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(54) Title: MIXER DESIGN FOR A PLURAL COMPONENT SYSTEM

(57) Abstract: A mixer for a plural component spray gun (100) is presented. The mixer has a mixer body comprising a mixing chamber (400) with an outlet. The mixer also has a first fluid component inlet (410), coupled to a first fluid conduit, configured to introduce a first fluid component into the mixing chamber (400). The mixer also has a second fluid component inlet (420), coupled to a second fluid conduit, configured to introduce a second fluid component into the mixing chamber (400). The first and second fluid component inlets are offset with respect to a centerline of the mixing chamber (412, 422) and positioned such that a first fluid flow from the first inlet is directed toward the outlet, and a second fluid flow from the second inlet is directed toward the outlet.

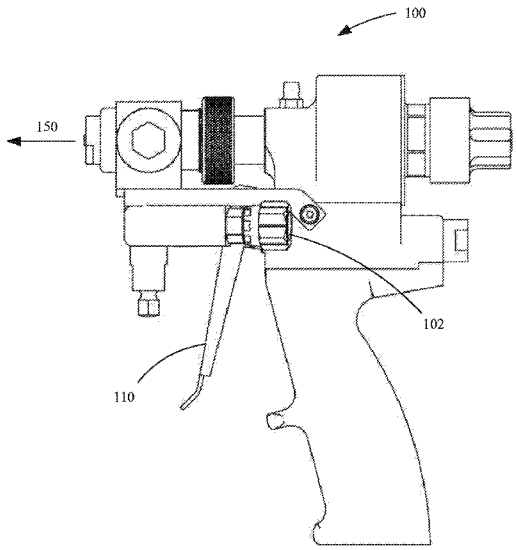


FIG. 1A

WO 2018/204231 A1

[Continued on next page]

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MIXER DESIGN FOR A PLURAL COMPONENT SYSTEM

BACKGROUND

[0001] Plural component systems mix two or more fluids and apply the mixture to an application site. Plural component systems are often used to spray two components that, when mixed, react and cure on a surface. One particular usage for plural component systems is to generate a foam through the reaction of an A component and a B component that, when sprayed, react and cure quickly. Proper foam generation requires sufficient fluid delivery, sufficient chemical mixing, and sufficient fluid dispersal.

[0002] A plural component spray gun has three main components: a coupling block, a gun block, and a gun handle. The coupling block facilitates the two plural components entering a mixer, for example through an A-chemical port and a B-chemical port. The gun block includes filters, side seals, the mixer, and a fluid spray tip. The gun handle includes an air purge supply, a trigger mechanism, and an attachment to the gun block.

SUMMARY

[0003] A mixer for a plural component spray gun is presented. The mixer has a first fluid component inlet configured to introduce a first fluid component into the mixer. The mixer also has a second fluid component inlet configured to introduce a second fluid component into the mixer. The first and second fluid component inlets are offset with respect to a centerline of the mixer and positioned such that a first fluid flow from the first inlet is directed away from the second inlet, and a second fluid flow from the second inlet is directed away from the first inlet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIGS. 1A-1C are diagrammatic side elevation, front elevation and exploded perspective views, respectively of a plural component spray gun in which embodiments of the present invention are particularly useful.

[0005] FIG. 2 illustrates a diagrammatic view of a fluid being applied to a wall.

[0006] FIGS. 3A and 3B illustrate a known mixer design.

[0007] FIGS. 4A-4H illustrate a comparison between a mixer in accordance with an embodiment of the present invention, and the known mixer of FIGS. 3A and 3B.

[0008] FIGS. 5A-5F illustrate diagrammatic views of a mixer in accordance with an embodiment of the present invention.

[0009] FIGS. 6A-6C illustrate a mixer within a removable spray tip in accordance with an embodiment of the present invention.

[0010] FIGS. 7A-7C illustrate alternative mixer configurations in accordance with some embodiments of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0011] A plural component spray gun receives at least two fluids that are reactively combined within a mixer, and then dispensed. The mixer receives each of the two fluids through a separate inlet. The mixer facilitates mixing of the plural components from their respective inlets, and emits, through an outlet, a product which is then sprayed or otherwise provided at an outlet. The mixer is responsible for effective mixing of the two components, for example a liquid component A and a liquid component B. Components A and B, when cured, can create a plurality of different materials, for example thermal insulation, protective coating, etc.

[0012] Some important process variables for plural component mixing and spraying are fluid delivery, fluid dispersal and chemical mixing. Fluid delivery is affected by flow rate control and filtering. Chemical mixing is affected by reducing jetting and reducing back pressure. Fluid dispersal is affected by spray pattern, which, in turn, can be affected by the tip geometry and / or size. Some embodiments described herein utilize a spray tip with a cat-eye outlet. However, embodiments described herein may also be used with any other suitable outlet and / or internal geometry.

[0013] Components A and B are each pumped into a plural component spray gun mixer through two separate entry points in order to reduce the risk of a crossover event, e.g. component A backflowing into a fluid line for component B and reacting within the component B fluid line. Crossover events can result in a plural component gun becoming unusable. Chemical mixing of components A and B can be improved by reducing jetting, and by reducing back pressure. Jetting can be reduced by modifying an orifice offset between entry points for components A and B. Back pressure can be reduced by modifying an orifice angle at which components A and B enter the mixer.

[0014] FIGS. 1A-1C illustrate plural component spray gun 100 in which embodiments of the present invention may be useful. Spray gun 100 is configured to spray a mixed fluid through outlet 150, when trigger 110 is actuated. Fluid components enter spray gun 100 through inlets 102 and 104 (shown in FIG. 1B). For example, component A may enter through inlet 102, and component B may enter through inlet 104.

[0015] FIG. 1C illustrates an exploded view of a plural component gun 100 illustrating a position of mixer 120 within spray gun 100. Mixer 120 received incoming components A and B from inlets 102, 104, respectively.

[0016] FIG. 2 illustrates a diagrammatic view of a fluid being applied to a surface. Using Bernoulli's principle and momentum conservation, the normal force exerted on the wall and flow rates can be derived using equations 1-3 presented below.

$$F_n = \rho A V^2 \sin\theta \quad (1)$$

$$Q_1 = \frac{1}{2}Q(1 + \cos\theta) \quad (2)$$

$$Q_2 = \frac{1}{2}Q(1 - \cos\theta) \quad (3)$$

[0017] In Equations 1-3, F_n is normal force 230, volumetric flow rates Q, Q1, and Q2 correspond, respectively, to flow rates 212, 232, and 234. A is the area of the nozzle, V is the velocity at the nozzle outlet, and θ is angle 222 of inclined wall 220, or the impingement angle.

[0018] Using Equation 1 it is determined that normal force 230 is maximum when the impingement angle 222 is 90°. Impinging the jet at an angle can decrease the normal force acting on the wall, which in turn, decreases the force. Flow rates 232 and 234 are also dependent on angle 222. In a scenario where angle 222 is not equal to 90°, the fluid has a higher tendency to move in a first direction as opposed to a second direction, for example, flow rate 232 is greater than flow rate 234.

[0019] As illustrated using Equations 1-3, in a first case scenario, a 90° impingement angle for an incoming component A, with respect to the inlet for component B may result in a higher back pressure, which may distribute the flow equally on both sides of a mixer. Such an equal distribution can present a disadvantage as there is only one outlet for most mixer designs. Fluid particles are diverted opposite in direction to the outlet, which restrict flow coming into the mixer. In turn, this requires more pressure to reverse the flow back towards the outlet. Since the mix chamber walls are curved, the fluid particles may have a tendency to move axially without bouncing back toward the inlet, as compared to a vertical wall.

[0020] In a second scenario, the fluid particles from liquid components A and B come to a complete rest when impinging on each other in the vicinity of their intersection within the mixer. The fluid particles may then have to be accelerated to gain axial velocity along the mixer, which affects the pressure required. Having a higher offset between inlets would decrease the impingement of the fluid components on each other, such that the pressure is solely through impingement off the chamber wall. However, having the flows of liquid components A and B impinging at each other does ensure efficient mixing.

[0021] Aside from the first and second case scenarios presented above, when the pressures at the orifices are varied by a higher amount, liquid from one inlet (for example, component A inlet) is at a higher risk of flowing into the opposite inlet (for example, component B inlet),

instead of exiting through the outlet. Such a scenario creates a crossover event, where the liquid components react and cure internally within the spray gun. In many cases, a spray gun that experienced a crossover event is no longer usable. It is desired, therefore, to improve efficiency without increasing the risk of crossover. At least some of the embodiments described herein achieve such improvements.

[0022] FIGS. 3A and 3B illustrate a known mixer design. For example, FIG. 3A illustrates a mixer available from Polyurethane Machinery Corporation, headquartered in Lakewood, New Jersey (hereinafter referred to as "the PMC chamber"). The PMC chamber illustrated in FIG. 3A is a standard 00 mix chamber and 00 tip configured to combine liquid components A and B in mixer 300 using two inlet apertures 310 and 320 arranged to have an offset of 0.010 inches from their respective centerlines (as illustrated in FIG. 3A). A portion of liquid component A impinges on the wall of mixer 300 while the rest impinges on liquid component B. Liquid component B behaves similarly. FIG. 3B illustrates a diagrammatic cross sectional view 350 of mixer 300, illustrating the overlap 330 between caused by offset centerlines between inlets 310 and 320.

