaping air
25 orifices 54. For example, as depicted in the air cap base 50 of FIG. 2, air horn 52B includes two shaping air orifices 54A, 54B. In various embodiments (not depicted), an air horn of an air cap base may include a widely different number of shaping air orifices 54 and/or may contain shaping air orifices 54 in other configurations or orientations as necessary for a particular application.

30 In some examples, each air passageway may terminate in a single shaping air orifice 54, while in other examples a single air passageway may terminate in a plurality of shaping air orifices 54. For example, a single air passageway of an air horn 52B may terminate at both a first shaping air orifice 54A and a second shaping air orifice 54B of the

air horn 52B. In other examples, a first air passageway of the air horn 52B may terminate at a first shaping air orifice 54A, while a second air passageway of the air horn 52B may terminate at a second shaping air orifice 54B. An air passageway and shaping air orifice 54 may together guide a stream of air (hereinafter interchangeably referred to as a stream of air or air jet) toward the spray axis 42. The air jet may impact an atomized coating fluid stream exiting from the center air orifice 60 to assist in creating the fan pattern as described herein.

As depicted in FIG. 2, the air cap base 50 may include auxiliary air orifices 64 in the distal surface of the air cap base 50. As depicted, the air cap base 50 includes two auxiliary air orifices 64 that are arranged diametrically opposed from each other across the spray axis 42. In other examples (not depicted), the air cap base 50 may include varying numbers of auxiliary air orifices 64 in similar or different locations (e.g., auxiliary air orifices 64 may not be in line with air horns 52 as depicted in FIG. 2). In some examples, the base 66 of the air cap base 50 may include one or more air passageways that each terminate at an auxiliary air orifice 64. In other examples, the base 66 of the air cap base 50 may include one or more air passageways that terminate at a plurality of auxiliary air orifices 64. Auxiliary air orifices 64 and respective air passageways may shape air jets that define the fan pattern. In some examples, the air jets from the auxiliary air orifices 64 may impact an atomized coating fluid stream exiting from the center air orifice 60 to assist in creating the fan pattern as described herein. In other examples, the air jets from the auxiliary air orifices 64 may impact or otherwise interact with air jets exiting from the shaping air orifices 54 so that the jets emitted from the shaping air orifices 54 may better create a fan pattern as described herein. In yet other examples, the air jets from the auxiliary air orifices 64 may impact or otherwise interact with both the atomized coating fluid stream from the center air orifice 60 and fluid tip 78 and the air jets exiting from some or all of the shaping air orifices 54 to improve the resulting fan pattern.

Air Guide / Channel Members

FIG. 2 also depicts an example air guide 70 that can be received by the air cap base 50. The air guide 70 is configured to be received by a distal portion 62 of the air cap base 50. The air guide 70 has a one or more channel members 74 each comprising one or more channel surfaces (as shown in the exemplary embodiments, 74A, 74B, 74C, ... , 74L). The channel members are configured to channel air of air jets emitted from the air cap

base 50. The air guide 70 may have a center air orifice 80 with an axis that is substantially or entirely co-linear with the spray axis 42 and/or a central axis of the air cap base 50.

5 A channel member 74 may be configured to alter an air jet by occupying some of the space that the air jet would otherwise expand into as described below, thereby causing impingement of the air jet against channel member(s) 74 to alter respective air jet(s) shape and/or direction. For example, in the embodiments depicted in FIGS. 5, 6A, 10, 13-18 channel surfaces 74B, 74C, 74E, 74F, 74H, 74I, 74K, and 74L may each be described as a “guidance wall” that concentrates air of an air jet that has exited a shaping air orifice, while corresponding channel surfaces 74A, 74D, 74G, and 74J may each be described as a
10 “control surface” that alters the trajectory of said air jet.

As used herein, “concentrate” means to lessen the diversion or spread of a free air jet that would, without being concentrated, otherwise be free to diverge at its natural diversion angle, while generally allowing the trajectory of the air to be maintained along the primary axis of the jet. For example, if a free air jet escaping a circular orifice would
15 ordinarily form a generally conical shape having a half-angle of 7 degrees, to concentrate such jet would result in decreasing the half-angle to less than 7 degrees (but not less than 0 degrees) as measured in at least one plane long the primary axis of the jet. Non-limiting examples of concentrated jets are shown in FIGS. 20 and 21, where initial and concentrated half-angles are respectively indicated as $\emptyset 1$ and $\emptyset 2$. It will be appreciated
20 that, by concentrating the air jet, a relatively greater proportion of the air may be usefully employed to shape the stream of atomized droplets, rather than potentially allowing air at the outer portion of the diverging jet to bypass the stream of droplets and have less or no effect on the resulting fan pattern.

As used herein, “alter the trajectory” means to change the direction of air flow of an air jet away from the primary axis of the jet such that the half angle of at least a portion
25 of the jet is reduced to less than 0 degrees. For example, if a free air jet escaping a circular orifice would ordinarily form a generally conical shape having a half-angle of 7 degrees, to alter the trajectory of such jet would result in decreasing the half-angle to less than 0 degrees as measured in at least one plane long the primary axis of the jet. A non-limiting
30 example of a jet whose trajectory has been altered is shown in FIG. 22, where initial and altered half-angles are respectively indicated as $\emptyset 1$ and $\emptyset 2$. It will be appreciated that the altered portion of the air jet will be “flattened” to an extent, generally resulting in that flattened portion of the air jet more closely resembling a sheet of air than a cone of air,

thereby allowing a more distributed and uniform intensity of impingement across the cross-section of the stream of atomized droplets. In the case of a shaping air jet, for example, this more distributed and uniform intensity can reduce the tendency for the jet to split the fan pattern.

5 It has been observed that, when the inlet pressure to the spray gun is changed, the primary direction and/or angle of divergence of a free (uncontrolled) jet of air may also change. Left uncontrolled, these changes in direction and/or angle may result in corresponding changes in the manner, location, and/or intensity by which the jet will impinge upon other air jets and/or the stream of atomized droplets exiting the coating fluid
10 orifice, thus changing the resulting fan pattern. With the provision of a channel member, any such changes in the primary direction and/or angle of divergence can be at least partially compensated for by virtue of the fact that the jet will be interrupted by static surfaces whose location and orientation do not change with respect to other jets and the coating fluid orifice. In this way, changes in the manner, location, and/or intensity by
15 which the jet will impinge upon other air jets and/or the stream of atomized droplets exiting the coating fluid orifice can be reduced, thereby reducing changes in the resulting fan pattern at varying inlet pressures. This effect can be observed in FIGS. 28A-29C, where the location of the point "X" is shown to remain relatively constant at varying inlet pressures when employing an air guide according to the present disclosure (FIGS. 29A-
20 29C), and where the location of "X" is shown to vary under the same conditions when an air guide is not employed (FIGS. 28A-28C). It can be further observed in FIGS. 24 and 25 that the resulting fan pattern remains relatively constant at these varying inlet pressures when employing an air guide according to the present disclosure (FIG. 25), and that the resulting fan pattern is shown to vary when an air guide is not employed (FIG. 24).

25 Using channel members 74, the air guide 70 may channel air of air jets of the spraying apparatus 10. Concentrating air of the air jets may have numerous positive impacts upon the operation of the spraying apparatus 10. For example, in some instances, concentrating air of air jets may mitigate or eliminate negative effects of manufacturing imperfections of aspects of the spraying apparatus 10. For example, an air cap base 50
30 may have a manufacturing imperfection that is within the manufacturing tolerance of the air cap base 50, such as an angular deviation of an internal wall of a shaping air orifice 54 or auxiliary air orifice 64 relative to the respective axis 98, 102 of the shaping air orifice 54 or auxiliary air orifice 64, or a slight burr or asymmetry. Depending upon the

design/material/cost of a spraying apparatus 10, some amount of manufacturing imperfections may be an inevitability. Without an air guide 70, air jets of the respective shaping air orifice 54/auxiliary air orifice 64 may exit the air cap base 50 at an undesired angle or shape due to the deviation. Channel members 74 of the air guide 70, when
5 received by the air cap base 50, may act to mitigate or eliminate the effect of the undesired deviations. Channel members 74 may act to mitigate or eliminate the effect of these deviations by post-correcting the path and/or shape of air exiting the shaping air orifice 54 or auxiliary air orifice 64, increasing chances for air jet definition and/or correction. The channel members 74 post-correcting the path and/or shape of the air exiting the shaping air
10 orifice 54 and/or auxiliary air orifice 64 may reduce the impact that a manufacturing imperfection of the shaping air orifice and/or auxiliary air orifice 64 may have upon a respective air jet.

Further, as a result of the channel members 74 post-correcting the path and/or shape of the air exiting the shaping air orifices 54 and/or auxiliary air orifices 64 as
15 described above, the fan pattern of the spraying apparatus 10 may be less sensitive to adjustments made to the spraying apparatus. For example, using an air guide 70, a spraying apparatus 10 may be able to achieve a desired fan pattern with a wider range of settings of a fan control 30 and/or fluid needle control 32 of the spraying apparatus 10. Put differently, without an air guide 70, a fan control 30 and/or a fluid needle control 32 of a
20 spraying apparatus 10, along with the inlet pressure, may need to be adjusted to one of a relatively small array of settings in order to achieve a desired fan pattern. Conversely, with an air guide 70, the spraying apparatus 10 may achieve the desired fan pattern with a relatively larger array of settings of the fan control 30 and/or fluid needle control 32 and/or inlet pressure. The air guide 70 may cause the spraying apparatus 10 to spray with the
25 desired fan pattern with a relatively large array of settings by effectively removing the focus of spraying apparatus 10 adjustment from the fan control 30 and/or fluid needle control 32, and/or inlet pressure, and placing the focus of spraying apparatus 10 adjustment on channel members 74 of the air guide 70. Specifically, air guides 70 may allow a spraying apparatus to achieve a desired fan pattern for various functions by
30 receiving air guides 70 that occlude different shaping air orifices 54 and or auxiliary air orifices 64, block different portions of hole paths 100 of a spraying apparatus 10, or include different channel member surfaces that concentrate and/or alter the trajectory of air jets irrespective of other spray gun settings.

In some examples, channel members 74 of the air guide 70 may channel air of the air jets by “flattening” air of the air jets. Flattening air of the air jets may include changing the cross-sectional shape of an air jet from a generally circular shape to a more generally oval or sheet-like shape. In some examples, uncontrolled air jets may exit a spraying apparatus 10 in a generally conical shape with a generally circular cross-section. Air jets with a circular cross-section may have a tendency to “split” an atomized coating fluid stream that intersects with said air jets (e.g., where the air jets hits and focuses its energy on the “center” of the atomized coating fluid stream). Splitting the atomized coating fluid stream reduces the relative amount of atomized droplets in a center of the atomized coating fluid stream to a point where there is a relatively higher density of droplets in the portion of the coating fluid stream immediately adjacent to the center of the atomized coating fluid stream than within the center of the atomized coating fluid stream. For example, an air jet from a shaping air orifice 54 may split an atomized coating fluid stream along the longitudinal axis 42 of the spraying apparatus 10 if the spraying apparatus 10 has not received an air guide 70 to flatten air of the air jet of the shaping air orifice 54. The coating fluid stream may then impact the target surface in a fan pattern similar to the split fan pattern shown as Profile A in FIG. 17 (in comparison to a more preferred fan pattern shown as Profile C).

As another example, an uncontrolled air jet of an auxiliary air orifice 64 of a spraying apparatus 10 may split air of an air jet of a shaping air orifice 54. Such splitting of a shaping air jet can cause the shaping air jet to impact the atomized coating fluid stream in an irregular and/or asymmetric fashion, thereby having a deleterious effect on the fan pattern. As such, a channel surface may be introduced to flatten the auxiliary air jet, thereby causing it to more evenly impinge across the cross-section of corresponding shaping air jet. This more even impingement can, in turn, assist in flattening the shaping air jet, leading to beneficial results as described herein.

By altering and concentrating air of the air jets, the air guide 70 may improve the ability of the air jets to impact the atomized coating fluid stream as discussed herein to create a more preferred fan pattern. By improving fan patterns, an air guide 70 may improve the uniformity of the appearance of the coating material deposited on the target surface. Further, the air guide 70 may make the spraying apparatus 10 less sensitive to manufacturing imperfections, inlet pressure, spraying apparatus adjustments, and the like.

In some examples, channel members 74 may be provided and configured to channel each air jet emitted from the air cap base 50. In other examples, channel members 74 may only be provided and configured to channel a portion of such air jets. For example, channel members 74 may be configured to channel air jets emitted from each shaping air orifice 54. Alternatively, or in addition, channel members 74 may be configured to channel air jets emitted from each auxiliary air orifice 64. As another example, channel members 74 may be configured to channel air jets emitted from each auxiliary air orifice 64 and from shaping air orifices 54 relatively near to the distal surface 68 (e.g., shaping air orifice 54A) while not channeling air jets from shaping air orifices 54 relatively further from the distal surface 68 (e.g., shaping air orifice 54B), or channeling such air jets from further shaping air orifices 54 relatively less. It should be understood that one or any number of emitted air jets may be acted upon by a channel member.

The particular design and configuration of the various air guides 70 of FIGS. 2, 10, 11, 12 is merely for purposes of illustration. Other designs with other shapes that accommodate other numbers and sizes of shaping air orifices 54 and auxiliary air orifices 64 are also possible. For example, in certain instances the air guide 70 may not include “guidance walls” (such as channel surfaces 74B, 74C, 74E, 74F, 74H, 74I, 74K, and 74L in the embodiments shown in FIGS. 5, 6A, 10, 13-18), instead exclusively containing “control surfaces” (such as channel surfaces 74A, 74D, 74G, and 74J in the aforementioned Figures).

FIG. 3 depicts a perspective view of an example air cap 90. The air cap 90 includes the air cap base 50 and the air guide 70. As depicted in FIG. 3, the air cap base 50 has received the air guide 70, such that the air guide 70 is retained (e.g., pressed, snapped, placed, etc.) against or integral with the distal surface 68 of the air cap base 50.

Attachment of air guides 70 is described in greater detail elsewhere in the present disclosure.

FIG. 4 depicts a top view of an air cap 90, while FIG. 5 depicts a partial cross-sectional view taken at 5-5 of FIG. 4. As shown in FIG. 5, a fluid tip 78 terminates at a distal end in a coating fluid outlet. The fluid tip 78 transmits the coating material through the air cap 90. The cross-sectional view includes hole paths 100A-B (collectively, “hole paths 100”) of shaping air orifices 54 and auxiliary air orifices 64 of the air cap base 50. Hole paths 100 are the projected area that extends straight axially outwardly from a shaping air orifice 54 or auxiliary air orifice 64 along its corresponding axis 98 / 102.

As further shown in FIG. 5, air passageways 92A-B (collectively, “air passageways 92”) of the air horns 52 connect to shaping air orifices 54, and air passageways 94A-B (collectively, “air passageways 94”) of the base 66 of the air cap base 50 connect to auxiliary air orifices 64. The depicted shape and configuration of these air passageways 92, 94 is provided for illustration purposes only; other shapes and configurations are also possible. For example, in some instances air passageway 92A may only terminate at shaping air orifice 54A (e.g., rather than terminating at both shaping air orifices 54A and 54B), and another air passageway 92 (not depicted) may terminate at shaping air orifice 54B.

FIG. 7A depicts a partial cross-sectional view of a portion of an air guide 70 as it is received by an air cap base 50 as viewed along 7A-7A of FIG. 6A. The Figure shows a view along a projected hole path through a shaping air orifice 54 whose emitted shaping air jet will be partially altered by a channel surface (in this case a control surface 74A). As shown, control surface 74A encroaches a distance 111 into the hole path of the shaping air orifice 54A. It is to be understood that the distance 111 depicted in FIG. 7A is for purposes of illustration only; other distances 111 are contemplated and possible.

FIG. 7B depicts a partial cross-sectional view of a portion of an air guide 70 as it is received by an air cap base 50 as viewed along 7B-7B of FIG. 6B. The Figure shows a view along a projected hole path through a shaping air orifice 54 whose emitted shaping air jet will be partially altered by a channel surface (in this case a guidance wall 74A).

FIG. 7C depicts a partial cross-sectional view of a portion of an air guide 70 as it is received by an air cap base 50 as viewed along 7C-7C of FIG. 6A. The Figure shows a view along a projected hole path through an auxiliary air orifice 64 whose emitted auxiliary air jet will be partially altered by a channel surface (in this case a control surface 74D). As shown, control surface 74D encroaches a distance 113 into the hole path of the auxiliary air orifice 64B. It is to be understood that the distance 113 depicted in FIG. 7C is for purposes of illustration only; other distances 113 are contemplated and possible.

FIG. 7D depicts a partial cross-sectional view of a portion of an air guide 70 as it is received by an air cap base 50 as viewed along 7D-7D of FIG. 6B. The Figure shows a view along a projected hole path through an auxiliary air orifice 64 whose emitted auxiliary air jet will be partially altered by a channel surface (in this case a guidance wall 74D).

FIG. 11 and 12 depict a perspective isometric view and a cross-sectional side view of an example air guide 70, respectively. The air guide 70 includes a plurality of channel members comprising variously oriented channel surfaces.

FIGS. 13-17 depict several additional views of the air guide 70 shown in FIG. 10. These views are provided for reference so that features such as the various channel surfaces may be seen with greater clarity and detail.

FIG. 18 depicts a cross-section of an air cap 90 comprising an air cap base 50 and an air guide 70 associated therewith. A shaping plane 200 is depicted as coplanar with the cross-sectional cut. As will be appreciated, this shaping plane 200 is a common plane intersecting the spray axis 42 and each of the axes 98 / 102 of the respective shaping air and auxiliary air orifices.

Though channel surfaces of channel members 74 are depicted in the appended Figures as being straight and continuous, other forms of channel surfaces are contemplated and consistent with this disclosure. For example, the channel surfaces can comprise curved portions or contain one or more interrupting features (e.g., ridges or grooves or less regular features such as discrete protrusions or depressions) that are arranged in any orientation (e.g., substantially parallel/perpendicular with an orifice axis 98, 102 of the shaping air orifice 54 or auxiliary air orifice 64, respectively). In some examples, channel members 74, or a collection of channel members 74, may comprise any combination of channel surfaces that are flat, that comprise curved portions, or that comprise interrupting features. Interrupting features or curved portions of channel surfaces may alter the direction or relative turbulence of respective air jets. Altering the direction or relative turbulence of air jets of the air cap 90 may result in a spraying apparatus 10 maintaining a preferred fan pattern with greater consistency as described herein. Alternatively, altering the direction or relative turbulence of air jets of the air cap 90 may result in a spraying apparatus 10 maintaining a fan pattern for a specific process (e.g., applying a first coat of a first material), while a different direction or relative turbulence of air jets of the air cap 90 may result in a fan pattern for a different process (e.g., applying a second coat of the same first material or a different second material).

Attachment of Air Guide to Air Cap Base

If not constructed integrally with an air cap, the air guide 70 may be configured to be fastened to the air cap base 50. For example, as depicted in FIGS. 2 and 10, the air

guide 70 may have retention members 72A-B (collectively “retention members 72”). The retention members 72 may interface with air horns 52 of the air cap base 50 such that the retention members 72 secure the air guide 70 upon the air cap base 50. In some examples, the retention members 72 may be configured to pseudo-permanently fasten/secure the air guide 70 to the air cap base 50, such that the air guide 70 is difficult or impossible to remove from the air cap base 50 after the air cap base 50 receives the air guide 70. In other examples, the retention members 72 may be configured to temporarily fasten/secure the air guide 70 to the air cap base 50, such that the air guide 70 may stay secured for one or a number of spraying applications, after which the air guide 70 may be removed from the air cap base 50 with no or minimal damage to either the air guide 70 or the air cap base 50.

In certain examples, the air guide 70 may be configured to be fastened to the air cap base 50 such that it cannot be readily removed. For example, the air guide 70 may be attached to the air cap base 50 with ultrasound, heat staking, or adhesive bonding. In other examples, the air guide 70 is integral with the air cap base 50 and cannot be non-destructively detached.

In some examples, the retention members 72 have a slight interference fit with the air horns 52 of the air cap base, so that the air guide can be manually pressed down (e.g., pressed down by a human operator) against the distal surface 68 of the air cap base 50 and remain as placed during use of the spraying apparatus 10, and following use manually removed (e.g., removed by a human operator). Further, in some examples, an inner wall 82 of the center air orifice 80 of the air guide 70 may have a retaining interaction with an outer wall 65 (in this example, a raised outer wall) of the center air orifice 60 of the air cap base 50. The fit of the center air orifice and central aperture 60, 80 may be in conjunction with (or an alternative of) a retaining interaction of the retention members 72 and the air horns 52. It is to be understood that retention members 72 interfacing with the air cap base 50 through the particular retaining interaction shown is discussed for purposes of illustration only; retention members 72 may fasten/secure the air guide 70 to the air cap base 50 using any fastening technique known to one skilled in the art of fastening. For example, retention members 72 may include bayonet-type fixtures, clamps, collars, magnets, threaded connections, or other components that mechanically interlock such as the retaining projections 18 of FIG. 1, to fasten air guide 70 to air cap base 50.