[0023] Several different design requirements are important to consider for a mixer. In addition to reducing crossover events, it is also desired to maintain or improve efficiency of fluid mixing within the mixer. Additionally, a functional spray pattern must be maintained by the spray gun during operation. Ideally, the mixer will also be compatible with existing plural component spray gun technology, with minimal or no retrofitting. It is also desired to maintain or increase the flow rate of fluid through the mixer. At least some embodiments herein increase the robustness of current mixer designs and make the designs more resistant to crossover, which can be caused by pressure imbalances between the two fluid entering the mixer. At least some embodiments described herein change the angle of one or both fluid component inlets, with respect to the mixer from directly perpendicular to the side walls of the mixer to an angle towards the outlet. In one embodiment, the angle is about 10°. Embodiments described herein may also increase the separation between the mixer inlets of the two fluid components. These changes can reduce back pressure on the inlet orifices, reduce jetting of the fluids into the opposite side orifice, and facilitate proper mixing of the chemicals within the mixer under all potential pressure differential conditions.

[0024] FIGS. 4A-4H illustrate a comparison between a mixer in accordance with an embodiment of the present invention, and the mixer of FIGS. 3A and 3B. Mixer 400, illustrated in FIG. 4A, includes a mixer body that receives a first fluid inlet 410, and a second fluid inlet

420. As illustrated, fluid component inlets 410 and 420 are each angled at an orifice angle 412 and 422, respectively. In one embodiment, orifice angles 412 and 422 are about 10°. However, embodiments can be practiced with other angles, such as 5° to 20°. Additionally, as illustrated, the positioning of inlets 410 and 420 differs with respect to previous designs.

[0025] One advantage of an angled orifice is that it results in a larger axial (i.e. in the direction of the outlet) component of the fluid velocity when the two fluids components enter mixing chamber 400 through inlets 410 and 420. When the two fluids enter the mixing chamber on offset planes, vorticity, or fluid rotation, is introduced, which improves the ability of the two fluids to mix and react. Angling orifices 410, 420 toward the outlet means that, as the fluid rotates in mixing chamber 400, there is less of an opportunity for it to circulate over to the opposing orifice and create a small recirculation zone that could be a trigger point for crossover in the event of a pressure loss on one side.

[0026] Orifice location is an important consideration for a crossover resistant design, in that inlet orifices 410, 420 should be offset from the centerline of the mixing chamber. In the design of FIGS. 3A and 3B, each orifice is offset by 0.010 inches from the mix chamber center line, resulting in a total offset distance of 0.020 inches between the entry plane of the inlets. Since the inlet diameter of mixer 300 is 0.032 inches, each orifice can see a small section of the other orifice, which results in fluid jetting from one side to the other, as well as recirculation in the inlet region of each orifice. As illustrated in FIG. 4A, in one embodiment, the offset of inlet orifices 410, 420 is increased to 0.040 inches from the center line, or 0.080 inches total offset, and the inner diameter of mixer 400 is increased to allow for greater offset.

[0027] FIG. 4B is a computational fluid flow pressure diagram illustrating pressure contours experienced along a surface of mixer 400, in fluid flow direction 430. The pressure contours of FIG. 4B were obtained using water as a medium flowing through inlets 410 and 420. The flow rates on both inlets was kept constant at 0.6 gallons/minute (GPM). FIG. 4C shows a similar pressure contour using mixer 300, shown in FIGS. 3A and 3B. As illustrated in the comparison between FIGS. 4B and 4C, the pressure drop experienced using mixer 400 is lower than that using mixer 300, with the same maximum velocity experienced at 160 meters/second.

[0028] FIG. 4D illustrates velocity for mixer 300. As expected, almost zero velocity is experienced at the intersection of fluid jets 415 and 425. Instead, as one end of mixer 402 is blocked, fluid particles are directed away from the outlet and are bounced back. The force from these particles, combined with the inlet fluid pressure impinging on the circular wall,

creates a whirling motion, as illustrated in FIG. 4E. In contrast, when liquid components A and B are inserted into a circular space tangentially, as illustrated in FIGS. 4F and 4G, they create an overall rotational motion. The swirling motion dissipates as the fluid flows along the length of mix chamber 400. This behavior is caused by a lower pressure region along axis 430. Fluid particles near the wall move inward into the low pressure region. The rotational motion is converted to axial motion along the length of mix chamber 400, as illustrated in FIG. 4F. FIG. 4G plots the vorticity contour for mixer 400, quantifying the decrease in rotational motion along length 430 of mixer 400.

[0029] Additional simulations were also conducted using polymeric fluids. In one example, A-isocyanate and B-polyol were used. The two components entered mixers 300 and 400 at a temperature greater than room temperature. The dynamic viscosity was consequently measured using a rotary viscometer. The dynamic viscosity values were found to be *A* - 0.045 *Pa.s* and *B* - 0.145 *Pa.s* when A was dispersed at 120 ± 3°F and B at 130° ± 30°F. CFD simulations quantified the differential pressure between the inlets. Using mixer 400, a pressure differential of 950 PSI was observed, while mixer 300 only reached a differential of 575 PSI. The larger pressure differential allows for mixer 400 to avoid crossover due to user error and/or pump malfunction. Flow rates were also calculated through the simulations with set pressures at the inlets. Mixer 400 experienced 0.147 pounds/second while mixer 300 experienced 0.108 pounds/second.

[0030] Experimental testing was also conducted between mixers 300 and 400. At a set pump pressure, gun pressures were compared for each design, using different fluids. For liquid component B, the gun pressure for mixer 400 was 260 PSI greater than that of mixer 300. For liquid component A, the gun pressure was 200 PSI. As illustrated, mixer 400 has a lower back pressure when compared to mixer 300. The lower back pressure allows for a higher flow rate a set pump pressure. This validated the simulated higher flow rate obtained using the CFD analysis discussed above.

[0031] Tests were also conducted to intentionally cause crossover between liquid components for both mixers 300 and 400. The results are illustrated in FIG. 4H as pressure differential values with the spray gun between components A and B for different B to A ratios. Mixer 400 was able to achieve a pressure differential of 841 PSI, while mixer 300 (illustrated in FIGS 4A-4H as mixer 402) maxed out at 384 PSI.

[0032] Additionally, densities of foam sprayed using mixers 300 and 400 were compared, and presented below as Table 1. Foam was sprayed with a 2000 PSI set point, with component

A delivered at 120°F and component B delivered at 130°F. It is noted that the two designs were tested for double pass samples, instead of a single pass with a specification of 46.45 kg/m^3. The obtained density values are similar using mixer 400, indicative of similar mixing capabilities.

Table 1

Chamber design	**Core Weight** *(gms)*	**Core Volume** *(mL)*	**Core Density** *(kg/m^3)*
Mixer 300	6.35	110	57.82
Mixer 400	6.07	110	55.34

[0033] The CFD analysis of mixer 300 resulted in crossover at a 560 PSI differential. When testing mixer 400, crossover did not occur until a differential of 950 PSI. Therefore, the chance of crossover was reduced by 70%. In a lab setting, crossover could not be induced using mixer 400.

[0034] The CFD analysis for the volume fraction demonstrated that mixing within chambers 300 and 400 are similar, with mixer 400 showing slightly improved mixing between components.

[0035] The spray pattern and spray atomization has improved when compared to mixer 300 for at least some embodiments. The spray pattern has widened in relation to that obtained using mixer 300. Additionally, as illustrated when comparing FIGS. 3A and 4A, mixer 400 is configured to be installed within similar spray gun configurations.

[0036] An additional benefit of mixer 400 is the increased mass flow rate achieved. Mixer 400 was tested using the same inlet size and spray nozzle. CFD results showed that the new design out-performed the current design by 28% with regard to mass flow rate. Higher flow rates allow operators to complete jobs faster, saving operators time and money on each job, and allowing operators to complete more jobs with the same equipment. Mixer 400, and similar embodiments discussed herein, can accomplish this while maintaining foam density standards and quality.

[0037] FIGS. 5A-5F illustrate diagrammatic views of a mixer in accordance with an embodiment of the present invention. Mixer 500 is configured to be used in a plural component spray gun. FIG. 5D illustrates a view taken along the cross-section of line A-A, illustrated in FIG. 5A. FIG. 5E illustrates a cross-section of the spray gun taken along line B-B, shown in FIG. 5B. FIG. 5F illustrates a cross-sectional view of the mixer 500 taken along section C-C, shown in FIG. 5C. Mixer 500 is configured to receive two components at inlets on opposing sides of the mixer, as illustrated in FIGS. 5E and 5F. Inlets comprise an offset distance 510, with an orifice angle 512. In one embodiment, as illustrated by mixer 500, both component A

and B experience the same offset angle 512 and inlet offset distance 510. However, other embodiments may be constructed differently, for example with the A and B inlets having different offset angles and / or different inlet offsets. Mixer 500 has a chamber diameter of 502, of about 0.113 inches, which may allow for a higher volumetric flow rate when compared to previous designs.

[0038] FIGS. 6A-6C illustrate a mixer within a removable spray tip in accordance with an embodiment of the present invention. As illustrated in FIG. 1C, in current designs, a mixer is typically located within a spray gun. In the event crossover occurs, the spray gun must be completely disassembled in order to remove the mixer and address the damage from the crossover event. Additionally, in the event the spray gun is to be used for a different operation, which can require a different mixer configuration, the spray gun must be disassembled and reassembled with the desired mixer configuration between uses. It is desired for a mixer to be more easily removed and replaced from a spray gun design. One embodiment that achieves these goals is illustrated in FIGS. 6A-6C. Spray tip 600 is configured to be inserted within a spray gun, such as spray gun 100, such that fluid flows through the spray tip prior to exiting outlet 150.

[0039] FIG. 6B illustrates a cross-sectional view of spray tip 600 taken along line A-A illustrated in FIG. 6A. In one embodiment, the mixer is incorporated into spray tip 600, such that a first liquid component enters through inlet 602 at an inlet offset (not shown), and offset angle 612, while a second component enters through inlet 604, at an inlet offset (not shown) and offset angle 614. The offsets for inlets 602 and 604 may be the same or different. Angles 612 and 614 may be the same or different. In one embodiment, the inlet offset is 0.010 inches, and inlet angles 612 and 614 are each 20° with respect to a centerline of the mixer. However, the offset angle 612 and/or 614, may have a magnitude greater than 20°, for example 21°, 22°, 23°, 24°, 25°, 26°, 27°, or 28°. Additionally, while the inlet offset for 602 and 604 has been described as 0.010, it could also be smaller, for example 0.005 inches, or 0.006 inches, or 0.007 inches, or 0.008 inches, or 0.009 inches. FIG. 6C illustrates volumetric flow through spray tip 600 along flow path 630 to an outlet. As illustrated, complete mixing is achieved between components A and B, along mixer 630 with minimal risk of crossover.

[0040] FIGS. 7A-7C illustrate alternative mixer configurations in accordance with some embodiments of the present invention. In FIG. 7A, a mixer 700 comprises an inlet 702 and an inlet 704 configured to allow components to enter a mix chamber 700 and exit through outlet 706. FIG. 7B illustrates an alternative mix chamber design with mix chamber design 710 with

inlets 712 and 714 and outlet 716. Additionally, FIG. 7C illustrates a mix chamber 720 with a first inlet 722, a second inlet 724, and an outlet 726.

WHAT IS CLAIMED IS:

1. A mixer for a plural component spray gun, the mixer comprising:

a mixer body comprising a mixing chamber with an outlet;

a first fluid component inlet, coupled to a first fluid conduit, configured to introduce a first fluid component into the mixing chamber;

a second fluid component inlet, coupled to a second fluid conduit, configured to introduce a second fluid component into the mixing chamber; and

wherein the first and second fluid component inlets are offset with respect to a centerline of the mixing chamber and positioned such that a first fluid flow from the first inlet is directed toward the outlet, and a second fluid flow from the second inlet is directed toward the outlet.

2. The mixer of claim 1, wherein the mixing chamber is incorporated into a removeable spray tip of the plural component spray gun.

3. The mixer of claim 1, wherein the first inlet is at a first angle with respect to the outlet, and the second inlet is at a second angle with respect to the centerline of the mixing chamber.

4. The mixer of claim 3, wherein the magnitude of the first angle is substantially the same as the magnitude of the second angle.

5. The mixer of claim 4, wherein the first and second angles are substantially mirror images of each other with respect to the centerline of the mixing chamber.

6. The mixer of claim 3, wherein the magnitude of the first angle is different from the magnitude of the second angle.

7. The mixer of claim 3, wherein one of the first and second angles is at least 10°.

8. The mixer of claim 3, wherein one of the first and second angles is at least 20°.

9. The mixer of claim 3, wherein one of the first and second angles is at least 25°.

10. The mixer of claim 1, wherein the first inlet has a first offset from an axis of the mixing chamber, and the second inlet has a second offset from the axis of the mixing chamber.

11. The mixer of claim 10, wherein one of the first and second offsets is at least 0.005 inches.

12. The mixer of claim 10, wherein one of the first and second offsets is less than 0.01 inches.

13. The mixer of claim 1, wherein the mixing chamber is shaped like a rectangular prism.

14. The mixer of claim 1, wherein the mixing chamber is shaped like a cylinder.

15. A plural component spray gun with a mixing unit, the spray gun comprising:

a spray tip configured to disperse a fluid mixture;

a first component source configured to provide a first component, to a mixing chamber within the mixing unit, at a first process temperature;

a second component source configured to provide a second component, to the mixing chamber within the mixing unit, at a second process temperature; and

the mixing chamber comprising:

a centerline extending along a center axis of a body of the mixing chamber;

a first inlet configured to deliver the first component from the first component source to the mixing chamber;

a second inlet configured to deliver the second component from the second component source to the mixing chamber; and

wherein the first and second inlets are positioned with respect to the centerline such that the first component flows through the first inlet in a first direction, wherein the first direction substantially does not intersect with the second inlet.

16. The plural component spray gun of claim 15, wherein the first inlet is angled with respect to the centerline.

17. The plural component spray gun of claim 16, wherein the angle is greater than 10°.

18. The plural component spray gun of claim 17, wherein the angle is greater than 20°.

19. The plural component spray gun of claim 18, wherein the angle is greater than 25°.

20. The plural component spray gun of claim 15, wherein the mixing chamber is incorporated into a spray tip of the plural component spray gun.

21. The plural component spray gun of claim 15, wherein the mixing chamber is incorporated into a gun block of the plural component spray gun.

22. A mixer for a multi-component system, the mixer comprising:

a mixing chamber within a mixing body of the mixer, the mixing chamber comprising an outlet;

a first inlet configured to receive a first component fluid flow;

a second inlet configured to receive a second component fluid flow;

wherein each of the first and second inlets are angled with respect to a centerline of the mixer such that fluid entering the first and second inlets is directed toward the outlet.

23. The mixer of claim 22, wherein the first and second inlets are each angled with respect to a centerline of the mixer, and wherein the angle is less than 90°.