As shown in several of the Figures, the air guide 70 optionally comprises feet 108. In some examples, the feet 108 of the air guide 70 press against the bearing surface 109 of

the air cap base 50 to maintain proper positioning of the channel members 74 of the air guide 70 relative to the air cap base 70. In other examples (not depicted), the air cap base 50 may not have a bearing surface 109 as depicted, meaning that the air guide 70 does not need (and therefore may not comprise) feet 108. In such examples, a bottom surface of the air guide 70 may press against or otherwise be located near to the distal surface 68 of the air cap base 50.

FIG. 10 depicts a perspective view of an example air guide 70. As depicted in the perspective view, in some examples the retention members 72 include notches 148A-B (collectively “notches 148”). These notches 148 may mate with ridges of the air horns 52 of the air cap base 50 to provide a more stable connection. The placement and number of notches 148 within FIG. 10 is purely for purposes of illustration; it is to be understood that other examples with more or fewer notches 148 in different locations is contemplated and consistent with this disclosure. Further, it is to be understood that the use of retention members 72 and notches 148 to securely connect an air guide 70 to an air cap base 50 is discussed for purposes of example only; in other examples, other mechanisms can be used, such as bayonet-type fixtures, clamps, collars, magnets, or threaded connections, among other possibilities.

It should be understood that the shape of the air guide 70 as depicted is configured specifically to be received by the particular shape of the example air cap base 50 of FIG. 2. To the extent the shape of the air cap base 50 may dictate at least parts of the shape of the air guide 70, alternate air guide 70 shapes that are configured differently to be received by alternate air cap base 50 shapes are both contemplated and consistent with aspects of this disclosure.

Materials / Construction of Air Guide

The air guide 70 may be a unitary structure (e.g., not an assembly but a single component constructed from a single material). In some examples, the air guide 70 may be made from metallic or ceramic or composite materials. In other examples, the air guide 70 may be polymeric. For example, the air guide 70 may be polyethylene, polypropylene, polyphenylene sulfide, polyoxymethylene, polyamide, a fluoropolymer, or copolymers thereof, among other possibilities. In some examples, rather than being a thermoplastic material, the polymeric material may be a thermoset material or a partially thermoset material. Examples of the former are liquid silicone rubber and non-silicone crosslinked hydrocarbon elastomers, and an example of the latter is Santoprene™, a family of

thermoplastic vulcanizate materials, which is made by the crosslinking of a hydrocarbon elastomer while blending it with a polyolefin. The polymeric materials may be filled with suitable fillers and/or additives (e.g., glass fibers, pigments, etc.) and thereby composite in nature. In examples where the air guide 70 is plastic, the air guide 70 may be constructed as part of a single injection molding operation. Other possibilities include molding all or some of the air guide 70 as part of the air cap base 50 or making a portion of the air guide 70 from one material and another portion of the air guide from another material. The spray gun with which the air guide is used may be constructed from any suitable combination of polymeric, metallic, ceramic, and/or composite materials.

Optional Additional Functions of Air Guides

In certain examples, the air guide 70 may be configured to occlude one or more shaping air orifice(s) 54 and/or auxiliary air orifices 64 of the air cap base. An air guide 70 may occlude a shaping air orifice 54 and/or auxiliary air orifice 64 by entirely covering the respective shaping air orifice 54 and/or auxiliary air orifice 64. In some examples, the air guide 70 may occlude a shaping air orifice 54 and/or auxiliary air orifice 64 such that a seal is made between the air guide 70 and the air cap base 50 over the respective shaping air orifice 54 and/or auxiliary air orifice 64. In some examples, a seal may be made between the air guide 70 and the air cap base 50 such that little or no air is emitted from the respective shaping air orifice 54 and/or auxiliary air orifices 64 during the operation of the spraying apparatus 10. An air guide 70 that creates a seal with the air cap base 50 may in some examples be made of softer plastic material (possibly as a result of a multi-shot injection molding manufacturing technique) to create such a seal. An air guide 70 that is so configured may also be configured to have a relatively stronger interference fit to withstand the pressure of the occluded air jets.

In some examples, an air guide 70 may be configured to occlude a shaping air orifice 54 and/or auxiliary air orifice 64 of a respective air cap base 50 to alter the number or configuration of shaping air orifices 54 and/or auxiliary air orifices 64 of the respective air cap base 50 that emit air jets. By altering the number or configuration of shaping air orifices 54 and/or auxiliary air orifices 64 that emit respective air jets, an operator may alter the functionality of the assembled air cap. For example, an air cap base 50 may have six different auxiliary air orifices 64 of different sizes configured to create air jets in different directions. A first air guide 70 may occlude a first set of four of the six auxiliary

air orifices 64, leaving air jets of the other two auxiliary air orifices 64 un-occluded (but possibly still channeled by respective channel members 74) to define a first fan pattern for a first spraying operation. After this, a second air guide may occlude the other two auxiliary air orifices, leaving air jets of the first set of four auxiliary air orifices 64 un-occluded (but possibly still channeled by respective channel members 74) to define a second fan pattern for a second spraying operation.

Optional Adjustable Air Guide

FIG. 8 depicts a top view of an adjustable air guide 70. An adjustable air guide 70 may be an air guide 70 that includes a plurality of air horn holders 124A-F (collectively “air horn holders 124”) and a plurality of channel members 74A-F (collectively “channel members 74”), where only a first subset of the plurality of channel members 74 are configured to channel air of air jets of the spraying apparatus 10 at a given time. Though in FIG. 8 only six channel members 74 are identified (three pairs of two), it is to be understood that in other examples widely varying numbers of channel members 74 consistent with this disclosure are possible in different arrangements. In some examples, all channel surfaces of an adjustable air guide 70 may be control surfaces. In other examples, all channel surfaces of an adjustable air guide 70 may be guidance walls. In yet other examples, channel surfaces of an adjustable air guide 70 may include both control surfaces and guidance walls. A particular first orientation of the adjustable air guide 70 on an air cap base 50 (e.g., the manner in which the air cap base 50 receives the adjustable air guide 70) defines a first subset. The orientation of the adjustable air guide 70 on the air cap base 50 may be adjusted such that a second and/ or third subset of channel members 74 are selectively configured to channel air of air jets of the spraying apparatus 10.

For example, adjustable air guide 70 may be received by an air cap base 50 as depicted in the perspective view of FIG. 9. As depicted in FIG. 9, air horn 52A is in air horn holder 124E and air horn 52B is in air horn holder 124B. Correlating this to FIG. 8, this means that a first subset of channel surfaces 74B, 74E is set to channel air of air jets exiting from shaping air orifices 54 of the air horns 52 of the air cap base 50. In some examples, adjustable air guide 70 may be removed from the air cap base 50 and adjusted to be received by the air cap base 50 in a different orientation, such that air horn 52A is in air horn holder 124D and air horn 52B is in air horn holder 124A. In this way, a second subset of channel surfaces 74A, 74D is set to channel air of air jets exiting from shaping

air orifices 54 of the air horns of the air cap base 50. A third subset may be similarly employed using air horn holders 124C and 124F and channel surfaces 74C and 74F.

In some examples, subsets of channel members 74 of the adjustable air guide 70 may have shared characteristics that are different from other subsets of channel members.

5 For example, channel surfaces 74A, 74D may both be configured to create a relatively large fan pattern, while channel surfaces 74B, 74E are configured to create a relatively medium-sized fan pattern, while channel surfaces 74C, 74F are configured to create a relatively small fan pattern. Alternatively, different channel member 74 sets may be configured to channel air of air jets differently to create a relatively consistent fan pattern
10 when paired with different coating materials (e.g., a first coating material is sprayed with a first fan pattern using channel members 74A, 74D, while a second coating material is sprayed with a second fan pattern using channel members 74B, 74E, etc.). In such examples, an operator may use a single spraying apparatus 10 and a single air cap base 50 and a single adjustable air guide 70 to alter the utility of the spraying apparatus 10 by
15 merely altering the orientation of the adjustable air guide 70.

In some examples, an adjustable air guide 70 may not have discrete sections with discrete subsets of channel members 74. Instead, an adjustable air guide 70 may have one or more continuous sections (e.g., a single section which encompasses all or a portion of the entire ring) that may receive the air horns 52. The one or more continuous sections
20 may have one or more continuous channel surfaces that continuously change(s) with circumferential position. For example, an angle of a continuously changing channel surface may continuously change relative to a hole path 100 of a respective air jet (e.g., the jet of a shaping air orifice 54). In one example, the angle of a continuously changing channel surface, relative to the hole path 100, may increase/decrease 10° during a 30°
25 rotation around a longitudinal axis 42 of the adjustable air guide 70. The relative angle may be the same as reflected across a central aperture 80 of the adjustable air guide 70, such that the angle facing the diametrically opposed air horns 52 is always consistent (e.g., such that shaping air orifices 54 of both air horns 52 face a portion of the pseudo-continuously changing channel member 74 that is at a same angle relative to the shaping
30 air orifices 54). In other examples, a continuous channel surface may not continuously change, but may instead change in steady increments (e.g., such that a relative angle of the continuous channel surface changes incrementally (e.g., by step) by 10° every 30° rotation around the longitudinal axis 42 of the adjustable air guide 70). An adjustable air guide 70

with a continuous channel surface may allow an operator of a spraying apparatus 10 to rotate (without removing and reinstalling) an adjustable air guide 70 to quickly and precisely alter the manner in which channel members 74 channel air of air jets to create a fan pattern for a desired spraying operation.

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Method of Use

FIG. 19 depicts a method 150 of using an air guide to use a spraying apparatus. In certain examples, the spraying apparatus, air guide, and/or air cap base may be predominantly plastic. In other examples, the spraying apparatus, air guide, and/or air cap base may be predominantly metal but may also include polymeric and/or ceramic components. It is to be understood that the ordering of boxes in method 150 are for purposes of illustration only, and operations could happen in different orders or skipped entirely. The method 150 may begin with the spraying apparatus receiving an air cap base (152). The spraying apparatus may be substantially similar to the spraying apparatus 10 of FIG. 1. The spraying apparatus may be adjusted to a first state, such that all controls of the spraying apparatus are set to a certain position. The air cap base may be substantially similar to the air cap base 50 of FIG. 2. For example, the air cap base may include a pair of diametrically opposed air horns that are configured to guide a plurality of air jets towards the spray axis 42 of the barrel of the spraying apparatus.

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The air cap base may receive the air guide (154). The air guide may be substantially similar to the air guide 70 of FIG. 2. For example, the air guide may have one or more channel members that are configured to channel air of air jets of the spraying apparatus/air cap base. A channel member may include one or more control surfaces that alter the trajectory of air jets and/or one or more guidance walls that concentrate air of air jets. The air cap base may securely receive the air guide. For example, the air cap base may receive the air guide with a mechanically interlocking fit, so that the air guide will not loosen during operation of the spraying apparatus. Tabs (e.g., retention members 72 of FIG. 2) and/or notches (e.g., notches 148 of FIG. 7A) of the air guide may be configured to provide such fit with air horns of the air cap base. Other means known to one skilled in the art may also be used to temporarily or pseudo-permanently affix the air guide to the air cap base.

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The spraying apparatus may be operated using the air cap base and air guide (156). Operating the spraying apparatus may include spraying a surface with a coating fluid that

is dispensed between the air horns of the air cap base through a center air orifice of the air cap base and air guide. The surface may be sprayed by the spraying apparatus in a first fan pattern. When this first spraying operation is completed, the air guide may be removed (158). In some examples, a human operator may remove the air guide by manually pulling the air guide off. In certain examples (e.g., where the air guide is plastic), it may be economically feasible to dispose of the air guide (160) rather than going through the effort of cleaning the air guide. In other examples, the air guide may be cleaned for reuse.

Where an operator needs to use the spraying apparatus to spray a surface with a different fan pattern, the air cap base may receive the air guide in a new orientation (162). The air cap base may receive the same air guide in a new orientation when the air guide is an adjustable air guide, similar to the air guide 70 of FIGS. 8 and 9. When the air guide is configured in a new orientation, the spraying apparatus may spray the surface (156). It may be the same surface or a different surface. The spraying apparatus may spray the surface with a second fan pattern as a result of the new orientation of the air guide. The adjustment of the spraying apparatus may be substantially similar to the adjustment of the spraying apparatus during the first spraying operation.

In some examples, after removing a first air guide, an air cap base may receive a second air guide. The second air guide may have a second set of channel members that are different than the channel members of the first air guide. The second set of channel members may be configured to alter the air streams of the air cap base in a different manner than the channel members of the first air guide. The spraying apparatus may spray the surface with a second fan pattern when using the second air guide.

Examples

Unless stated otherwise, the following components and materials, described according to their respective trade designations and part numbers, were obtained from 3M Company, St. Paul, Minnesota.

The following abbreviations are used to describe the examples:

AAJ:	auxiliary air jet
cm:	centimeters
ipm:	inches per minute
kPa:	kiloPascals
mil:	10-3 inches

mL:	milliliter
μm:	micrometer
mm:	millimeters
m/min:	meters per minute
pgv:	pixel gray values
psi:	pounds per square inch
SAJ:	shaping air jet
Std. Dev.:	Standard deviation

FIG. 24 depicts a chart of pixel gray values in relation to pattern locations of Comparative Example A, as well as an image of the corresponding fan pattern. A model “PPS” 600 mL paint gun cup, Part No. 16122, with a 200 μm filter, lid and liner assembly, Part No. 16300, was filled with a water-based black paint, obtained under the trade designation “ENVIROBASE T407” from PPG Industries, Inc., Pittsburgh, Pennsylvania. A model “ACCUSPRAY HG14 SPRAY GUN, PART No. 16579”, with a “1.3 mm ATOMIZING HEAD, PART No. 16583”, having six, 65 mil (152.4 μm) air atomization passages, was connected to the gun cup assembly. This assembly was subsequently attached to an automated spray painting machine, model “310940” from Spraymation, Inc., Fort Lauderdale, Florida. A spray pattern, approximately 12 by 20 inch (30.5 by 50.8 cm), was then applied to a white paperboard substrate, type “WHITE TANGO C1S” obtained from MeadWestvaco Corporation., Richmond, Virginia, under the following conditions:

Spray Gun Inlet Pressure:	28 psi (193 kPa)
Shaping Air Valve:	Fully open
Fluid Valve:	Fully open
Spray Gun-to-Panel Distance:	8 inches (20.32 cm)
Spray Gun Traverse Speed:	800 ipm (20.32 m/min)

FIG. 24 further depicts charts of pixel gray values in relation to pattern locations for Comparative Examples B and C, as well as images of the corresponding fan patterns. The process generally described for generating the Comparative A spray pattern was repeated, wherein the spray gun inlet pressure was set to 20 and 36 psi (138, and 248 kPa) for Comparatives B and C, respectively.

FIG. 25 depicts a chart of pixel gray values in relation to pattern locations of Example 1, as well as an image of the corresponding fan pattern. An air guide as described above, having 20 mil (0.508 mm) and 24 mil (0.610 mm) encroachment in the auxiliary air jets (AAJ) and the shaping air jets (SAJ), respectively, was press-fitted around the air horns and flush with the spray outlet orifice of the spray gun nozzle. A spray pattern was then generated as generally described in Comparative Example A.

FIG. 25 further depicts charts of pixel gray values in relation to pattern locations for Examples 2 and 3, as well as images of the corresponding fan patterns. The process generally described for generating the Example 1 spray pattern was repeated, wherein the spray gun inlet pressure was set to 20 and 36 psi (137 and 248 kPa) for Examples 2 and 3, respectively.

Digital images of the spray patterns (shown as the “Fan Pattern Image” in FIGS. 18 and 19) were taken using model “OPTIO E90” digital camera from Pentax Corporation, and saved as a “jpeg” file. Using the image processing software “IMAGEJ”, the pixel gray values (pgv) were subsequently measured across the width of each spray pattern. Plots of the paint distribution profiles, as represented by pgv, are given in FIGS. 18 and 19. Pattern size corresponds to the width, in cm, of the spray pattern at a pgv of < 200. Descriptions of the various paint distribution profiles are provided in FIG. 23. The profiles and pattern sizes of Comparatives and Examples of aspects of the disclosure are listed in FIGS. 24 and 25.

Schlieren images of a comparative spray gun and one with an exemplary air guide operated at pressures 139, 193, 248 kPa without coating fluid are shown in FIGS. 26A-29C. For the sake of clarity, although the respective Schlieren images are labeled as “Comparative A,” “Example 1,” etc., the images strictly speaking differ from the Examples of FIGS. 24 and 25 insofar as the spray guns are not loaded with the ENVIROBASE T407. Rather, the spray guns were operated with compressed air alone, under the same pneumatic conditions as the Examples in FIGS. 24 and 25.

The Schlieren images were obtained using a z-type Schlieren system mounted vertically and modified such that the source slit and cut-off filter were each approximately 2 inches (5.1 cm) behind the vertical plane (z-plane), their light path directions perpendicular to the z-plane. A 1 inch (2.5 cm) mirror reflected the light emanating from the slit to the first 6 inch (15.2 cm) mirror. The light then traversed the z-path exiting the second 6 inch (15.2 cm) mirror being reflected with a second 1 inch (2.5 cm) mirror

behind the z-plane and towards the cut-off. The air cap was mounted and positioned in the light path, its spray direction perpendicular to the z-plane and directed to the right-hand side of the images as shown. The air cap was rotated so that the air horns and air guide were parallel to the light beam cross-section between the two 6 inch (15.2 cm) mirrors.

5 The slit and cut-off were adjusted to be parallel to the orientation of the air horns and air guide. The light source was a CREE XM-L-H LED focused onto a 1mm slit formed from two razor blades separated by approximately 1mm. The Schlieren mirrors were each 6-inch diameter, 60 inch (152.4 cm) focal length spherical mirrors. The cut-off was a razor blade, and the slit was formed from two razor blades separated approximately 1 mm.

10 The camera was a Nikon D90 that utilized a Kenko Teleplus PRO 300 2X AF and a Nikon AF Zoom-NIKKOR 80-200mm f/2.8D ED Lens at 200 mm for a 400mm focal length. The photos were taken at 1/4000s, f/5.6, and ISO 640.

Using Photoshop CC (available from Adobe Systems Incorporated), each Schlieren image was converted to 8-bit grayscale such that each pixel had an absolute intensity level
15 “k” ranging from 100 (corresponding to pure black) to 0 (corresponding to pure white). Each image was then color corrected so that relative intensity levels were consistent from image to image. To perform the color correction, a white point was chosen for each image at a point where the lower-right-most shaping air jet (as seen in the images) emerged from the air horn, while a black point was chosen over the body of the bottom air horn. This
20 color correction mapped the original absolute “k” value for each pixel to a new percentage value relative to the new white point (now corresponding to 0%) and the new black point (now corresponding to 100%). The color corrected images are shown in FIGS. 26A-27C.

Starting with each color corrected image, a point “X” was placed a distance away from the fluid tip along the spray axis at the pixel whose intensity “k” was 50%. This
25 location “X” was defined as the jet intersection position. The images bearing jet intersection positions “X” are shown in FIGS. 28A-29C.

For each image, the distance in centimeters from the fluid tip to the jet intersection position “X” was determined based on the known, controlled distance between the tips of the air horns. The various jet intersection positions are reported in the table in FIG. 30,
30 along with the percent-wise change in distance for each set of three pressures. Jet intersection positions at varying inlet pressures are plotted in FIG. 31. Percent-wise changes in jet intersection position at varying inlet pressures are plotted in FIG. 32.

Optional Self-Contained Center Air Orifice

Alternatively or additionally, in some embodiments, the central aperture 80 of the air guide 70 may itself comprise center air guiding surfaces, as opposed to merely providing clearance for a center air orifice 60 on an air cap base 50. For example, instead of an arrangement as depicted in FIGS. 2 and 3, an arrangement as shown in FIGS. 33-37A may be provided – *i.e.*, whereby the inner wall 82 of the central aperture 80 comprises at least one outer center air guiding surface 82' to guide and shape a center air flow exiting the air cap base 50 to assist in atomizing liquid emitting from the fluid tip. By arranging the central aperture in this manner, a degree of control over center air flow can be achieved alongside the benefits of the air guides described elsewhere herein.

For example, a painter or paint manufacturer may desire certain spray characteristics for successful application of a particular coating. These parameters may include, for example, droplet size, coating liquid flow rate, center air flow rate, shaping air flow rate, overall air flow rate, and transfer efficiency. To achieve this conventionally, the painter may need to select a particular spray gun, fluid tip, and air cap, and carefully set up the gun by adjusting the inlet pressure and balancing individual air flow controls for the center air and shaping air. By providing at least a portion of the center air orifice along with an air guide 70, it is possible to preconfigure the gun to lessen the need for such manual adjustments. For example, an air guide 70 may be provided with preconfigured geometry designed to optimize spray characteristics for a given coating manufactured by a particular paint manufacturer, such that the painter need only install such an air guide and make few (if any) adjustments to gun settings to obtain good results. Such preconfiguration may allow successful application by painters with less training or experience than would otherwise be required.

Moreover, such a system may allow a single spray gun to be used to carry out multiple jobs that would ordinarily require multiple spray guns. For example, a painter may use different spray guns for application of primer, base coat, sealer, and clear coat. For each of these coatings / guns, a particular balance of center to shaping air and/or a particular degree of atomization may be desired, and each dedicated gun may be set up to deliver such characteristics. Using a device as described herein, the painter may be able to employ a single spray gun to carry out two or more of these applications simply by switching air guides (or by using a new atomizing head or nozzle assembly that carries a

different air guide). For example, a manufacturer or painter may employ methods 154 as depicted in FIG. 38.