24. The mixer of claim 23, wherein the first and second inlets are each offset from the centerline.

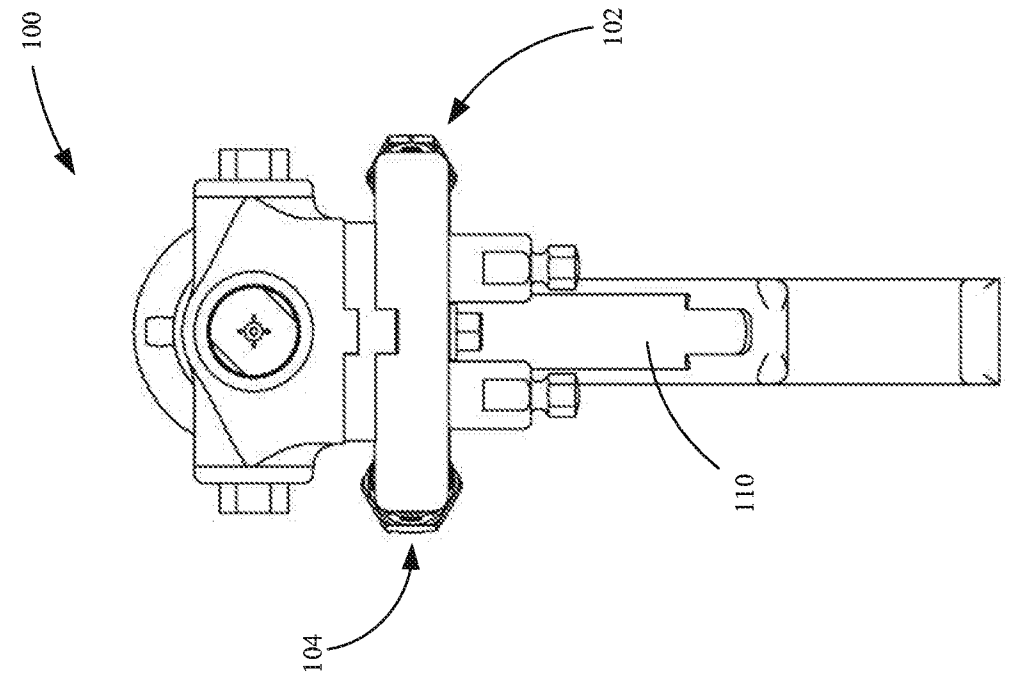


FIG. 1B

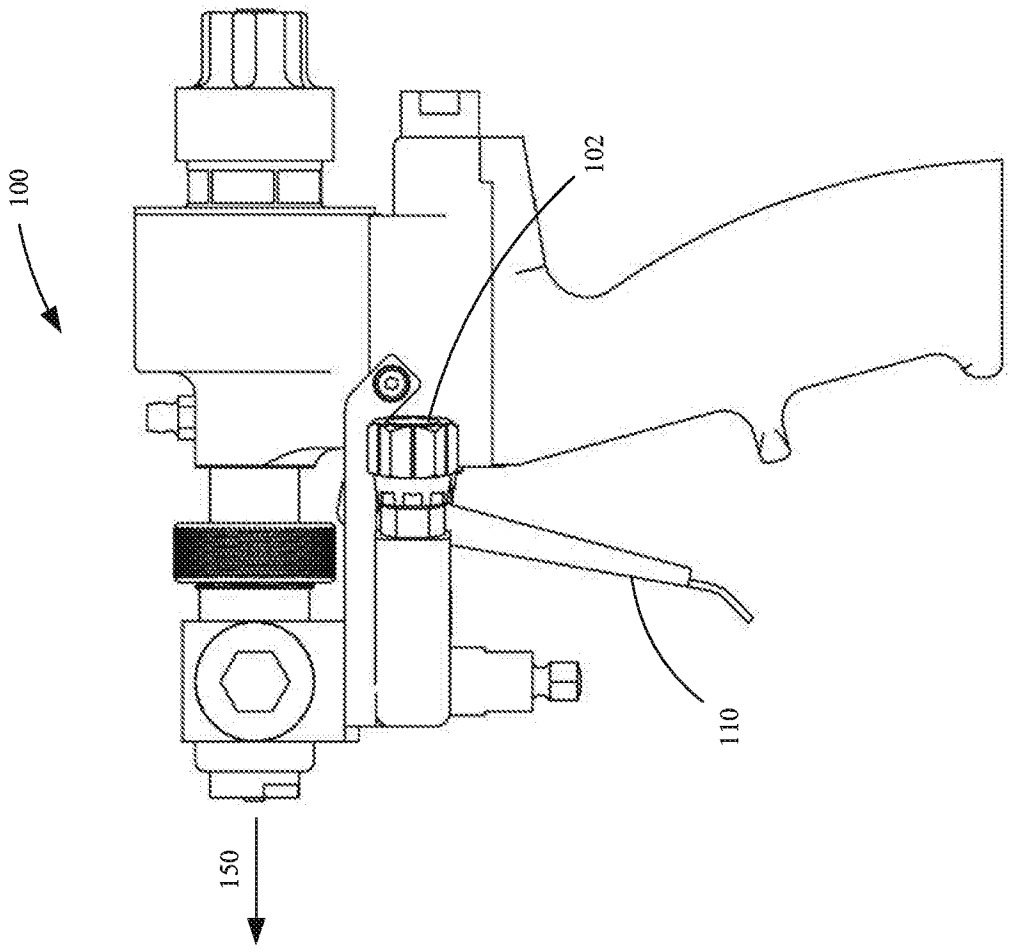


FIG. 1A

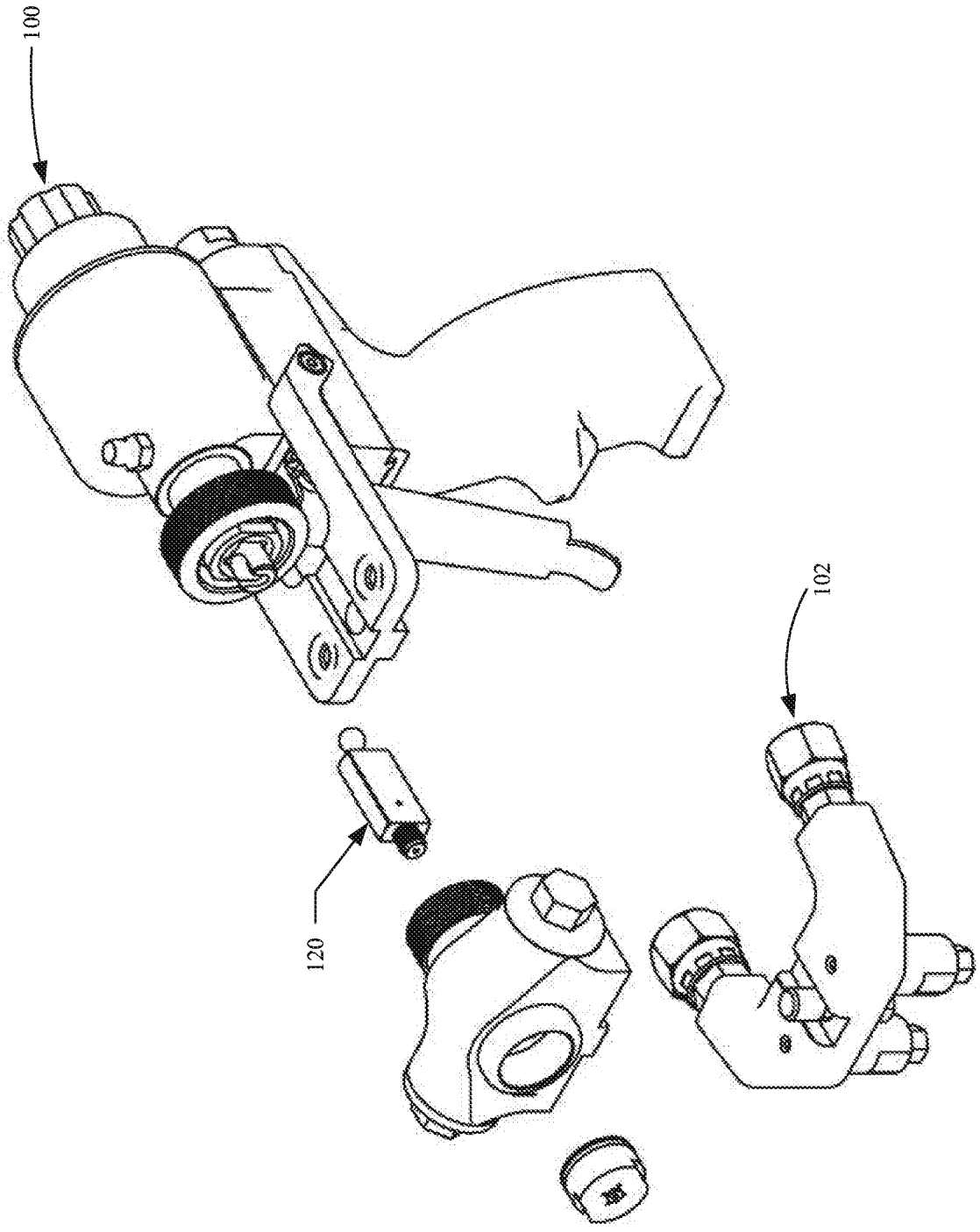