As shown in FIG. 37A, the position, size, and shape of the center air annulus between the fluid tip 78 and the inner wall 82 can be adjusted as desired for a given application. For example, it will be appreciated that providing a greater center air annulus area 'A' for the center air annulus will permit relatively more air to escape at a given pressure, and vice versa. Assuming the shaping air apertures and flow control adjustments on a spray gun are not altered, such changes in the center air annulus area A of the center air annulus will in turn change the relative balance of air flow between shaping air and center air. It will also be appreciated that the axial position of the center air orifice relative to the fluid tip can have an effect, for example, on the angle and manner upon which center air will act upon fluid exiting the fluid tip.

As shown in FIG. 37A, a fluid tip position 'F' is defined as the distance along the spray axis 42 between the distal end 79 of the fluid tip 78 and the axially outermost edge 83 of the inner wall 82. The fluid tip position F may be chosen to be zero (wherein the axially outermost edge 83 of the inner wall 82 is flush with the distal end 79 of the fluid tip 78), positive (wherein the fluid tip 78 is recessed beneath the axially outermost edge 83 of the inner wall 82), or negative (wherein the fluid tip 78 is proud of the axially outermost edge 83 of the inner wall 82).

Also shown in FIG. 37A is a transition position 'T', which is defined as the distance along the spray axis 42 between the distal end 79 of the fluid tip 78 and a transition 84 at which the outer center air guiding surface 82' begins expanding outwardly into an inner center air guiding surface 85 of the center air passage within the spray nozzle. In the embodiment shown, the transition 84 occurs at the intersection of a conical interior wall (inner air center air guiding surface 85) and a cylindrical inner wall (outer center air guiding surface 82'). It will be appreciated that the transition position T may be selected (in conjunction with A and F) to "funnel" and/or "aim" the center air (*i.e.*, to shape the center air flow), thereby permitting center air to directly radially impinge upon the coating liquid (*i.e.*, if unimpeded by the exterior guiding surface 78' of the fluid tip 78), or to impinge upon exterior guiding surface 78' of the fluid tip 78 that lie in the path of (and therefore deflect) the center air to direct it more parallel to the coating liquid flow. Such changes can affect the degree of atomization, droplet size, and coating liquid flow (*e.g.*, by altering the Venturi effect created by the exiting center air).

By way of example, sample air guides were made to demonstrate the manner in which various spray characteristics may be changed by varying the aforementioned dimensions T, A, and F. The samples air guides were fabricated using a SLA-type 3D printer (Viper si2 manufactured by 3D Systems, Inc.). The air cap of a 3M Accuspray™ 1.3 mm Atomizing Head (Model 16583) was modified by machining out the center air orifice of the commercially available air cap, thereby enlarging the opening to accommodate the center air guiding surface 82' of the modified air guides. Each Sample air guide was assembled to the modified atomizing head and tested in turn as described below. Assembled dimensions for three samples are reported in Table 1 below.

Table 1

Assembled dimensions for air guides with
self-contained center air orifice

Sample	Transition Position 'T'	Center Air Annulus Area 'A'	Fluid Tip Position 'F'
1	0.052 in (1.32 mm)	0.0185 in ² (11.94 mm ²)	0.010 in (0.254 mm)
2	0.042 in (1.07 mm)	0.0113 in ² (7.29 mm ²)	0.010 in (0.254 mm)
3	0.032 in (0.813 mm)	0.0137 in ² (8.84 mm ²)	0.010 in (0.254 mm)

Measurements were performed with each Sample on a 3M Accuspray™ spray gun:

1. Spray gun (3M Part Number 16579) inlet pressure required to result in a pressure of 10 psi (68.9 kPa) under the air cap (Ashcroft Air Pressure Gauge Part #DG2531N2NAM02L300#) while spraying.
2. Total air flow rate through the spray gun while maintaining 10 psi (68.9 kPa) under the air cap (Dwyer Air Flow Meter Model RMC-106).
3. Average liquid flow rate from fluid tip while maintaining 10 psi (68.9 kPa) under the air cap (calculated by measuring water mass loss in 30 second starting with 600g of water in a standard size 3M PPS™ spray gun cup system).

For all measurements, the spray gun fluid adjustment knob was 5 turns open and the shaping air adjustment knob, 1.5 turns open.

Measurement results for the three sample are reported in Table 2 below.

Table 2

Pressure and flow measurements for air
guides with self-contained center air
orifice

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Sample	Air Cap Pressure	Inlet Air Pressure	Air Flow Rate	Water Flow Rate
1	10.0 psi (68.9 kPa)	28.4 psi (196 kPa)	9.5 grams/s	3.2 grams/s
2	10.0 psi (68.9 kPa)	21.0 psi (144.8 kPa)	7.4 grams/s	3.5 grams/s
3	10.0 psi (68.9 kPa)	23.8 psi (164.1 kPa)	8.3 grams/s	3.4 grams/s

It can be seen that, of the Samples measured under these conditions, Sample 2 produces the highest water flow rate while consuming the least air. This could be beneficial to the painter in several ways. First, higher paint flow rates in conjunction with lower air flow rates generally result in greater paint transfer efficiency. Therefore, the spray gun configured with the Sample 2 air guide will not only spray a relatively greater volume flow rate of paint than with the other Samples, but more of that paint is likely to reach the workpiece. Such an increase in transfer efficiency enables the painter to complete a job with lower material and time costs. Further, the spray gun configured with the Sample 2 air guide should also reduce energy costs and compressor wear and tear versus the other exemplary options, since less compressed air is required to transfer an equivalent volume of paint to a workpiece.

CLAIMS

What is claimed is:

1. An air guide configured to be disposed on a spraying apparatus that is configured to emit a plurality of air jets to shape an atomized coating fluid stream of a coating material into a fan pattern along a spray axis, the air guide comprising a first channel member configured to shape a first air jet of the plurality of air jets to alter the fan pattern.
2. The air guide of claim 1, wherein the first channel member comprises a control surface configured to alter the trajectory of the first air jet.
3. The air guide of any of claims 1 to 2, wherein the first channel member comprises a guidance wall configured to concentrate the first air jet.
4. The air guide of any of claims 2 to 3 further comprising an air cap base upon which the air guide is configured to be received.
5. The air guide of claim 4 wherein the air cap base is configured to be received by a distal portion of a spraying apparatus.
6. The air guide of any of claims 4-5 wherein the air cap base comprises:
 - a center air orifice comprising a first orifice axis that is substantially parallel with the spray axis; and
 - a first air horn extending substantially parallel to the spray axis and comprising an air passageway that feeds a first shaping air orifice, wherein the first shaping air orifice is configured to emit a first shaping air jet along a first shaping axis towards the spray axis;wherein a shaping plane is defined as a common plane passing through the spray axis and the first shaping axis.

7. The air guide of any of claims 4-5 wherein the air cap base comprises:

a center air orifice comprising a first orifice axis that is substantially parallel with the spray axis; and

a first auxiliary air orifice configured to emit a first auxiliary air jet along a first auxiliary axis;

wherein a shaping plane is defined as a common plane passing through the spray axis and the first auxiliary axis.

8. The air guide of any of claims 4-5 wherein the air cap base comprises:

a center air orifice comprising a first orifice axis that is substantially parallel with the spray axis;

a first air horn extending substantially parallel to the spray axis and comprising an air passageway that feeds a first shaping air orifice, wherein the first shaping air orifice is configured to emit a first shaping

air jet along a first shaping axis towards the spray axis; and a first auxiliary air orifice configured to emit a first auxiliary air jet along a first auxiliary axis;

wherein a shaping plane is defined as a common plane passing through the spray axis, the first shaping axis, and the first auxiliary axis.

9. The air guide of any of claims 6 or 8 wherein the air cap base comprises:

a second air horn opposite the first air horn, extending substantially parallel to the spray axis and comprising an air passageway that feeds a second shaping air orifice, wherein the second shaping air orifice is configured to emit a second shaping air jet along a second shaping axis towards the spray axis;

wherein the shaping plane further passes through the second shaping axis.

10. The air guide of any of claims 7 or 8 wherein the air cap base comprises:
a second auxiliary air orifice configured to emit a second auxiliary air jet
along a second auxiliary axis;
wherein the shaping plane further passes through the second auxiliary axis.

5

11. The air guide of claim 8 wherein the air cap base comprises:
a second air horn opposite the first air horn, extending substantially parallel
to the spray axis and comprising an air passageway that feeds a second
shaping air orifice, wherein the second shaping air orifice is configured to
emit a second shaping air jet along a second shaping axis towards the
spray axis; and
a second auxiliary air orifice configured to emit a second auxiliary air jet
along a second auxiliary axis;
wherein the shaping plane further passes through the second shaping axis and
the second auxiliary axis.

10

15

12. The air guide of any of claims 6, 8, or 9 wherein the first air jet is the first shaping air jet.

20

13. The air guide of any of claims 7, 8, or 10 wherein the first air jet is the first auxiliary air jet.

25

14. The air guide of any of claims 9 or 11 comprising a second channel member configured to shape a second air jet, wherein the second air jet is the second shaping air jet.

30

15. The air guide of any of claims 10 or 11 comprising a second channel member configured to shape a second air jet wherein the second air jet is the second auxiliary air jet.

16. The air guide of any of claims 1-3 comprising a second channel member configured to shape a second air jet.

17. The air guide of any of claims 4-13 comprising a second channel member configured to shape a second air jet.

5 18. The air guide of any of claims 14, 15, or 17, wherein the second channel member comprises a control surface configured to alter the trajectory of the second air jet.

19. The air guide of claim 16 wherein the second channel member comprises a control surface configured to alter the trajectory of the second air jet.

10 20. The air guide of any of claims 14, 15, 17, or 18, wherein the second channel member comprises a guidance wall configured to concentrate the second air jet.

21. The air guide of any of claims 16 or 19, wherein the second channel member comprises a guidance wall configured to concentrate the second air jet.

15 22. The air guide of any of claims 4-15, 17-18, or 20, wherein the air guide is integral with the air cap base.

23. The air guide of any of claims 1-21 wherein the air guide is a unitary structure.

20 24. The air guide of claim 23 wherein the air guide is constructed of an injection molded polymeric material.

25 25. The air guide of claim 3 wherein the guidance wall of the first channel member is opposed by an opposing guidance wall, such that the first channel member is configured to concentrate the first air jet in two locations.

30 26. The air guide of any of claims 20 or 21 wherein the guidance wall of the second channel member is opposed by an opposing guidance wall, such that the second channel member is configured to concentrate the second air jet in two locations.

27. A method of using a spraying apparatus comprising

operating a spraying apparatus to cause the spraying apparatus to emit an atomized stream of a coating material and a plurality of air jets to shape the atomized stream into a fan pattern along a spray axis, the plurality of air jets comprising a first air jet; and

5 shaping the first air jet with a first channel member to alter the fan pattern.

28. The method of claim 27, wherein the first channel member comprises a control surface configured to alter the trajectory of the first air jet, the method comprising altering the trajectory of the first air jet to alter the fan pattern.

10

29. The method of any of claims 27-28, wherein the first channel member comprises a guidance wall configured to concentrate the first air jet, the method comprising concentrating the first air jet to alter the fan pattern.

15 30. The method of any of claims 27-29 wherein the plurality of air jets comprises a second air jet, the method comprising shaping the second air jet with a second channel member to alter the fan pattern.

20 31. The method of claim 30, wherein the second channel member comprises a control surface configured to alter the trajectory of the second air jet, the method comprising altering the trajectory of the second air jet to alter the fan pattern.

25 32. The method of any of claims 30-31, wherein the second channel member comprises a guidance wall configured to concentrate the second air jet, the method comprising concentrating the second air jet to alter the fan pattern.

33. The method of claim 29 wherein the guidance wall of the first channel member is opposed by an opposing guidance wall, such that the first channel member is configured to concentrate the first air jet in two locations, the method comprising concentrating the first air jet to alter the fan pattern.

5

34. The method of claim 32 wherein the guidance wall of the second channel member is opposed by an opposing guidance wall, such that the second channel member is configured to concentrate the second air jet in two locations, the method comprising concentrating the second air jet to alter the fan pattern.

10

35. The air guide of any of claims 1-21 or 23-26 comprising a center air orifice comprising an outer center air guiding surface.

15

36. The air guide of claim 35 comprising an inner center air guiding surface and a transition located between the inner center air guiding surface and the outer center air guiding surface.

20

37. A spraying apparatus comprising an air guide according to any of claims 35 or 36 wherein the liquid spray gun nozzle comprises a fluid tip comprising a distal end and an exterior center air guiding surface.

25

38. The spraying apparatus of claim 37 wherein the outer center air guiding surface comprises an axially outermost edge, wherein a fluid tip position F is defined as a distance along the spray axis from the axially outermost edge of the outer center air guiding surface and the distal end of the fluid tip, wherein the fluid tip position F is a positive value when the distal end of the fluid tip is recessed within the axially outermost edge of the outer center air guiding surface.

39. The spraying apparatus of any of claims 37 or 38 wherein a transition position T is defined as a distance along the spray axis from the distal end of the fluid tip to the transition between the inner center air guiding surface and the outer center air guiding surface, wherein the transition position T is a positive value when the transition between the inner center air guiding surface and the outer center air guiding surface is recessed behind the distal end of the fluid tip.

40. The spraying apparatus of any of claims 37-39 wherein a center air annulus area A is defined as the annular area between the outer center air guiding surface of the air guide and the exterior center air guiding surface of the fluid tip when viewed along the spray axis.

41. A method of providing an air guide for a spraying apparatus to tailor spraying apparatus for a given application, the method comprising:
selecting an air guide according to any of claims 35 or 36 to fit a spraying apparatus comprising a fluid tip comprising a distal end and an exterior center air guiding surface; and
assembling the air guide to the spraying apparatus.

42. The method of claim 41 wherein the outer center air guiding surface comprises an axially outermost edge, wherein a fluid tip position F is defined as a distance along the spray axis from the axially outermost edge of the outer center air guiding surface and the distal end of the fluid tip, wherein the fluid tip position F is a positive value when the distal end of the fluid tip is recessed within the axially outermost edge of the outer center air guiding surface, wherein selecting the air guide comprises selecting the air guide to result in a particular fluid tip position F.

43. The method of any of claims 41 or 42 wherein a transition position T is defined as a distance along the spray axis from the distal end of the fluid tip to the transition between the inner center air guiding surface and the outer center air guiding surface, wherein the transition position T is a positive value when the transition between the inner center air guiding surface and the outer center air guiding surface is recessed behind the distal end of

the fluid tip, wherein selecting the air guide comprises selecting the air guide to result in a particular transition position T.

5 44. The method of any of claims 41-43 wherein a center air annulus area A is defined as the annular area between the outer center air guiding surface of the air guide and the exterior center air guiding surface of the fluid tip, wherein selecting the air guide comprises selecting the air guide to result in a particular center air annulus area A.

10 45. The method of any of claims 41-44 wherein selecting the air guide comprises selecting from among a set of different air guides, wherein each air guide in the set of different air guides is configured to tailor the spraying apparatus for a different application.

15 46. The method of any of claims 27-32 comprising shaping a center air flow with an outer center air guiding surface, wherein the outer center air guiding surface and the first channel member are positioned on an air guide.

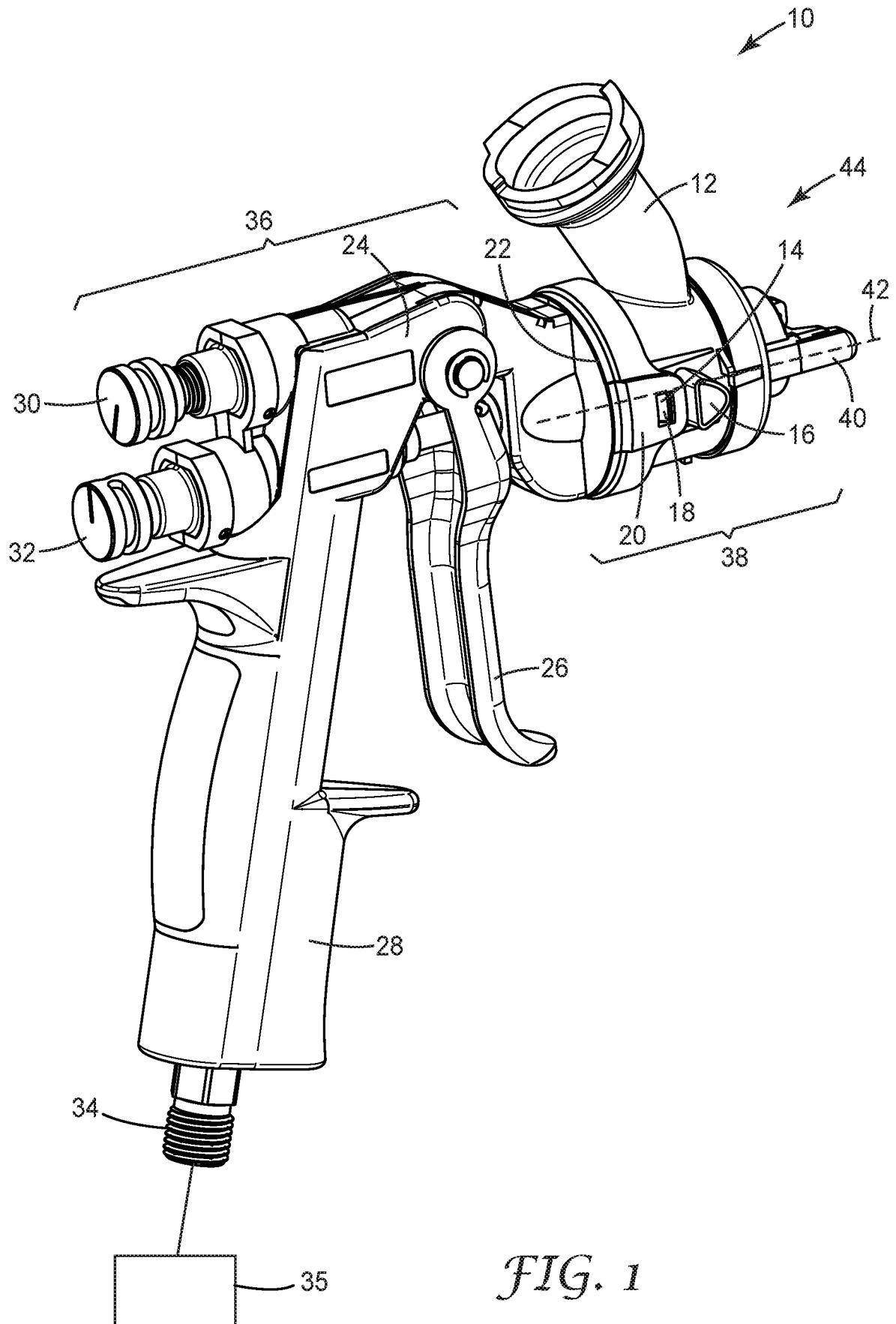


FIG. 1

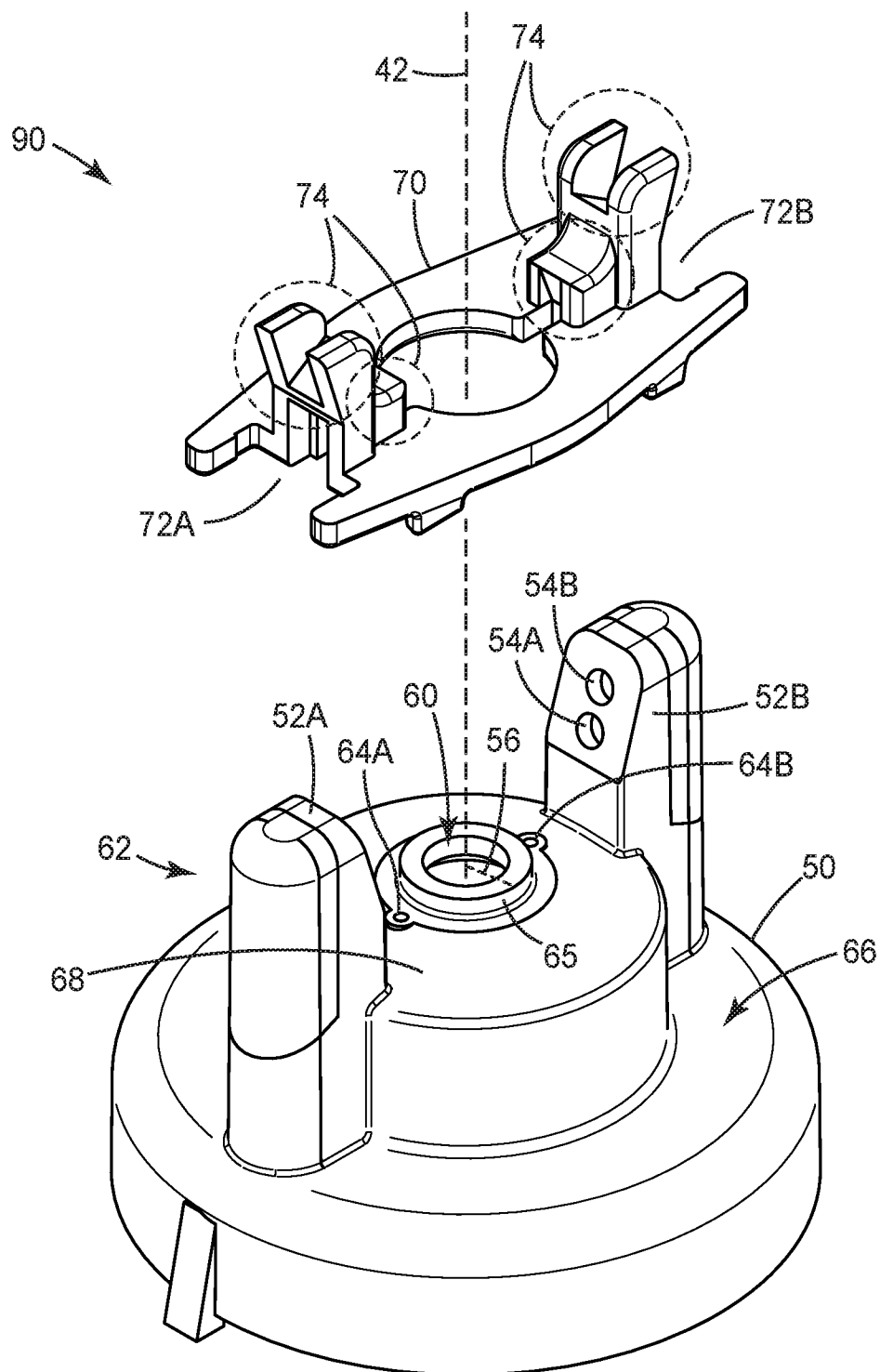


FIG. 2

3/29

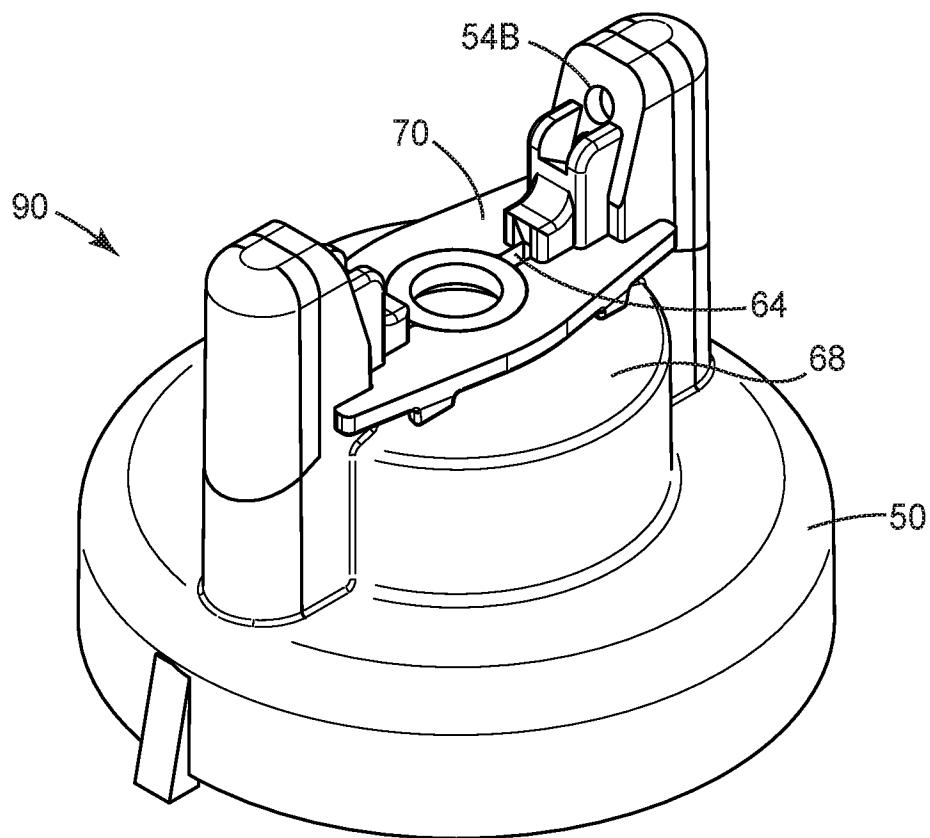


FIG. 3

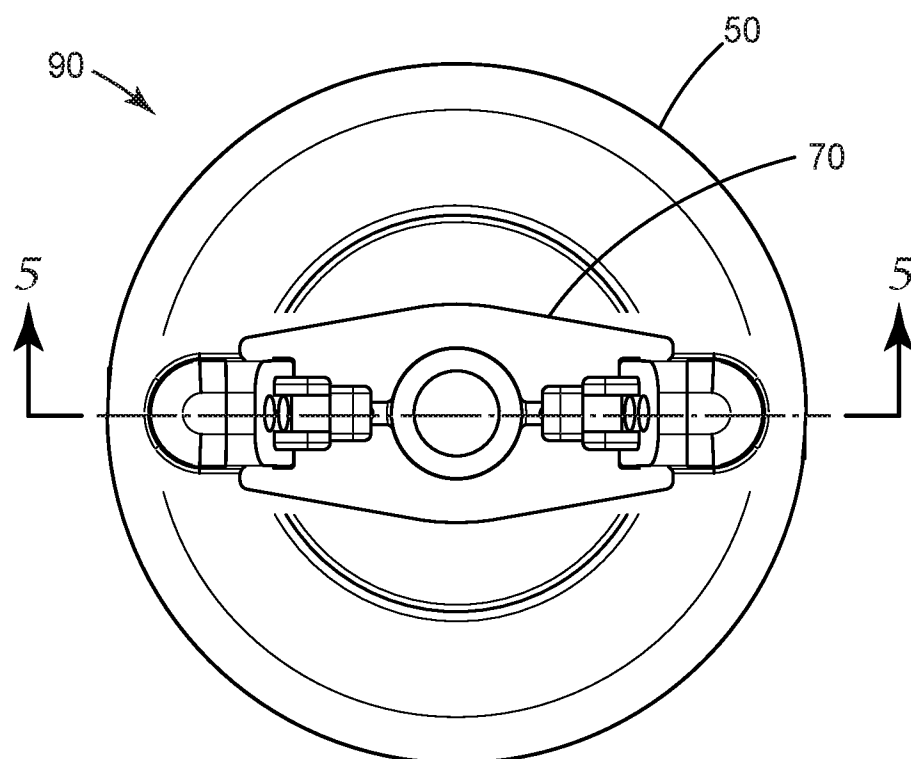


FIG. 4

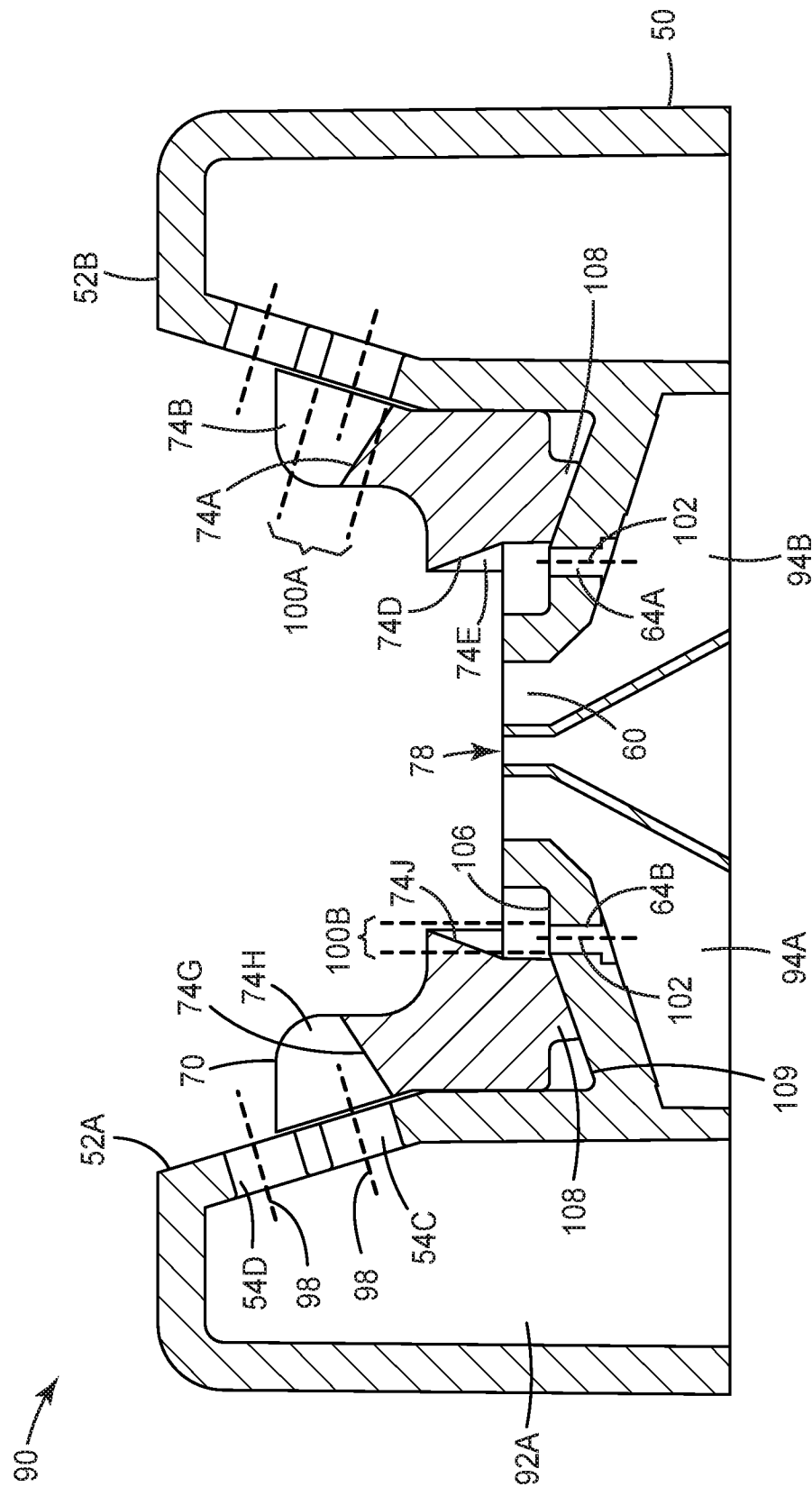
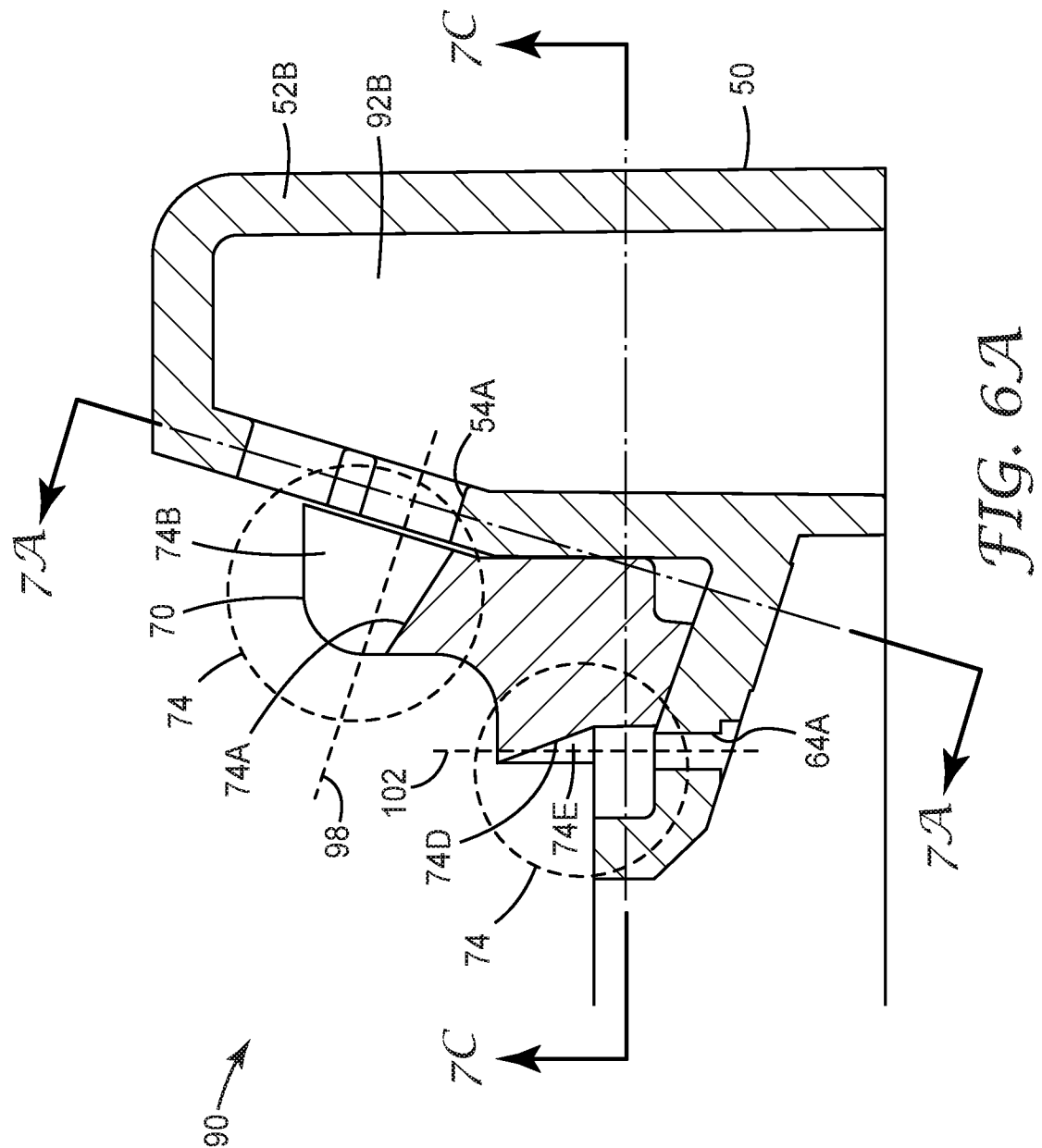
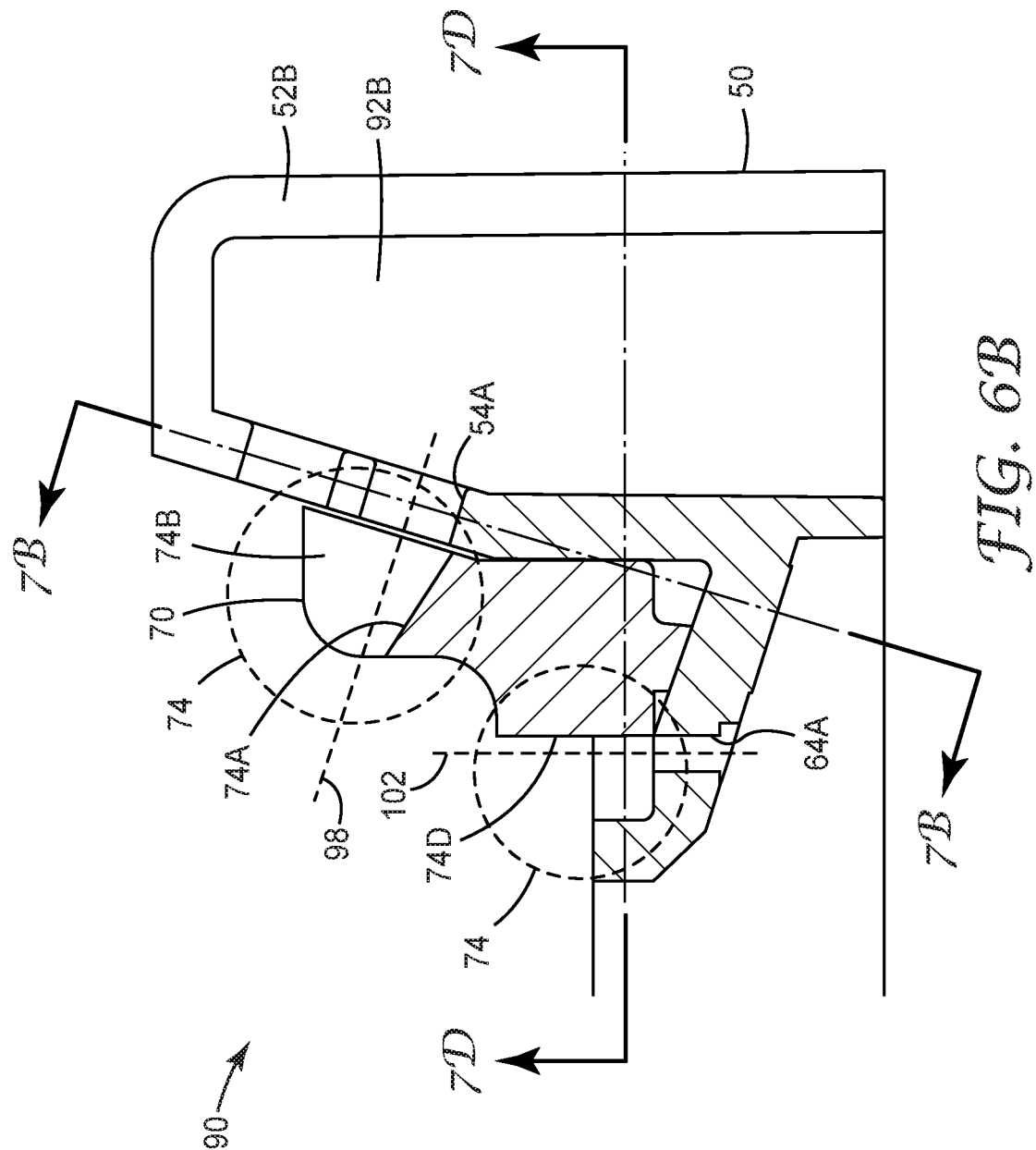