FIG. 1C

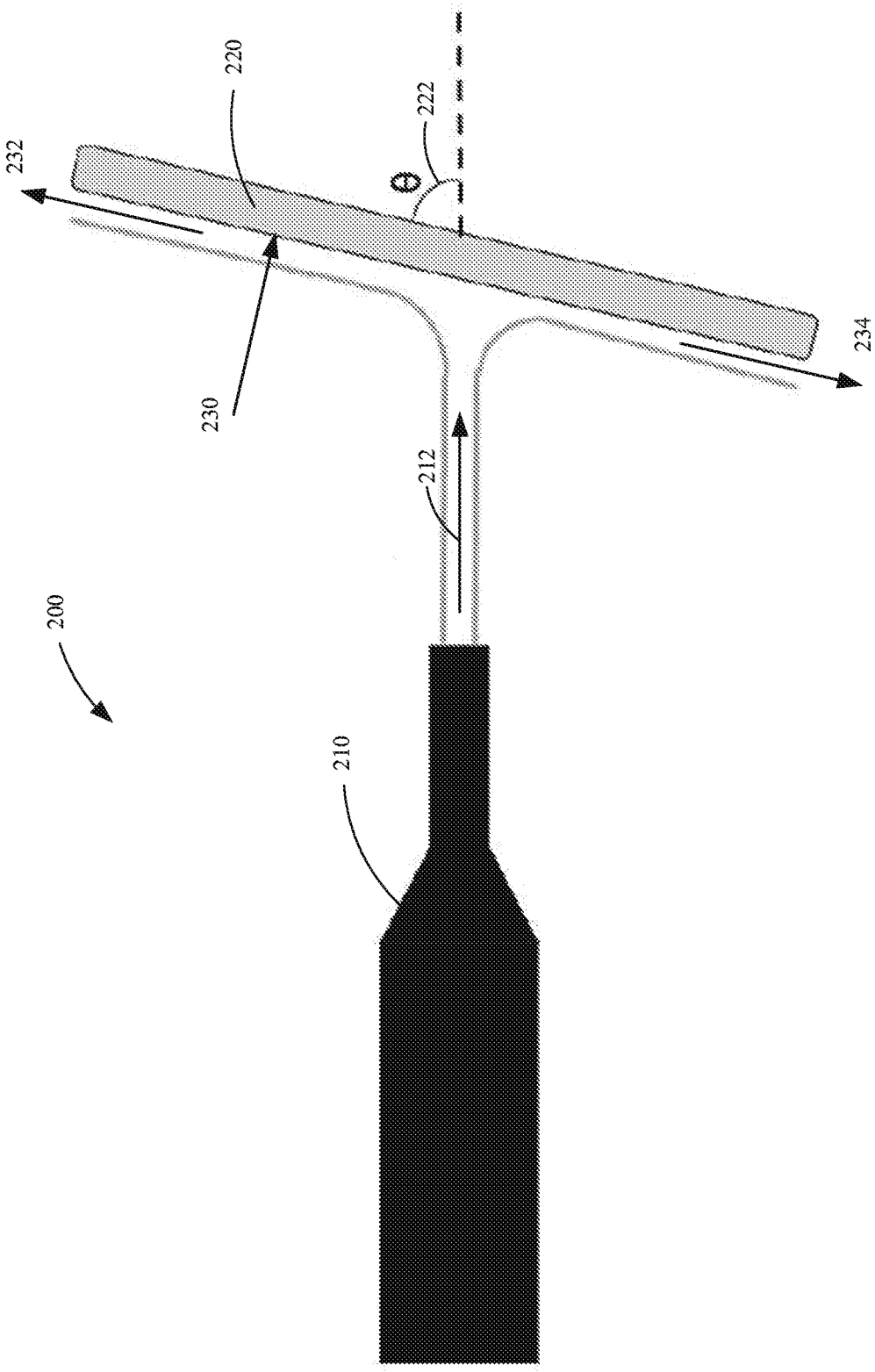


FIG. 2

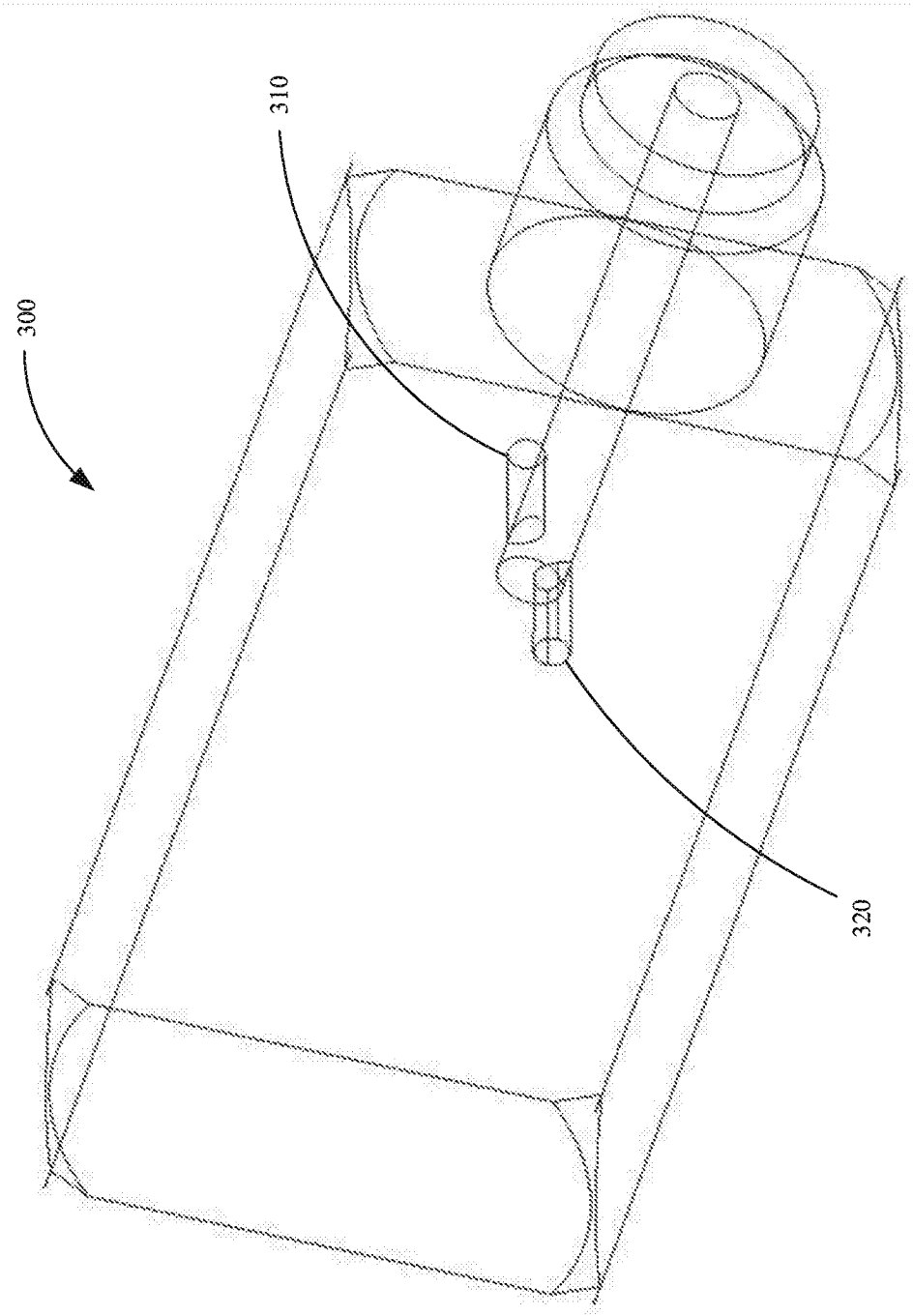


FIG. 3A

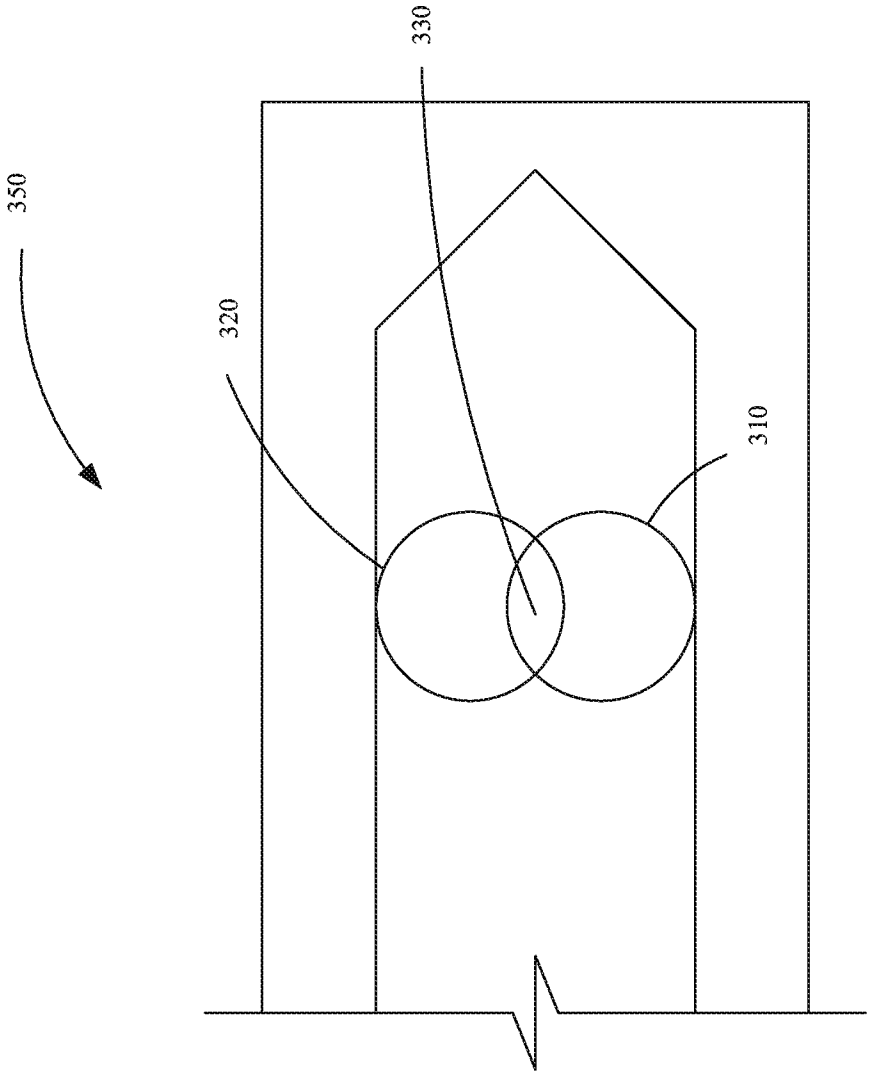


FIG. 3B

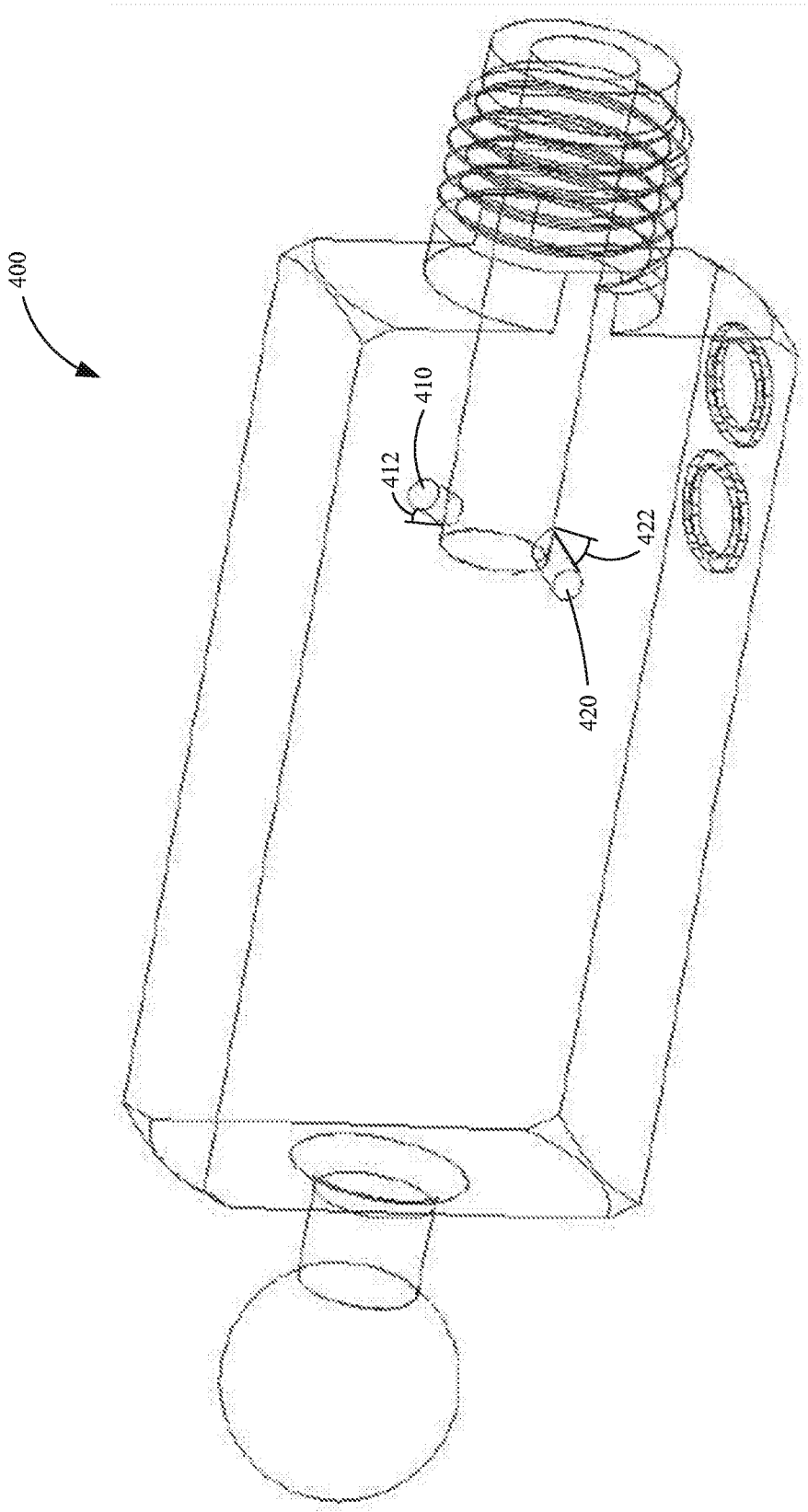


FIG. 4A

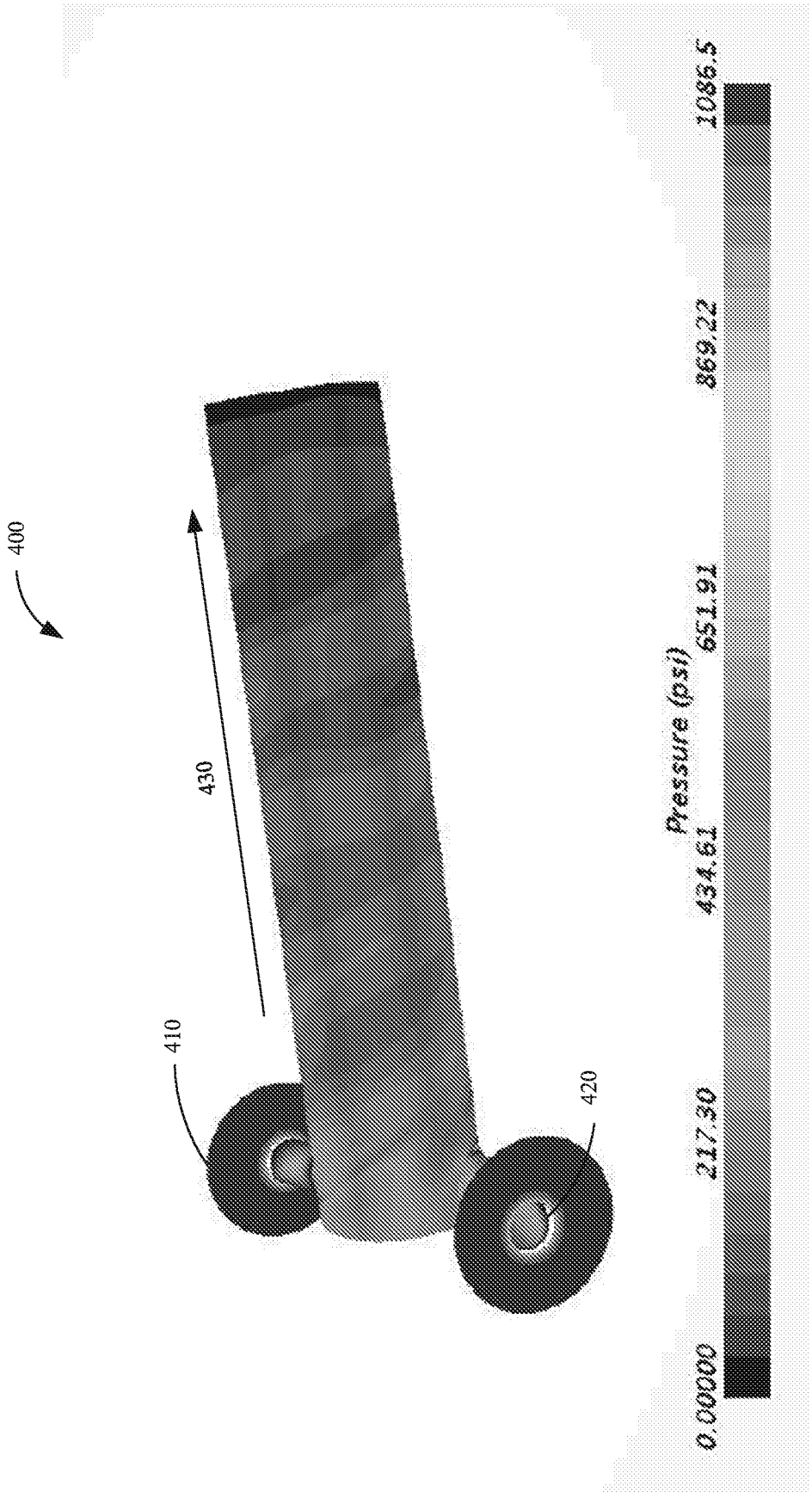

400
410
420
430
Pressure (psi)
0.00000
217.30
434.61
651.91
869.22
1086.5

FIG. 4B

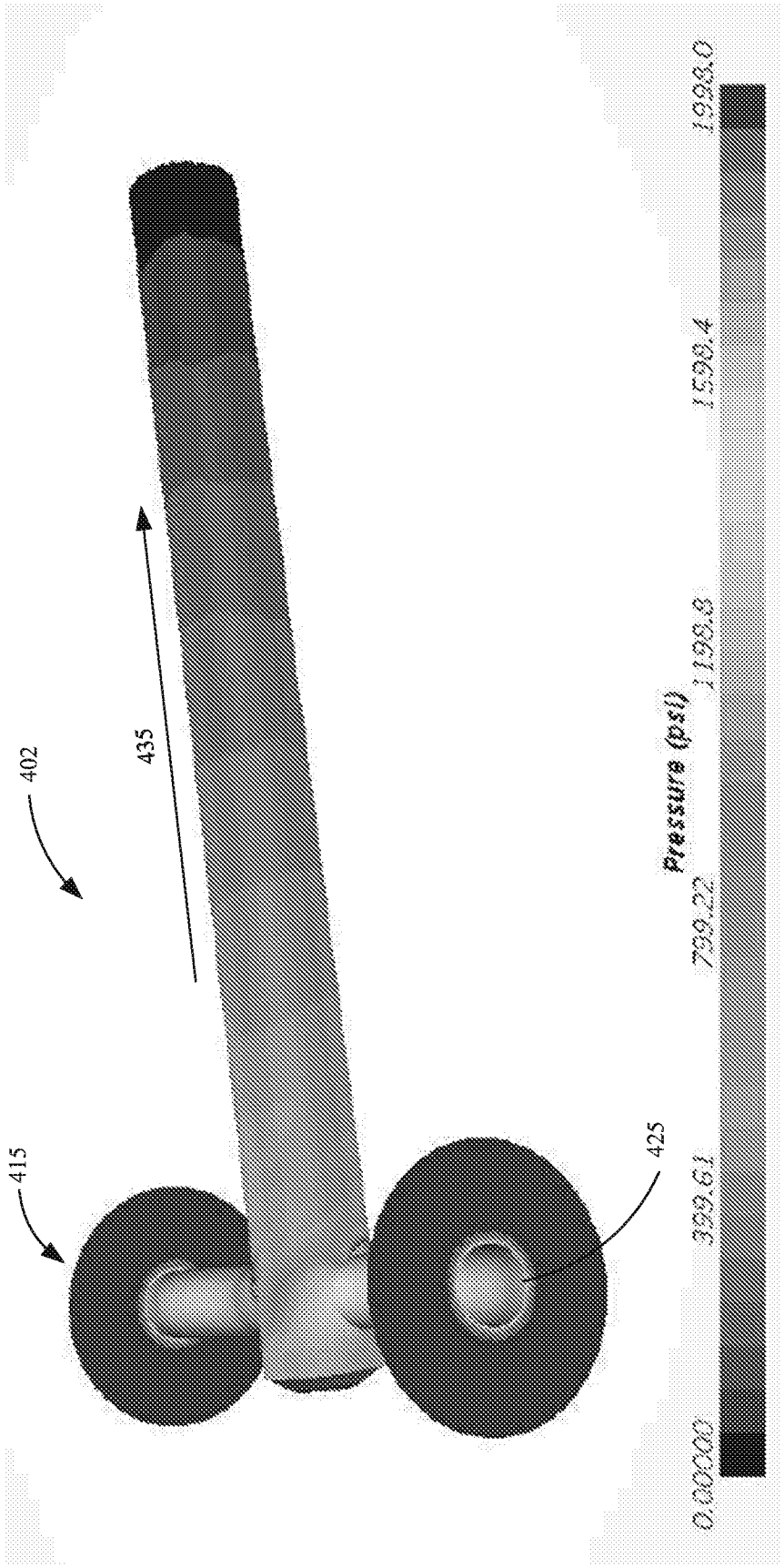

402
435
415
425
Pressure (psi)
0.00000
399.61
799.22
1198.8
1598.4
1998.0

FIG. 4C