FIG. 5





7/29

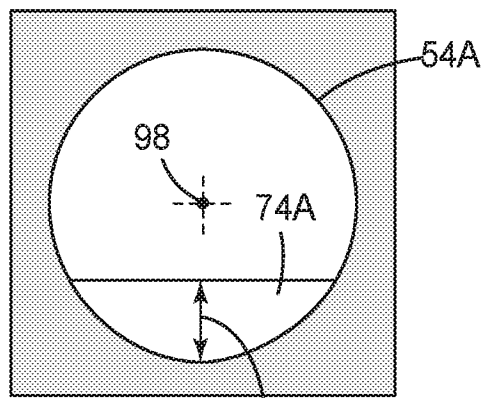


FIG. 7A

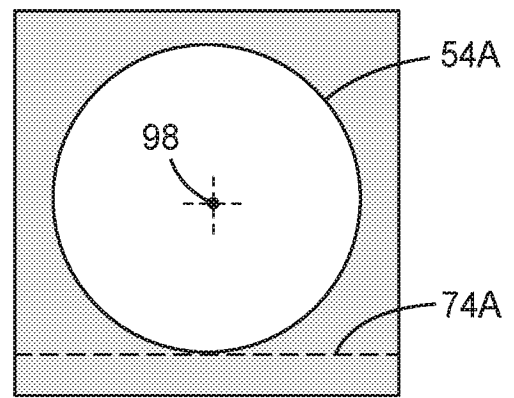


FIG. 7B

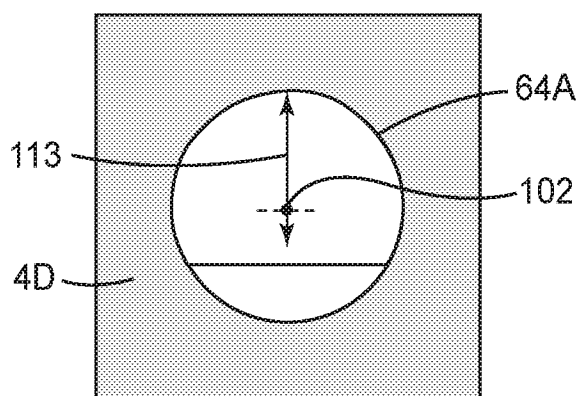


FIG. 7C

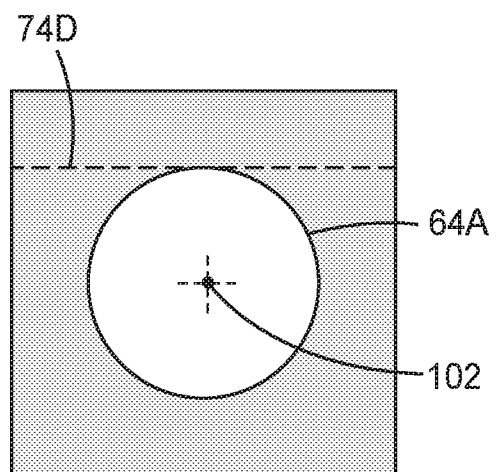


FIG. 7D

8/29

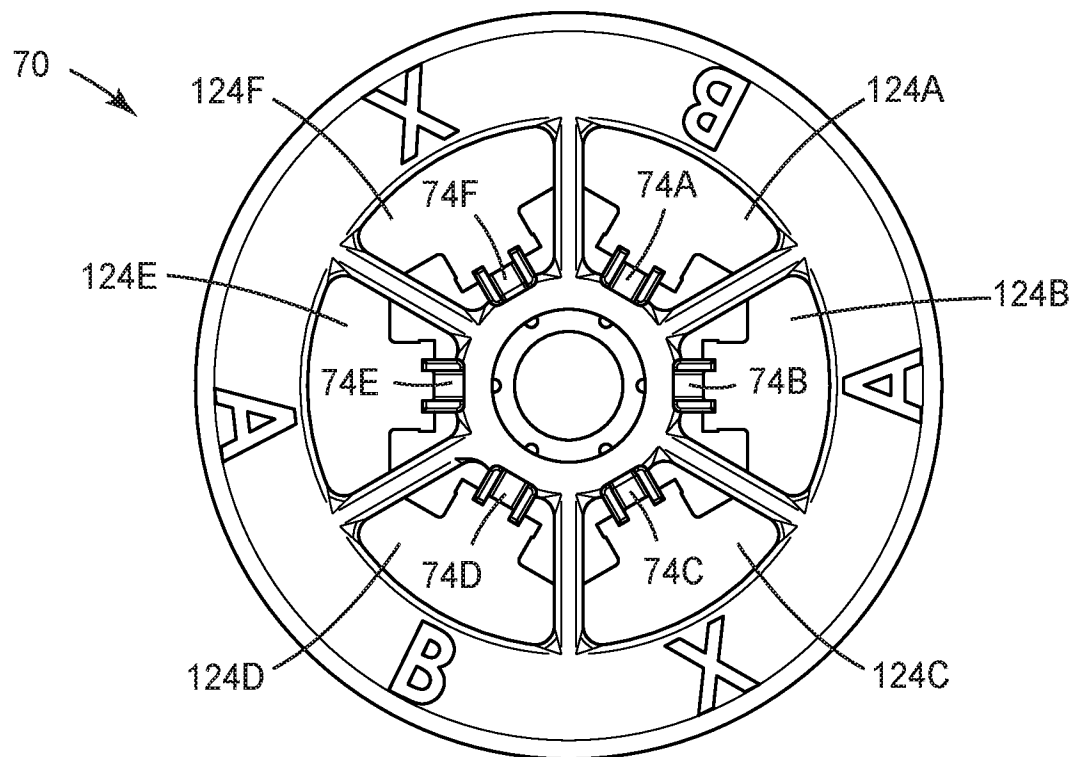


FIG. 8

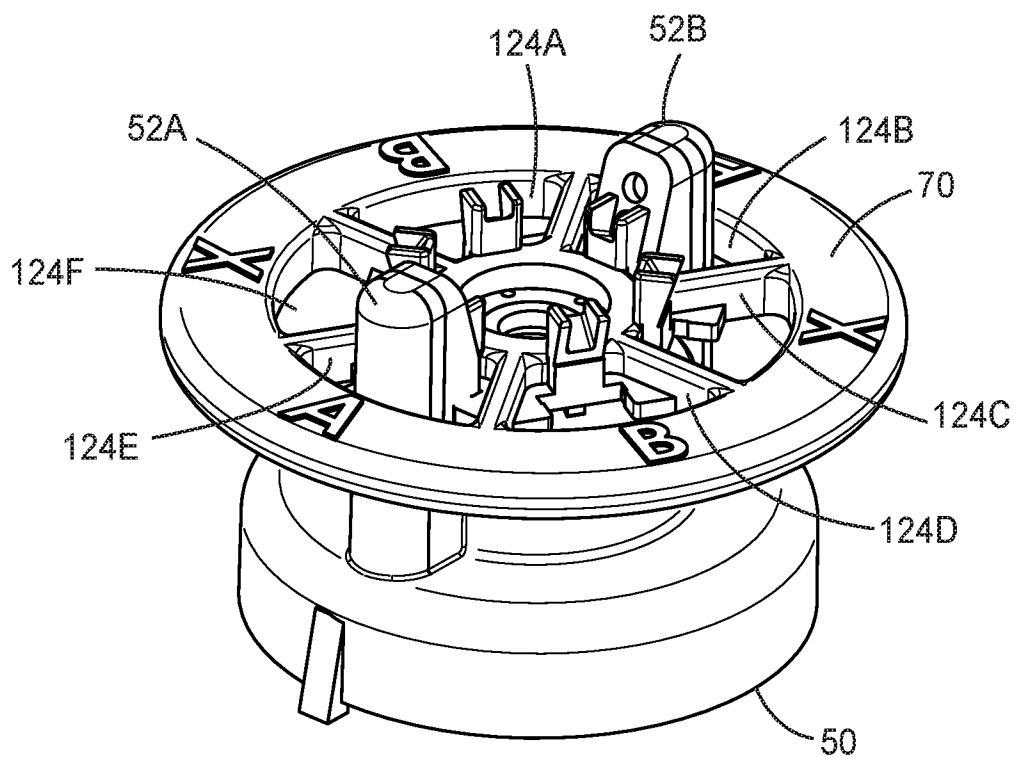
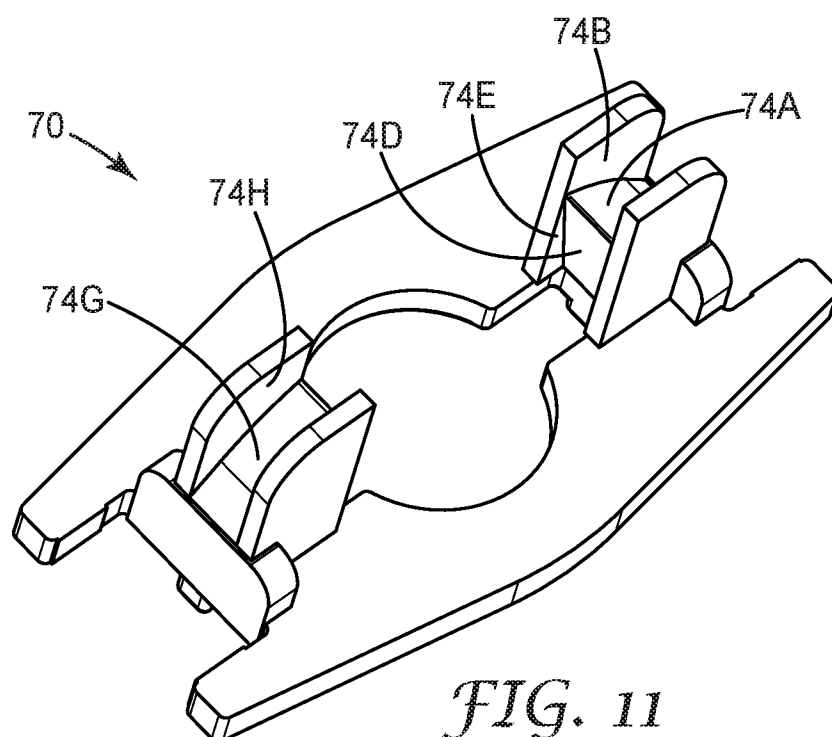
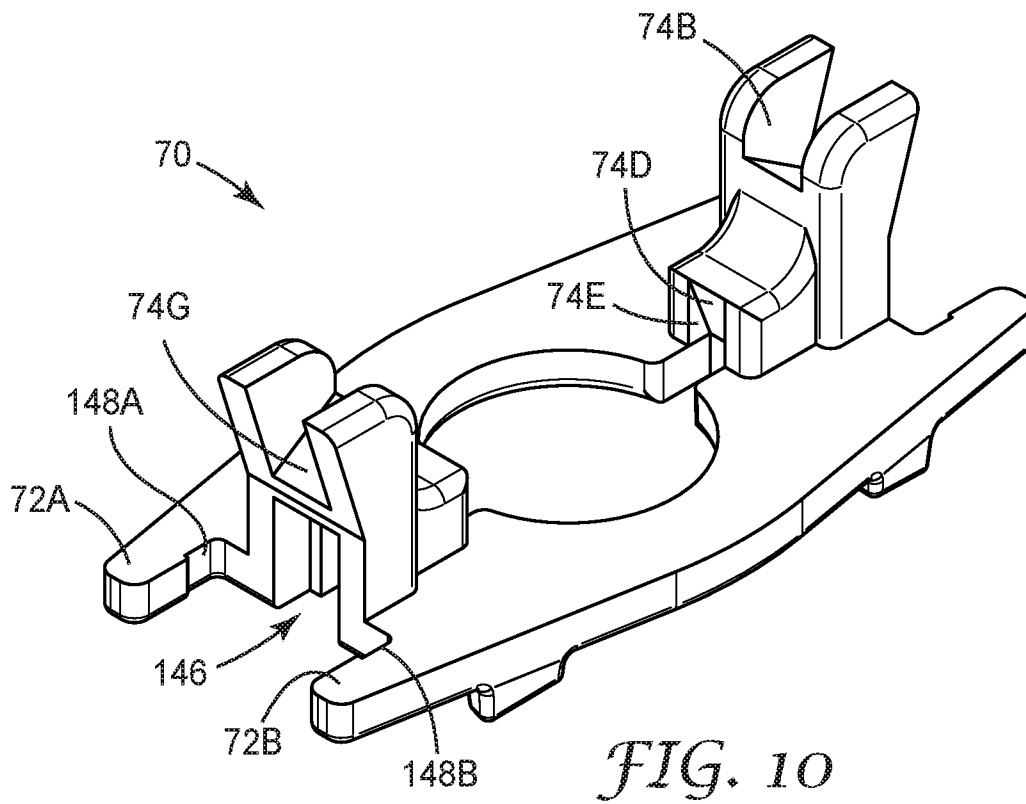