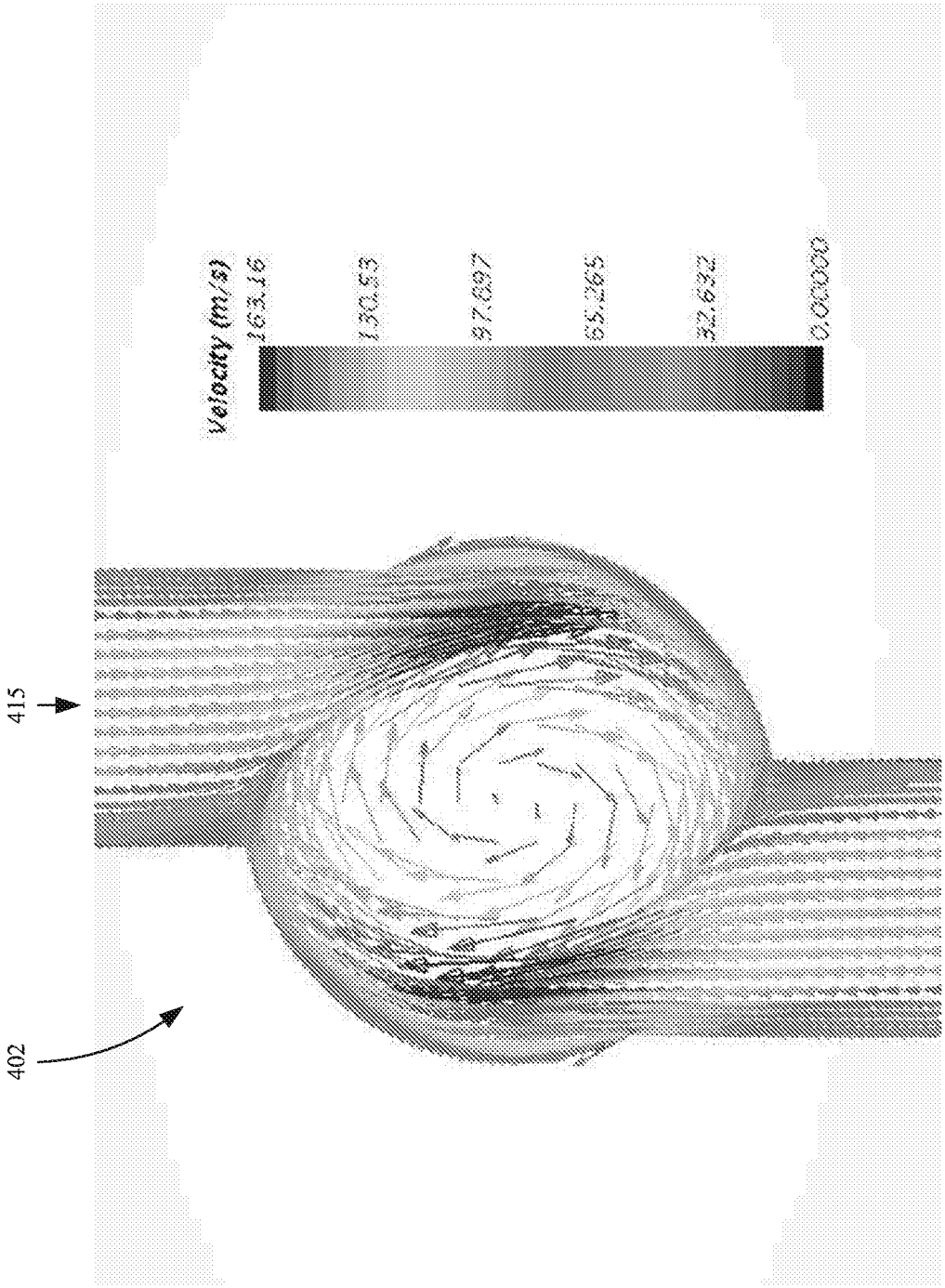

Velocity (m/s)
163.16
130.53
97.897
65.265
32.632
0.000000
415
425
402

FIG. 4D

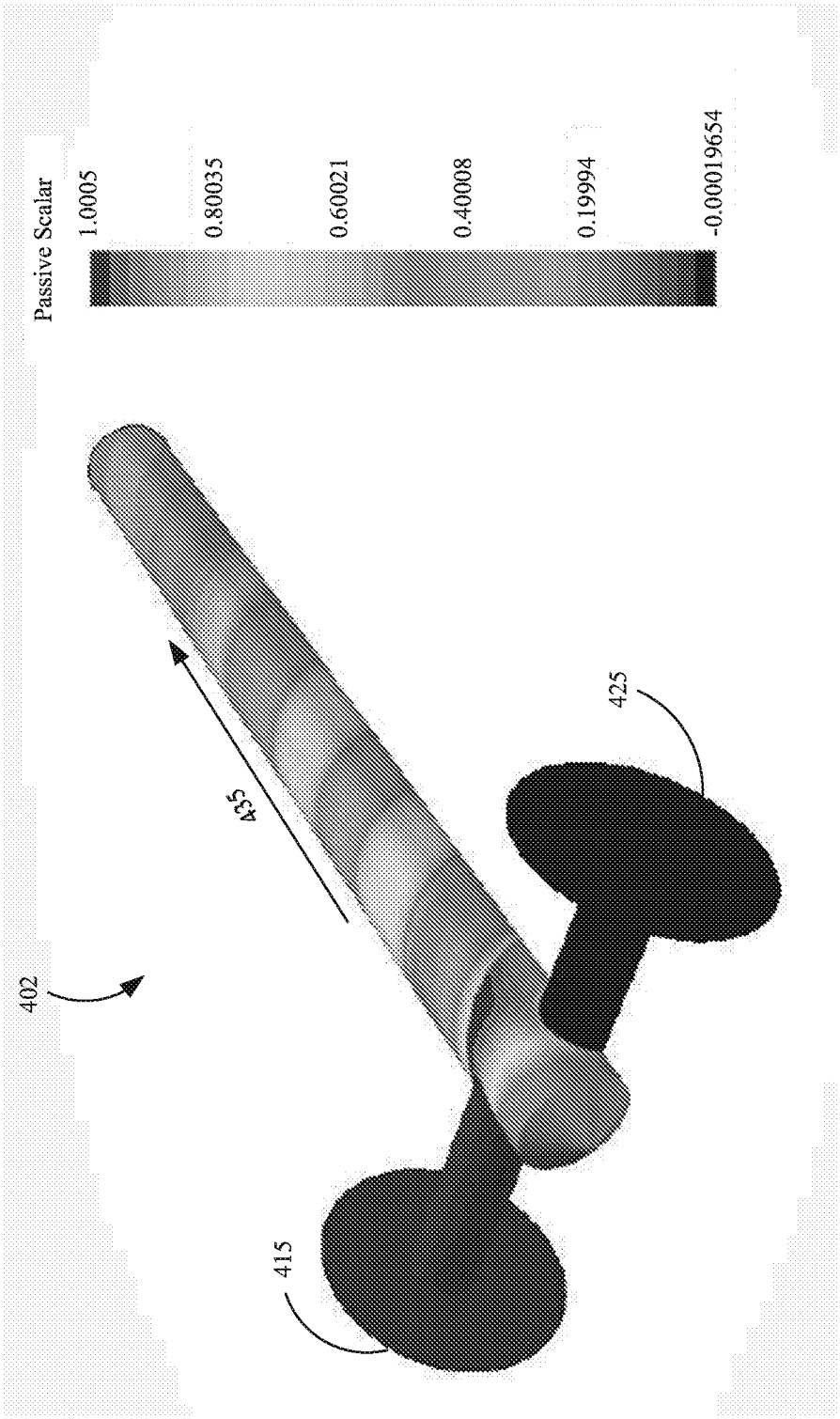

Passive Scalar
1.0005
0.80035
0.60021
0.40008
0.19994
-0.00019654
402
435
425
415