FIG. 9

9/29



10/29

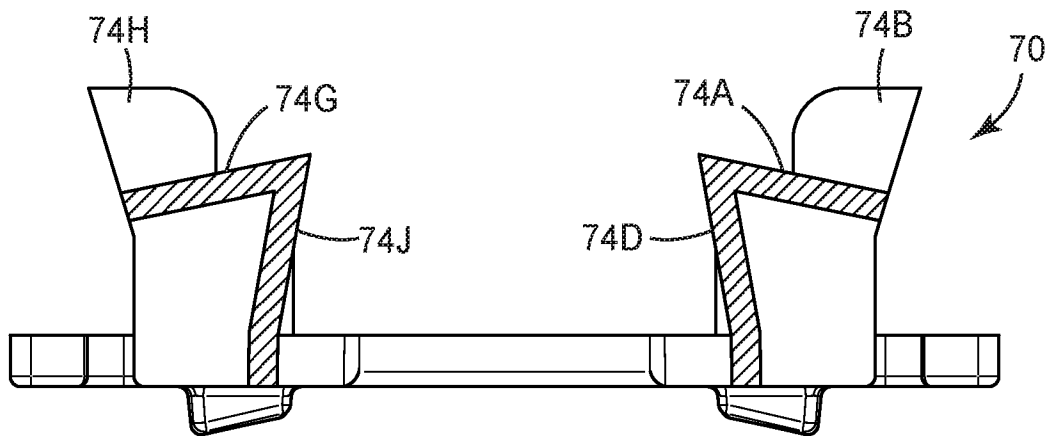


FIG. 12

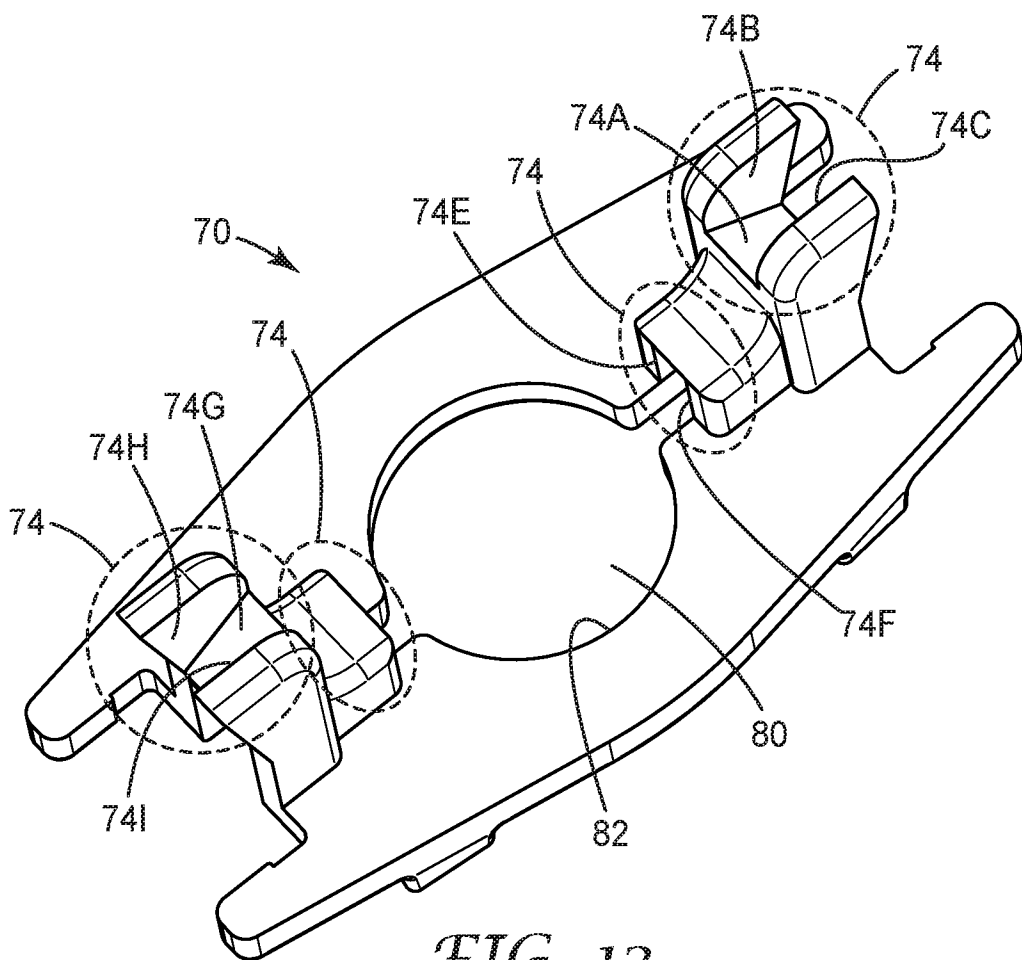


FIG. 13

11/29

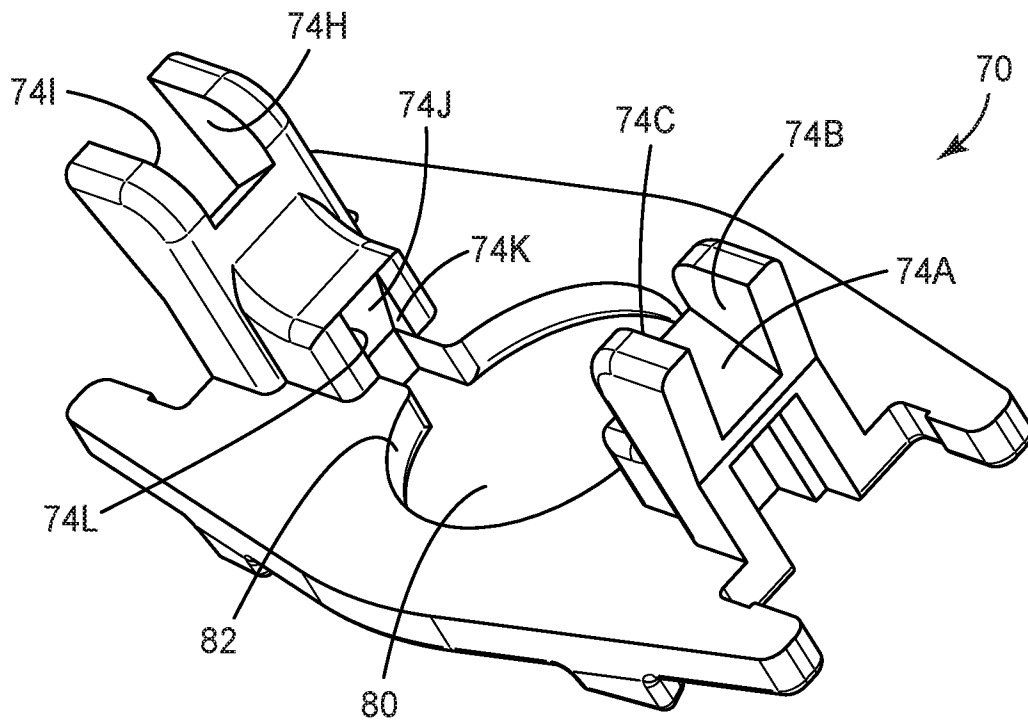


FIG. 14

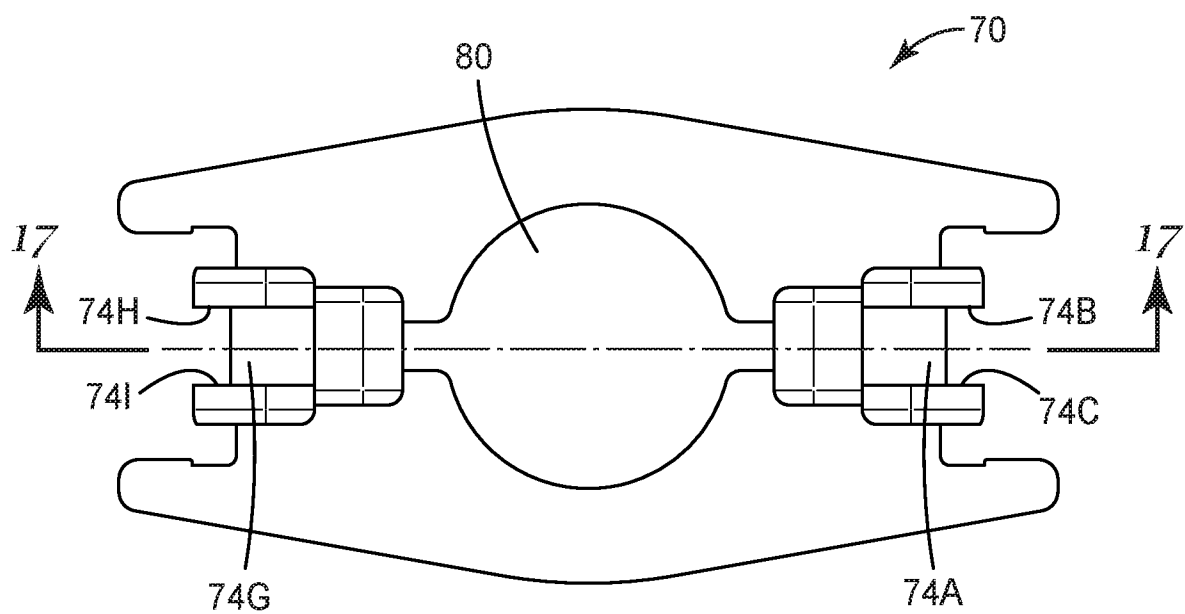


FIG. 15

12/29

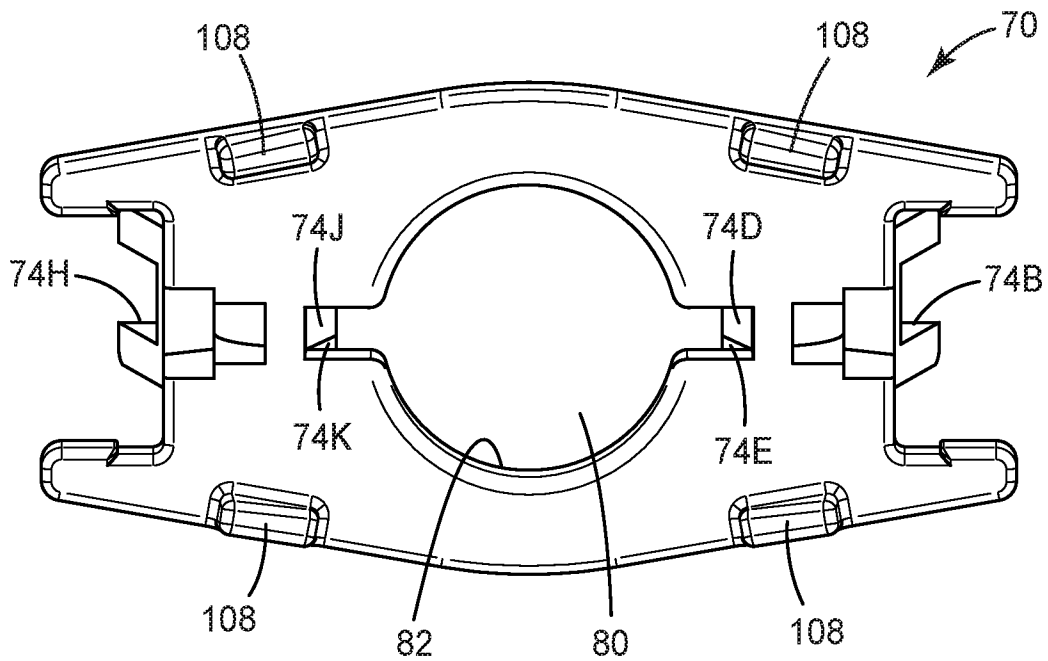


FIG. 16

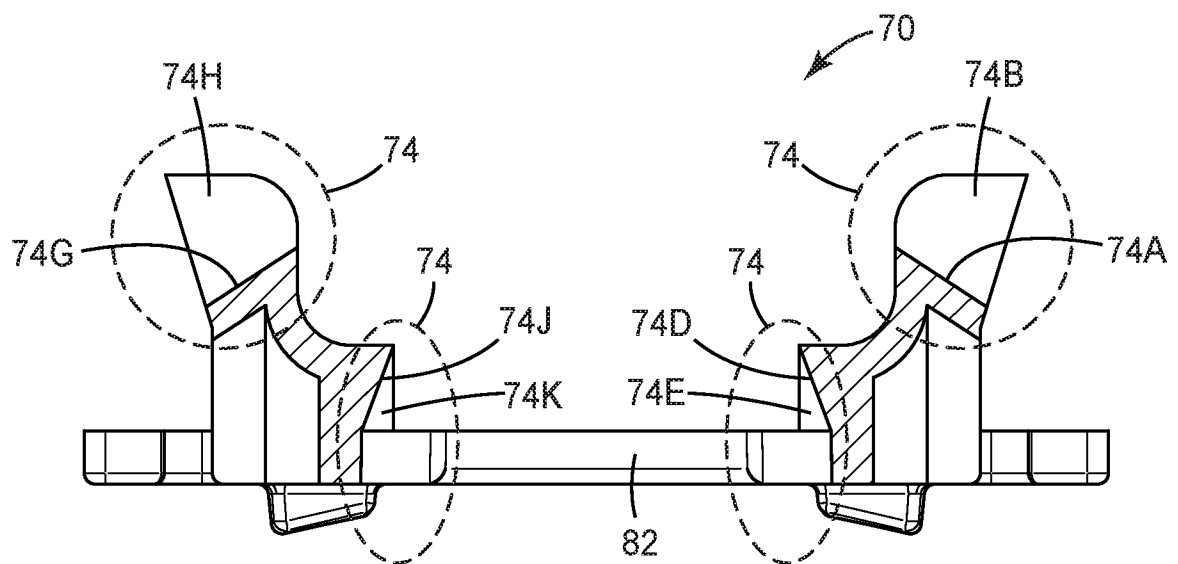


FIG. 17

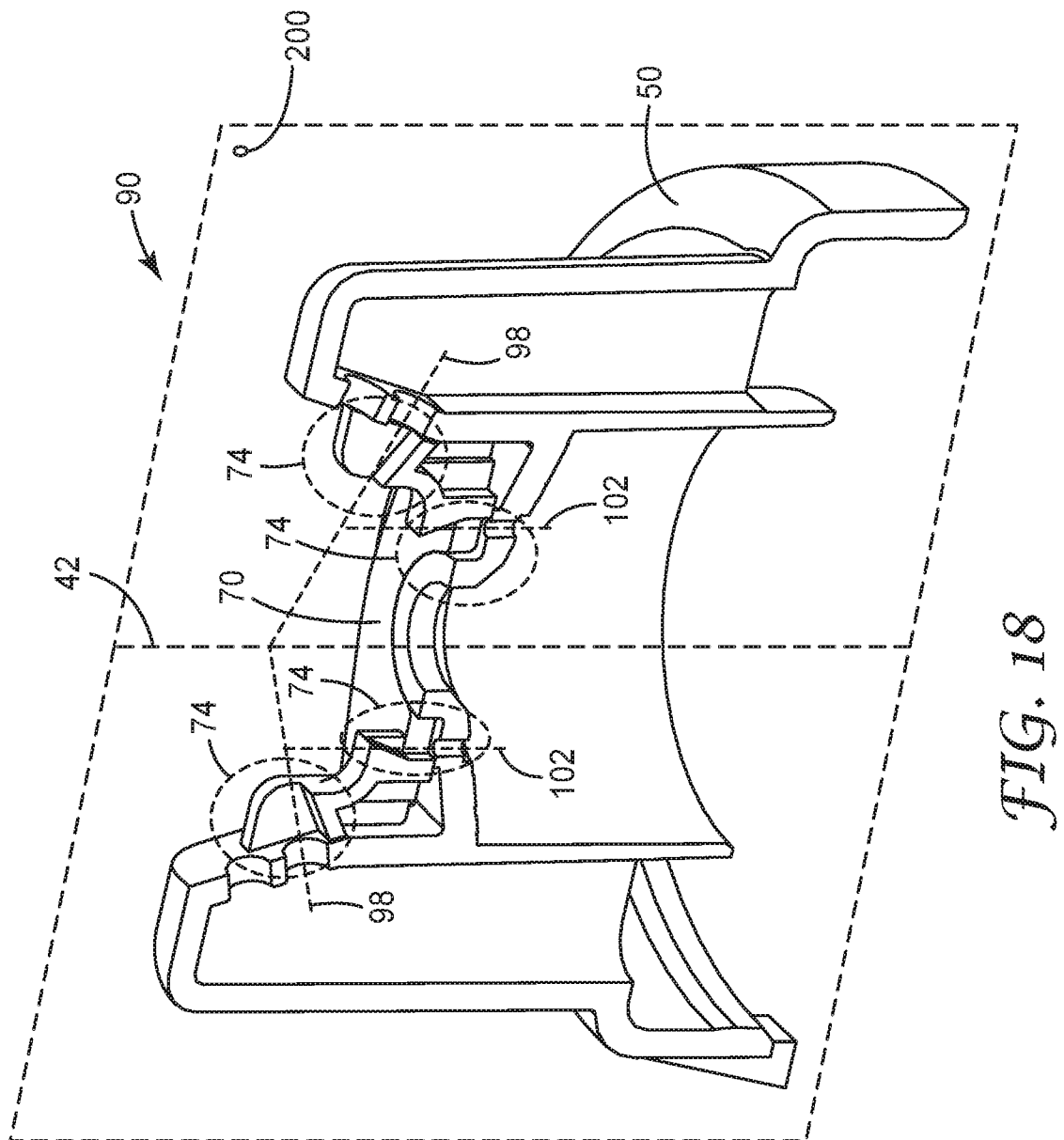
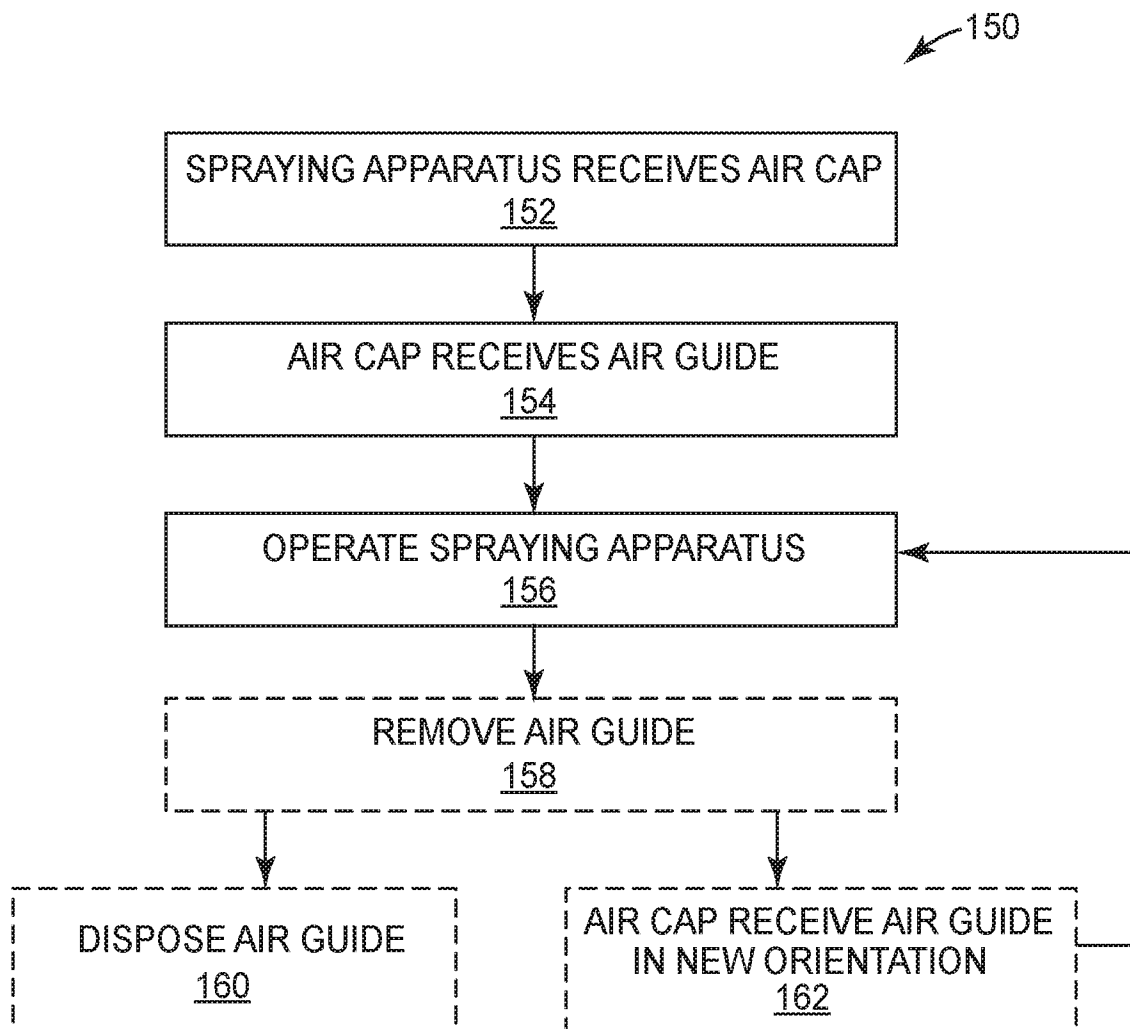
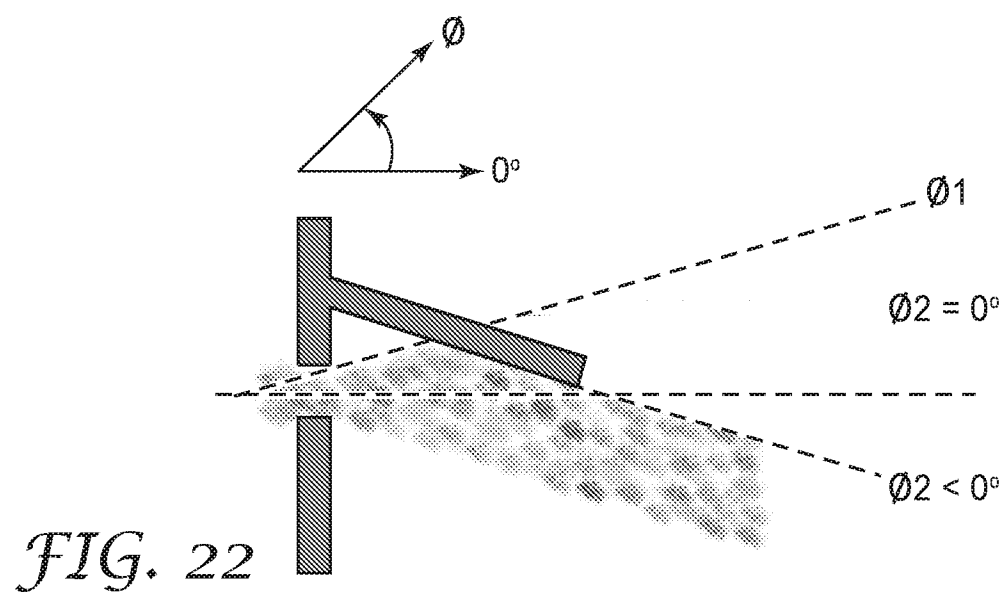
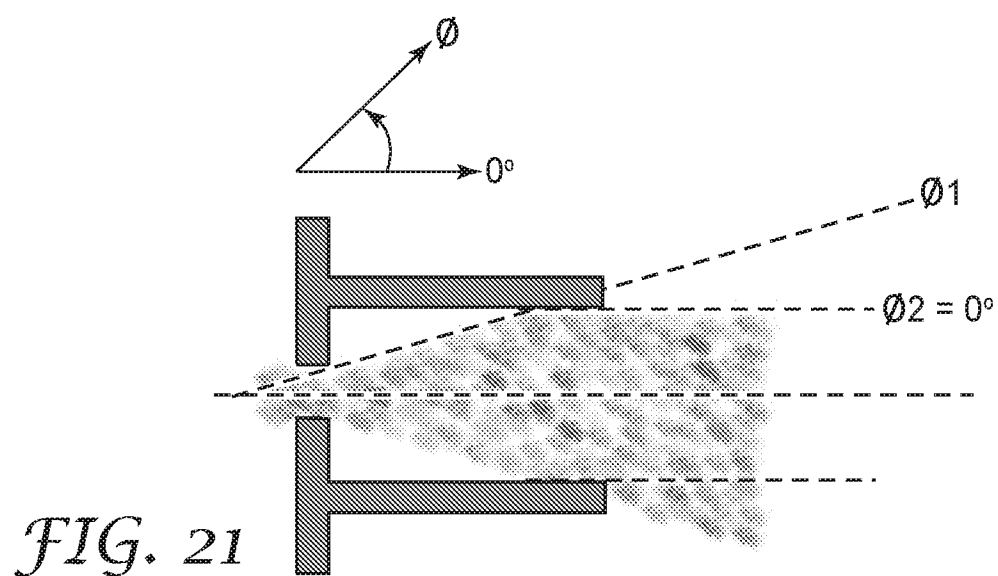
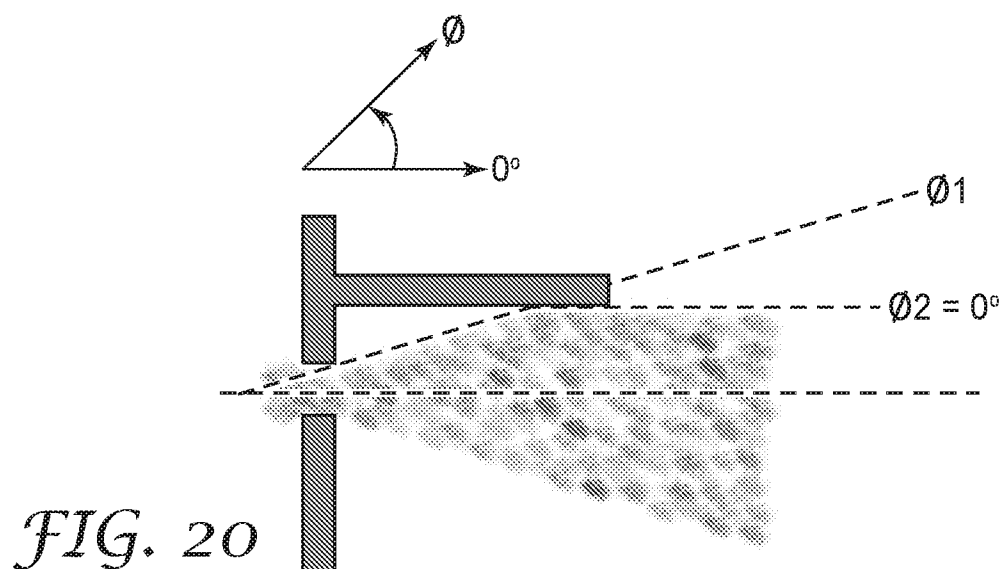


FIG. 18

14/29

*FIG. 19*

15/29



16/29

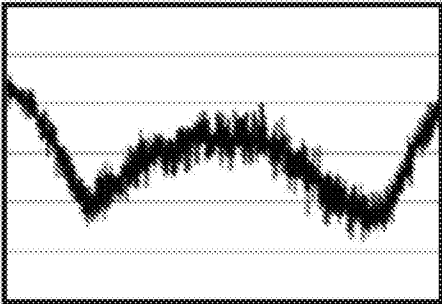
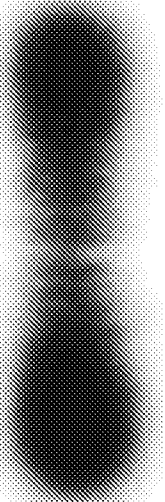
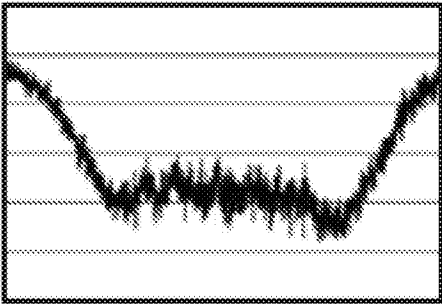
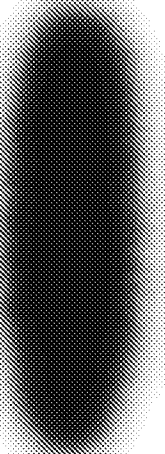
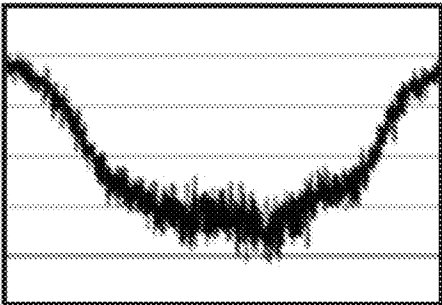
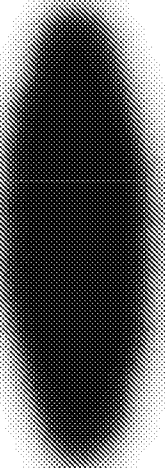
Profile Type	Paint Distribution Profile Plot	Profile Description	Fan Pattern Image
		Pattern is "split" and paint is concentrated in heavy bands at the pattern top and/or bottom that will likely result in coverage defects on the workpiece.	
		Sharp transitions in paint concentration are present that may result in coverage defects on the workpiece.	
		This is a more preferred profile shape. The pattern is sufficiently large for efficiently covering large areas without the presence of sharp transitions in paint concentration.	

FIG. 23

17/29

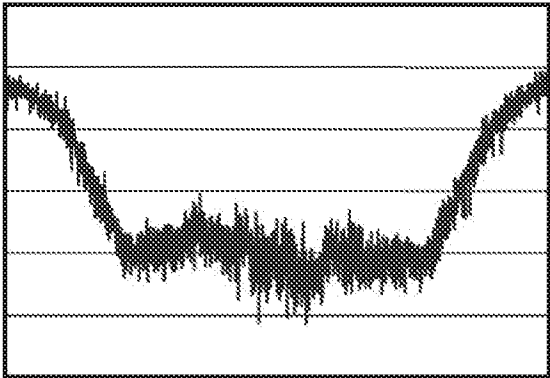
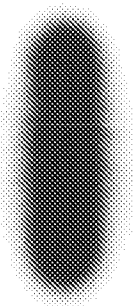
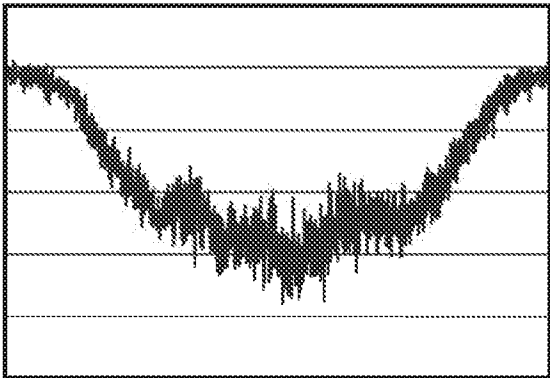
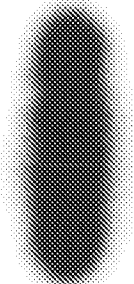
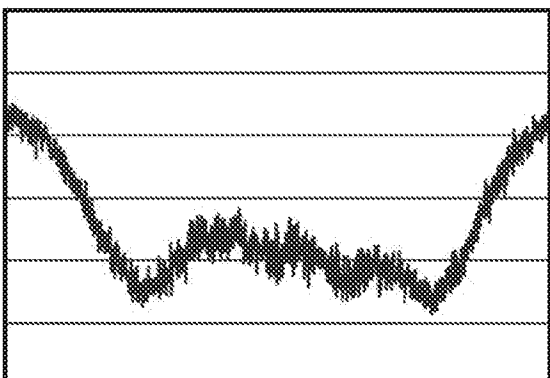
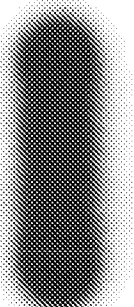
Example	Inlet Pressure (kPa)	Fan Pattern Distribution	Fan Pattern Image
Comparative A	193	 Profile Type: B; Pattern Size: 32 cm	
Comparative B	138	 Profile Type: C; Pattern Size: 29 cm	
Comparative C	248	 Profile Type: A; Pattern Size: 38 cm	

FIG. 24

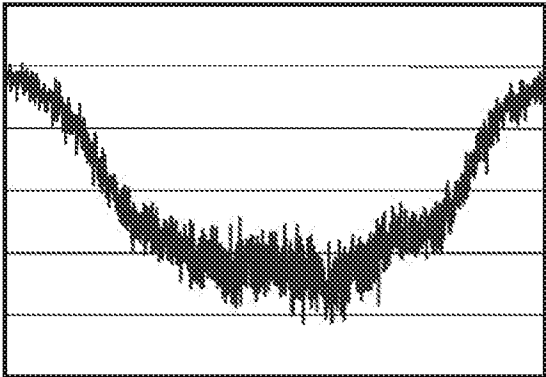
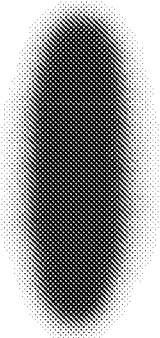
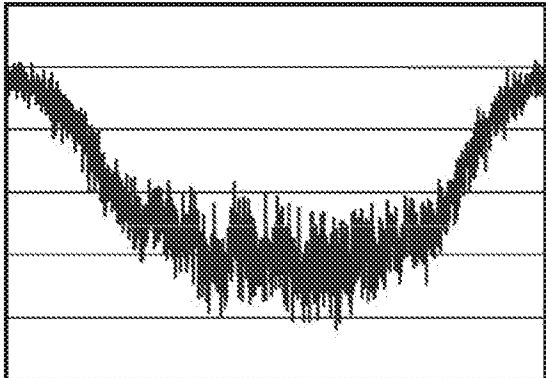
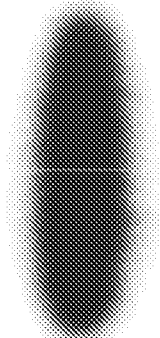
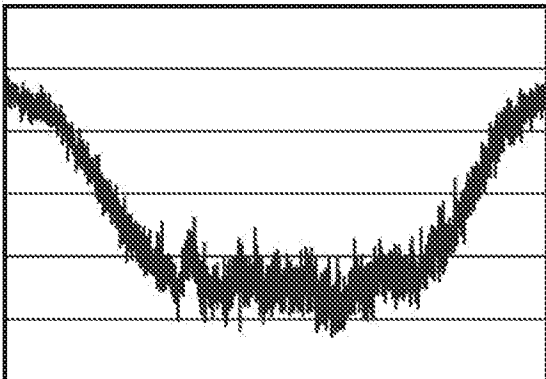
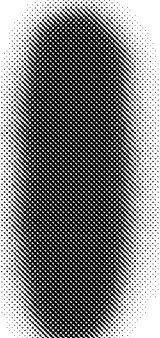
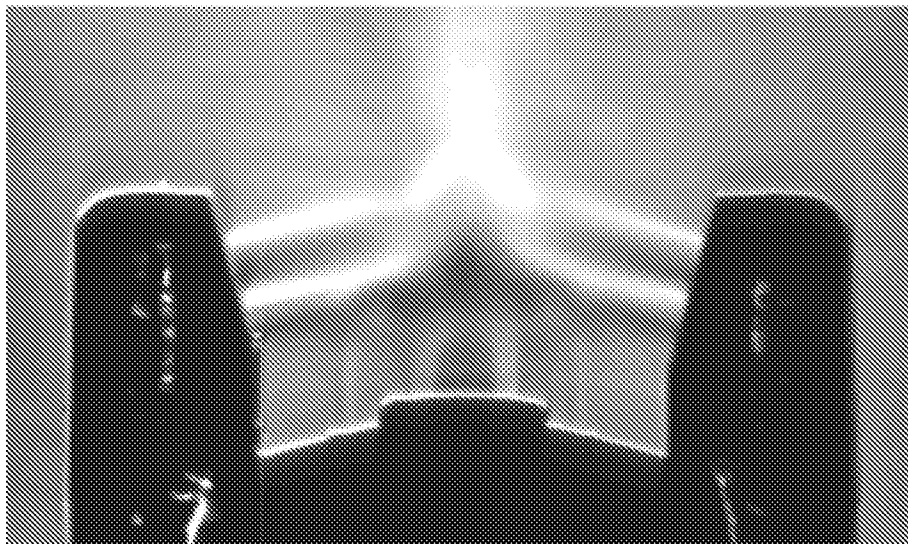
Example	Inlet Pressure (kPa)	Fan Pattern Distribution	Fan Pattern Image
Example 1	193	 Profile Type: C; Pattern Size: 32 cm	
Example 2	138	 Profile Type: C; Pattern Size: 32 cm	
Example 3	248	 Profile Type: C; Pattern Size: 34 cm	

FIG. 25



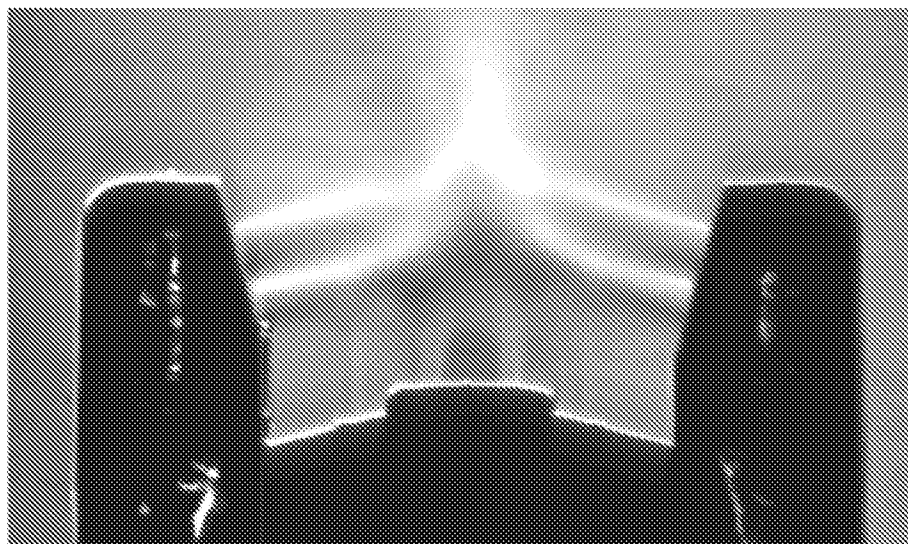
Comparative C
(248 kPa)

FIG. 26C



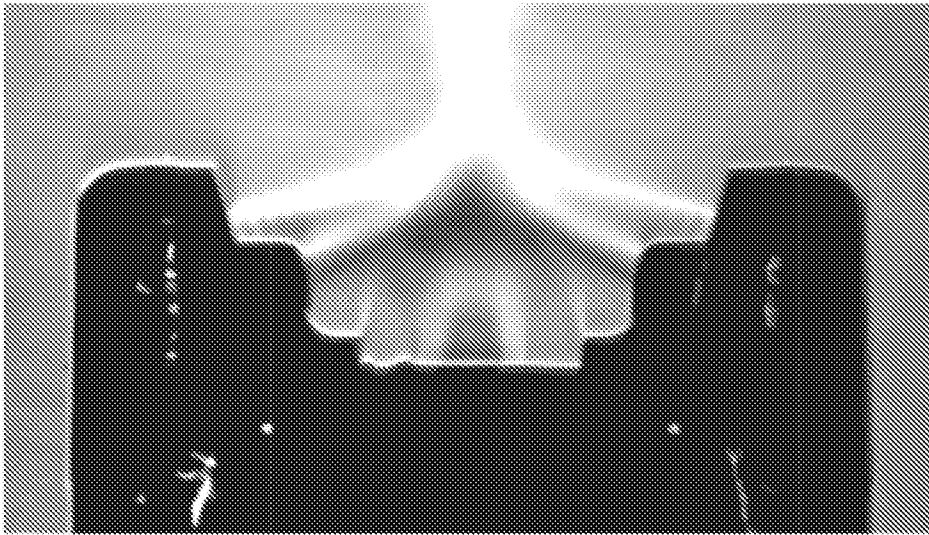
Comparative B
(193 kPa)

FIG. 26B



Comparative A
(138 kPa)

FIG. 26A



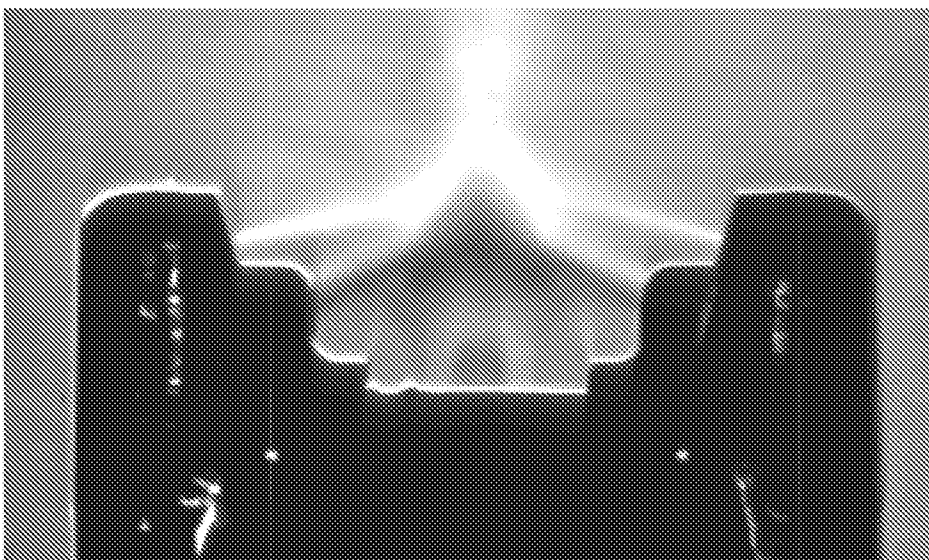
Example 3
(248 kPa)

FIG. 27C



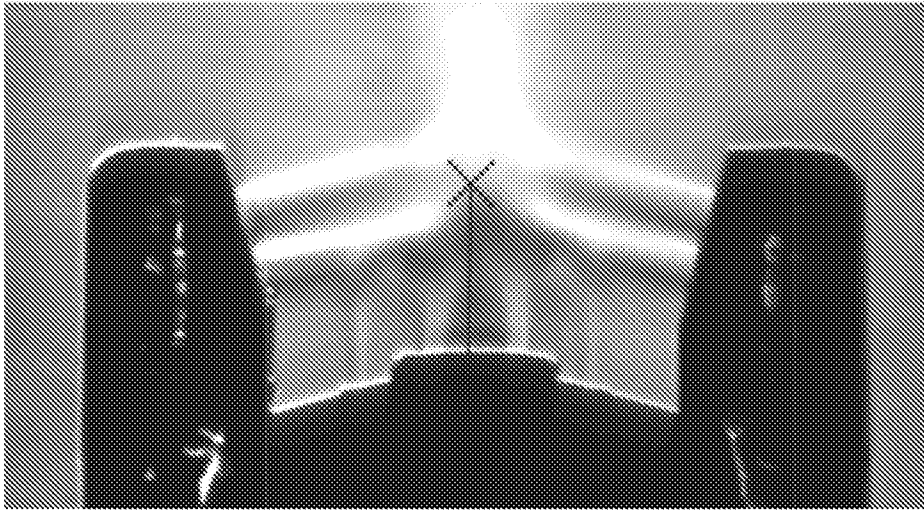
Example 1
(193 kPa)

FIG. 27B



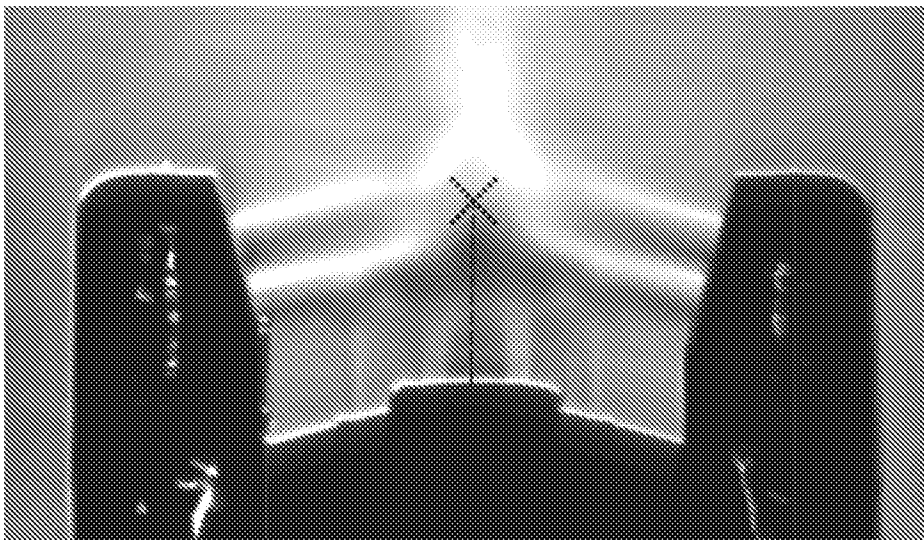
Example 2
(138 kPa)

FIG. 27A



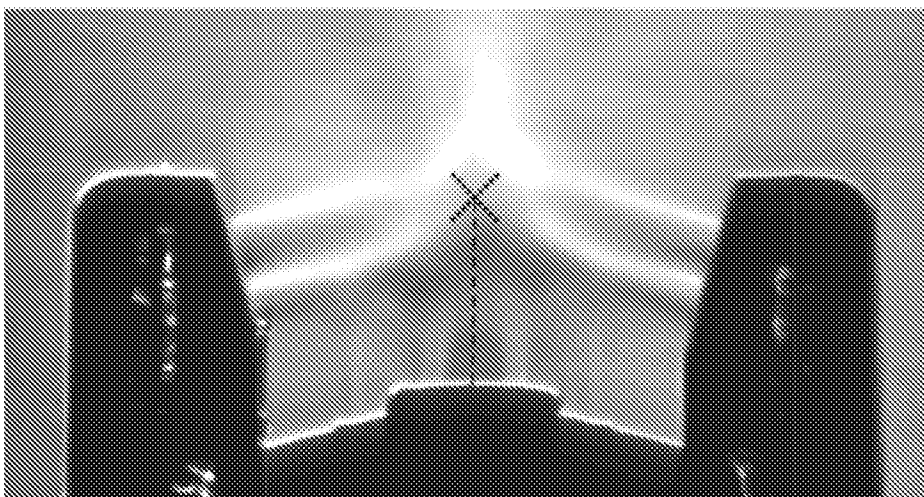
Comparative C
(248 kPa)

FIG. 28C



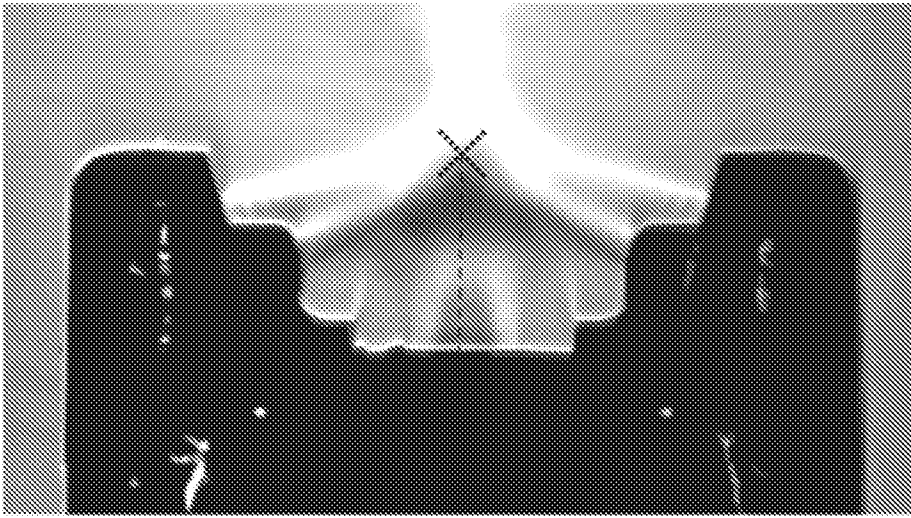
Comparative a
(193 kPa)

FIG. 28B



Comparative B
(138 kPa)

FIG. 28A



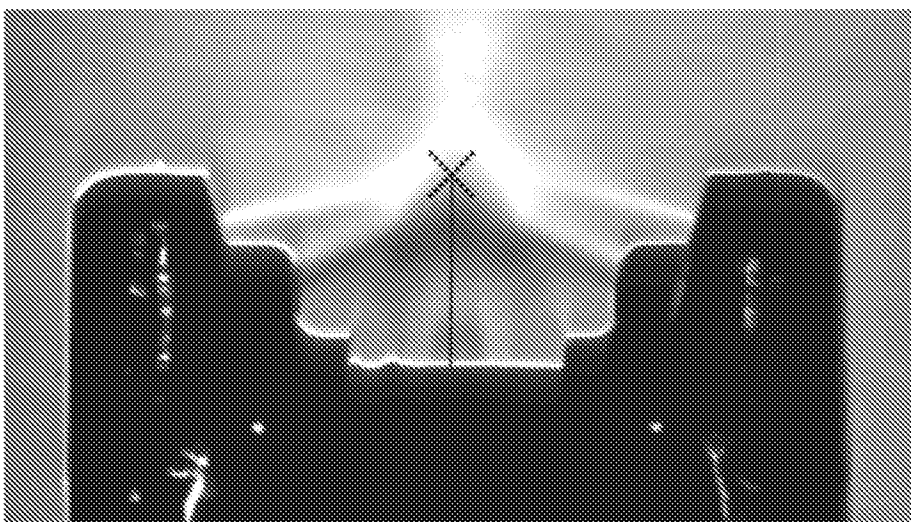
Example 3
(248 kPa)

FIG. 29C



Example 1
(193 kPa)

FIG. 29B



Example 2
(138 kPa)

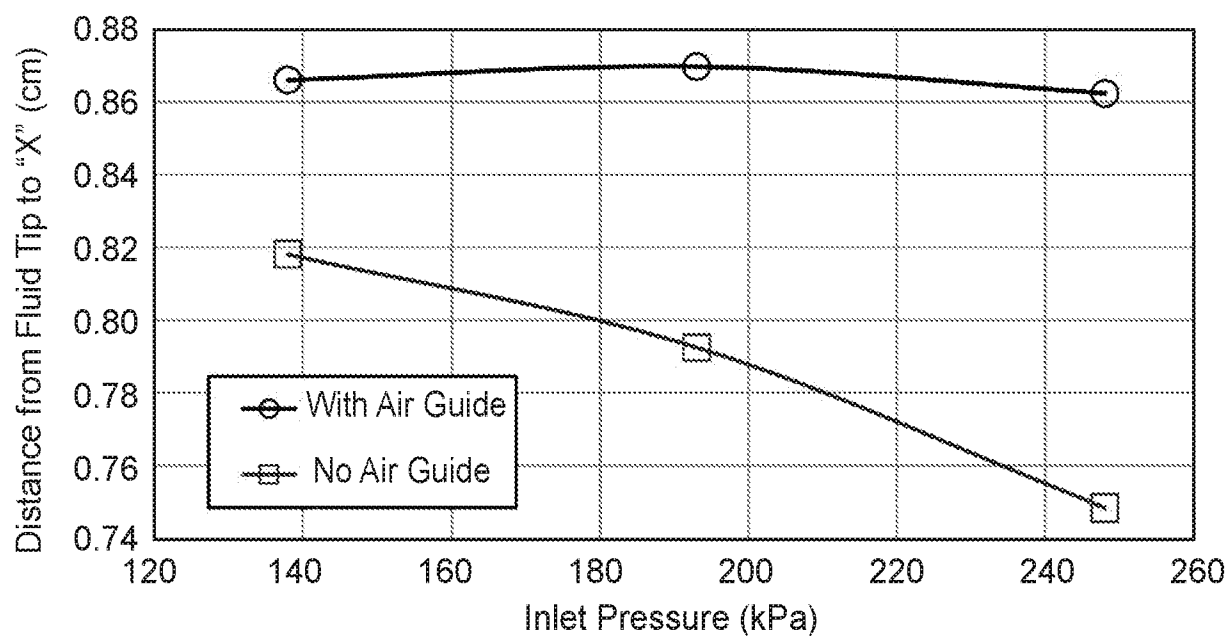
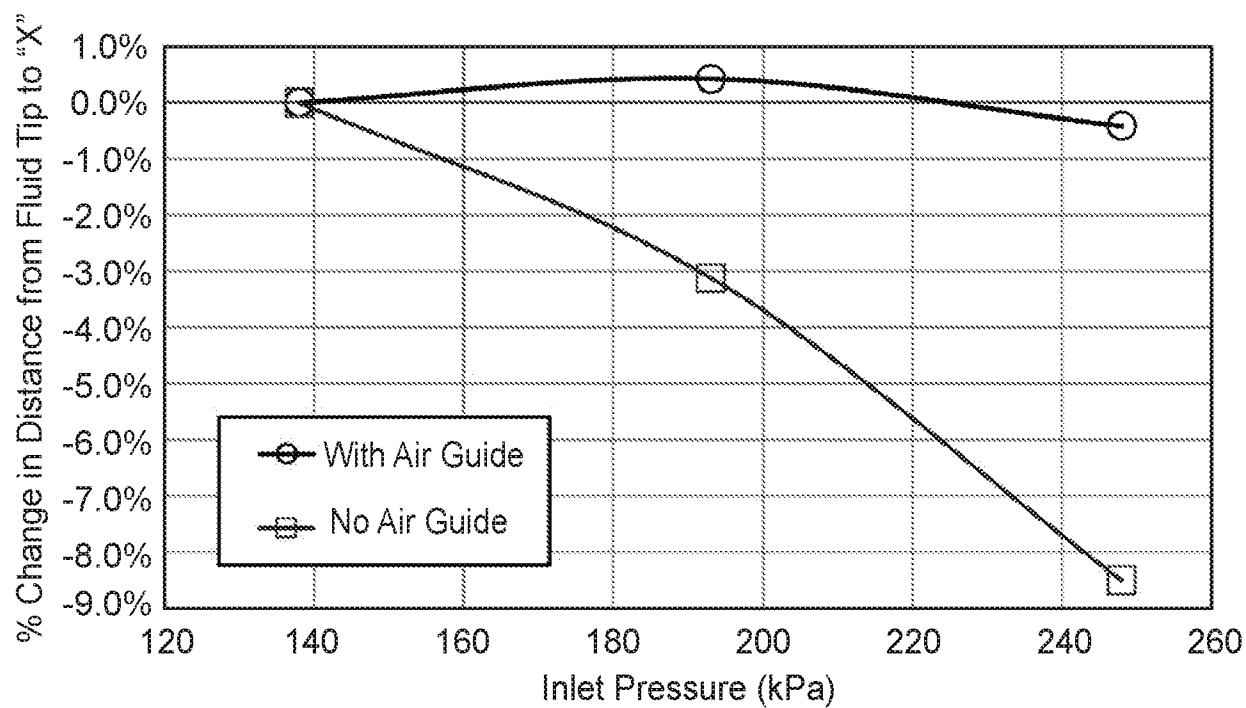
FIG. 29A

23/29

Example	Inlet Pressure (kPa)	Distance from Fluid Tip to X (cm)	% Change in X (Normalized to Position @ 138 kPa)
Comparative B	138	0.818	0.0%
Comparative A	193	0.793	-3.1%
Comparative C	248	0.749	-8.5%
Example 2	138	0.866	0.0%
Example 1	193	0.870	0.4%
Example 3	248	0.862	-0.4%

FIG. 30

24/29

*FIG. 31**FIG. 32*

25/29

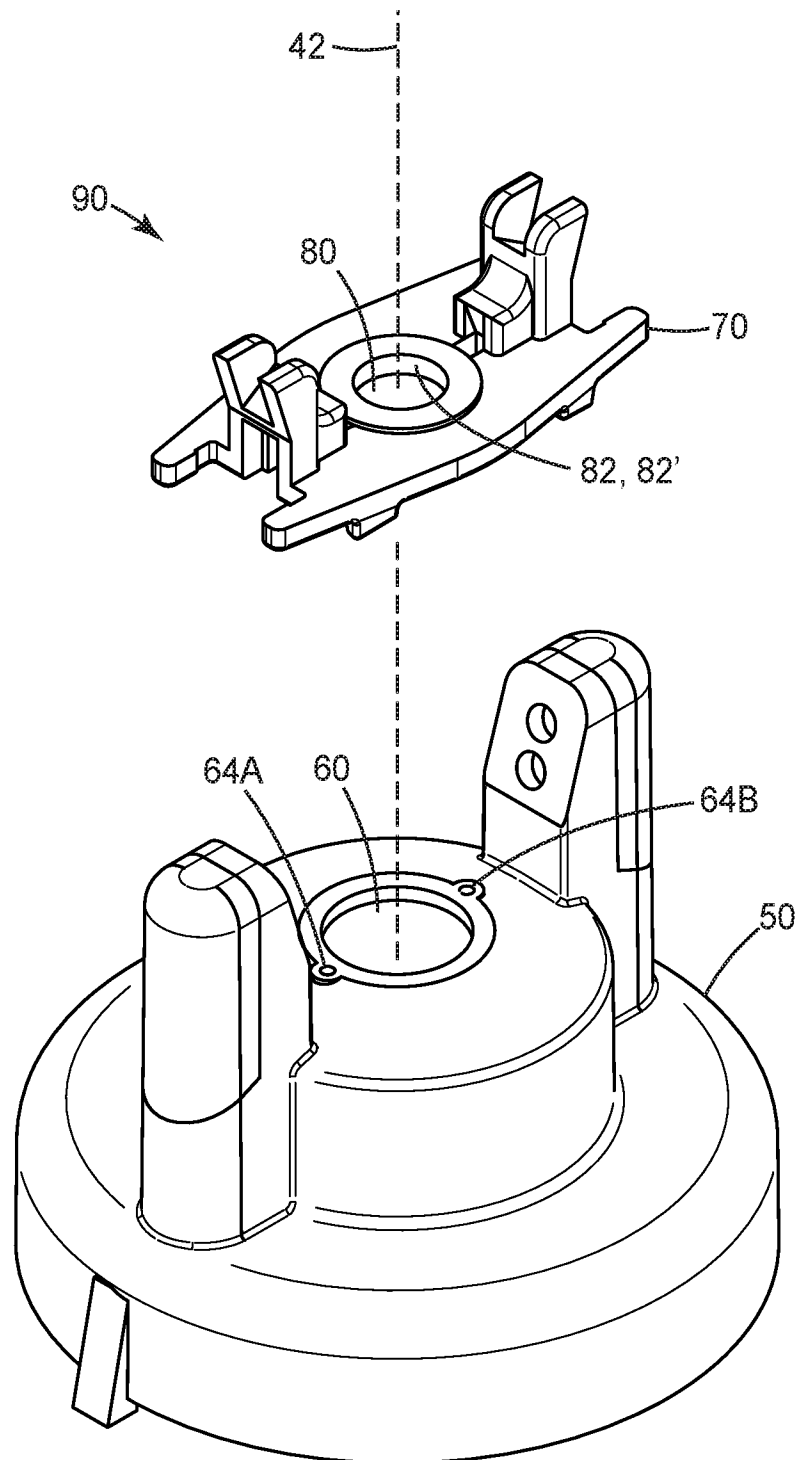


FIG. 33

26/29

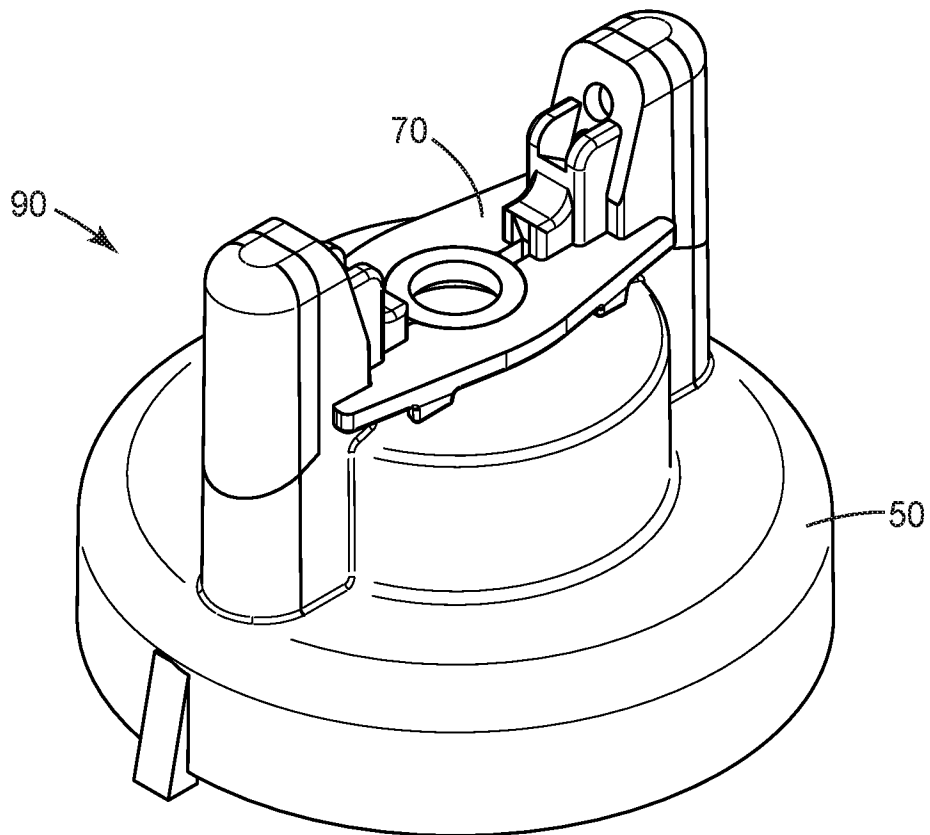


FIG. 34

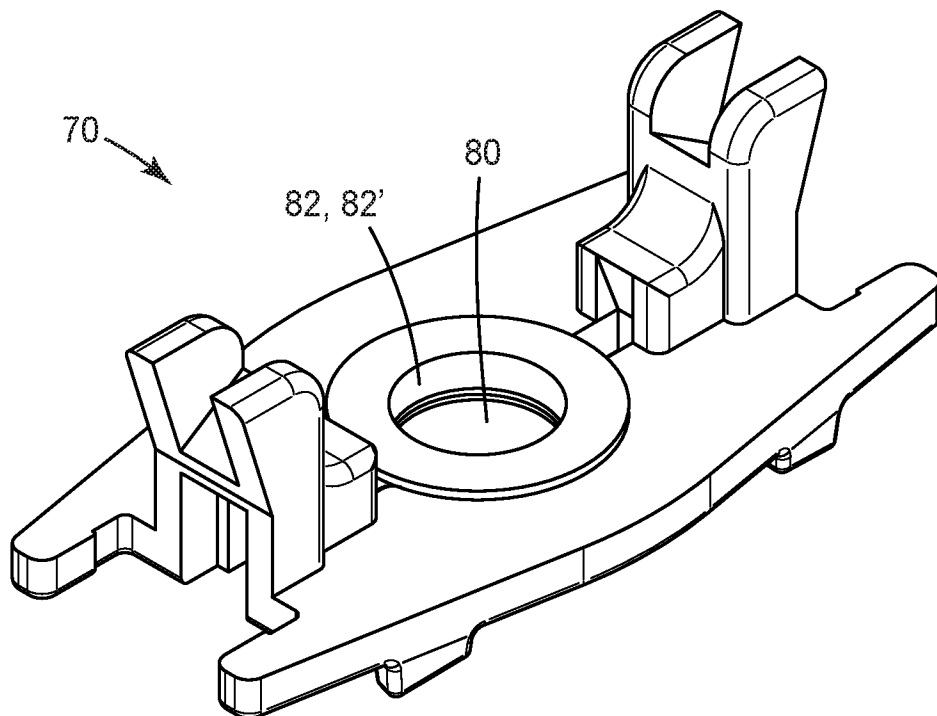


FIG. 35

27/29

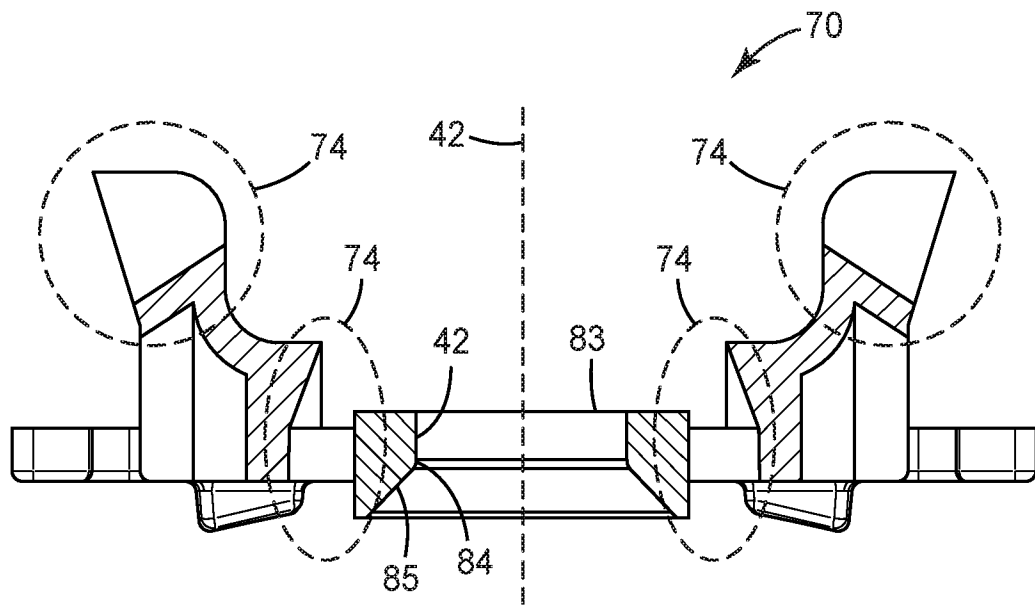


FIG. 36

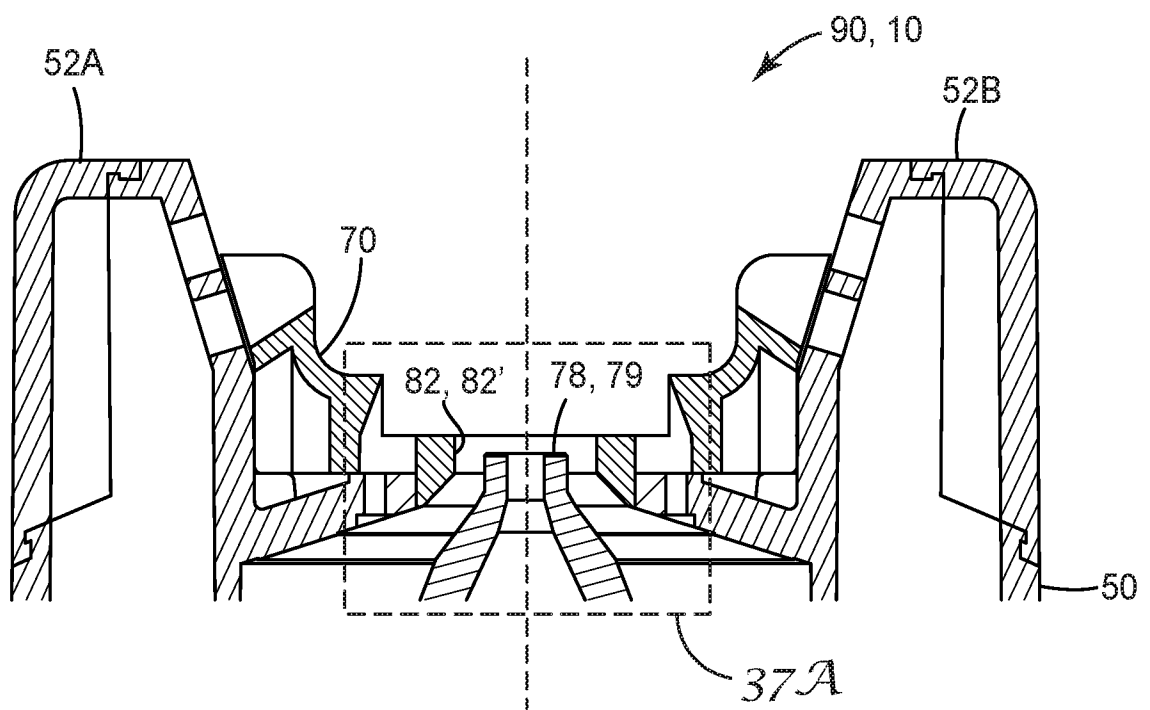


FIG. 37

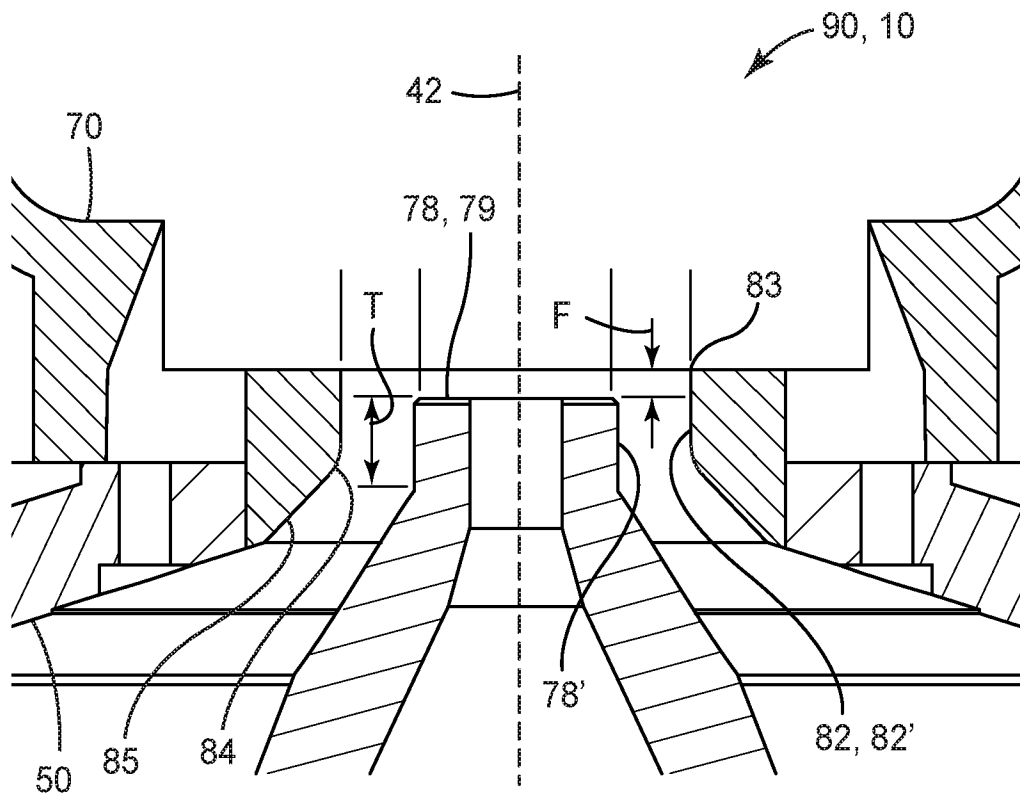
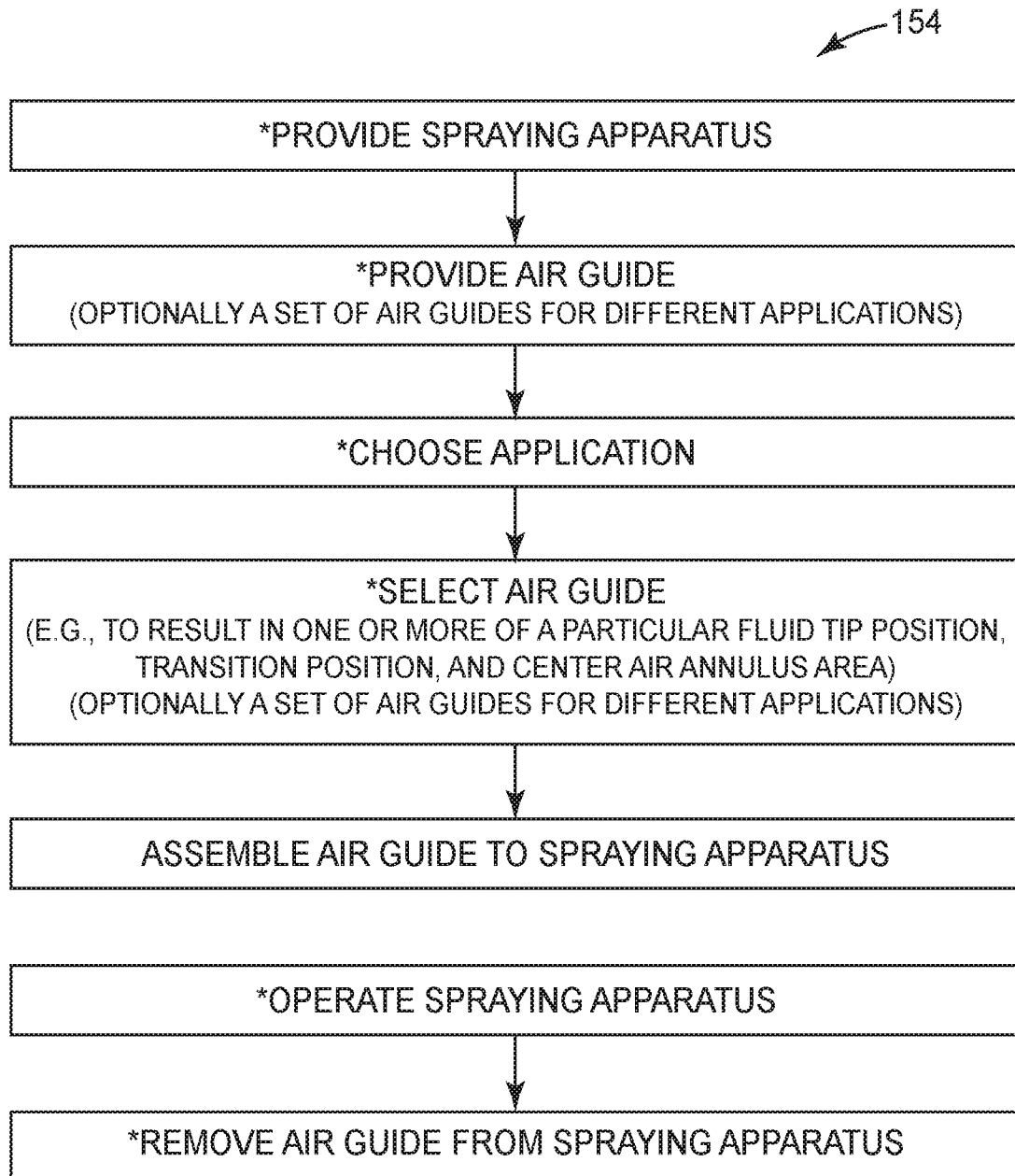


FIG. 37A

29/29



*Step(s) may be eliminated and/or reordered consistent with the specification.

FIG. 38

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/019741

A. CLASSIFICATION OF SUBJECT MATTER

INV. B05B7/08 B05B12/18
ADD.

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)
B05B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/191323 A1 (3M INNOVATIVE PROPERTIES CO [US]) 17 December 2015 (2015-12-17)	1-24, 27-32
Y	the whole document	41,45
X	US 2 304 857 A (RODOLPHE STAHL) 15 December 1942 (1942-12-15)	1-6,9, 12,14, 16-22, 27-32, 35-40,46
Y	the whole document	41,45
X	US 5 165 605 A (MORITA NOBUYOSHI [JP] ET AL) 24 November 1992 (1992-11-24)	1-22, 27-32
A	DE 27 05 642 A1 (SCHIEMANN OTTO) 17 August 1978 (1978-08-17)	1-46



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

9 April 2018

Date of mailing of the international search report

20/04/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Sodtke, Christof

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/019741

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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