FIG. 4E

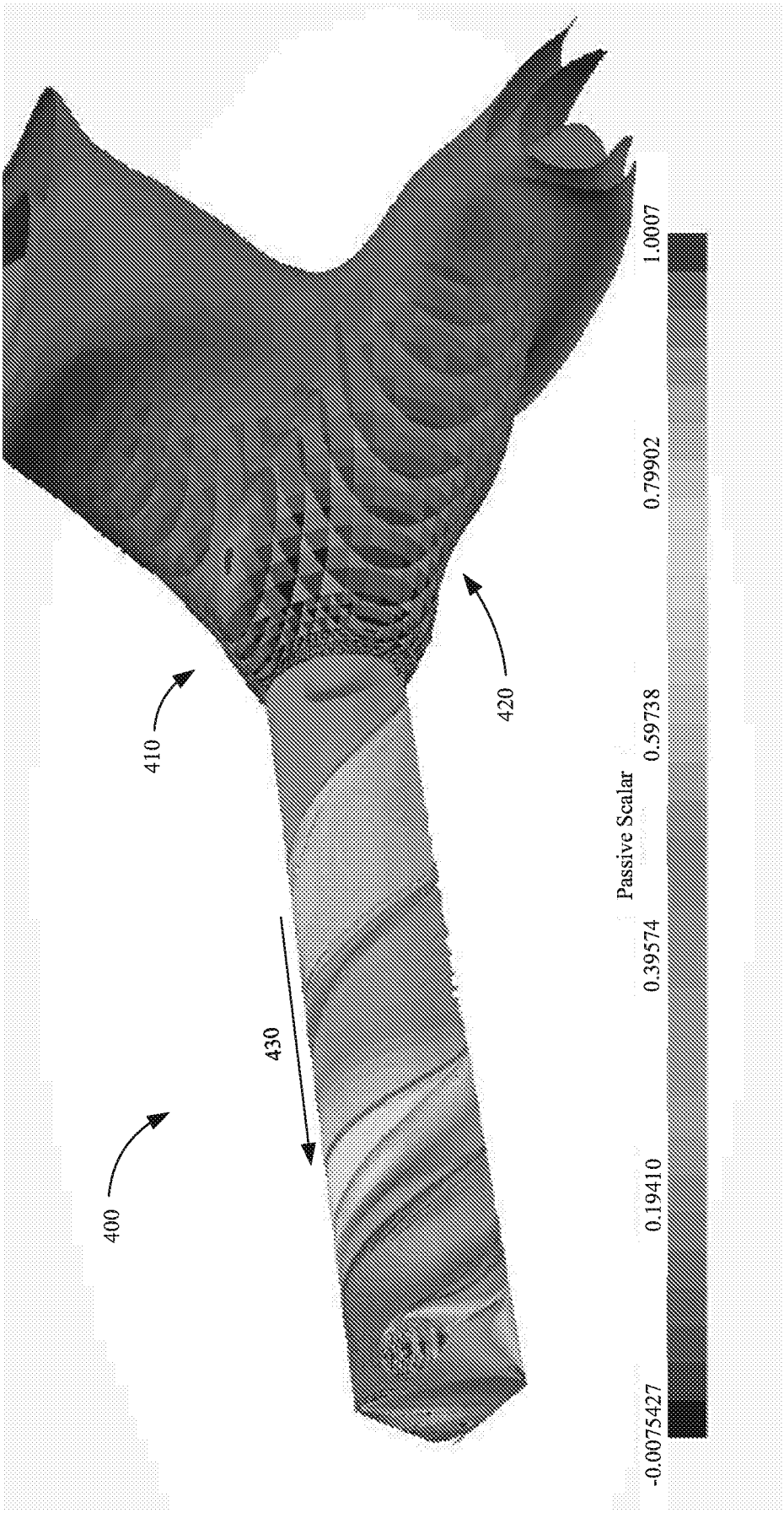

400
410
420
430
Passive Scalar
-0.0075427
0.19410
0.39574
0.59738
0.79902
1.0007

FIG. 4F

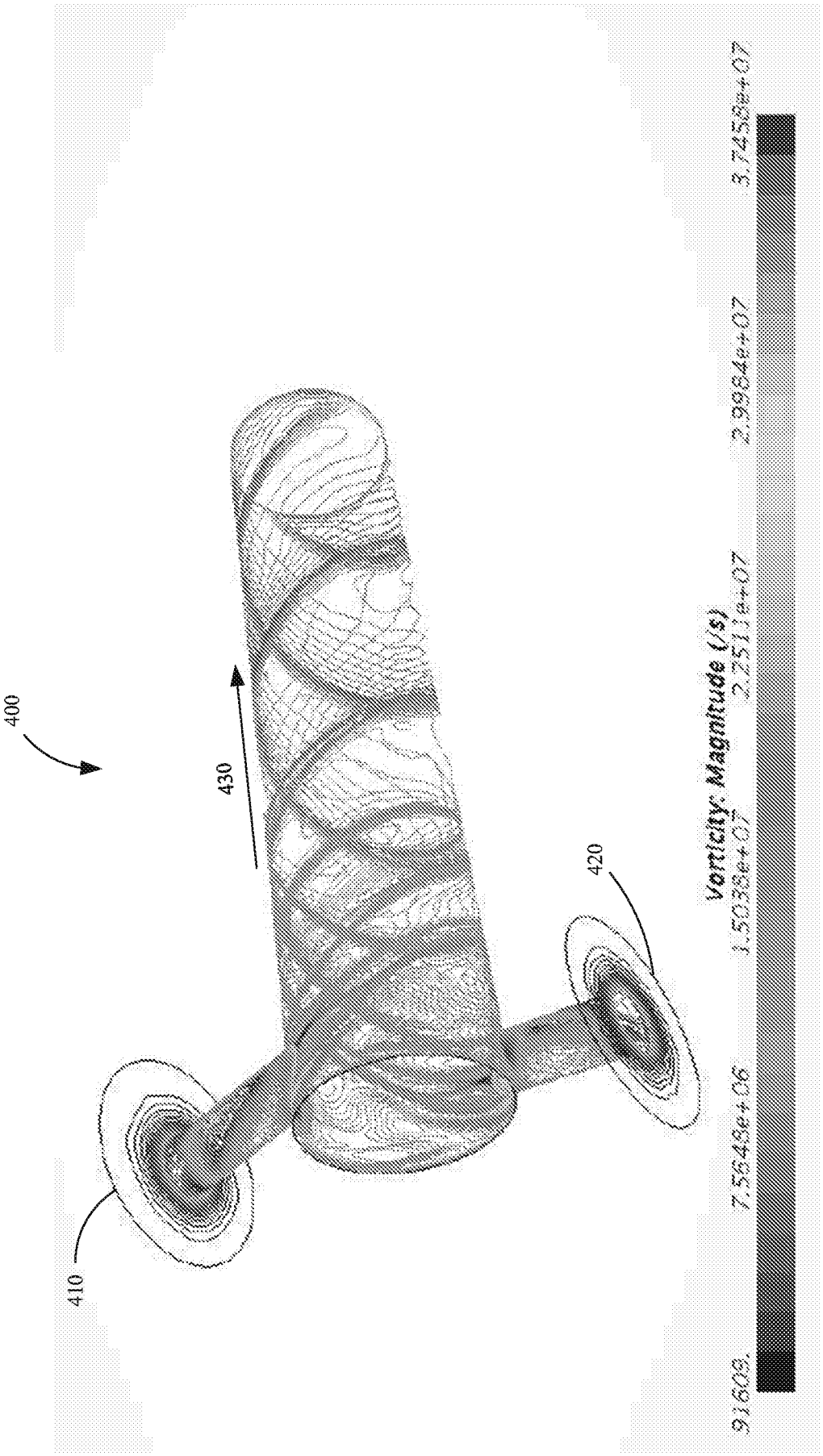

400
410
420
430
Vorticity: Magnitude (/s)
91603.
7.5648e+06
1.5033e+07
2.2511e+07
2.9984e+07
3.7456e+07

FIG. 4G

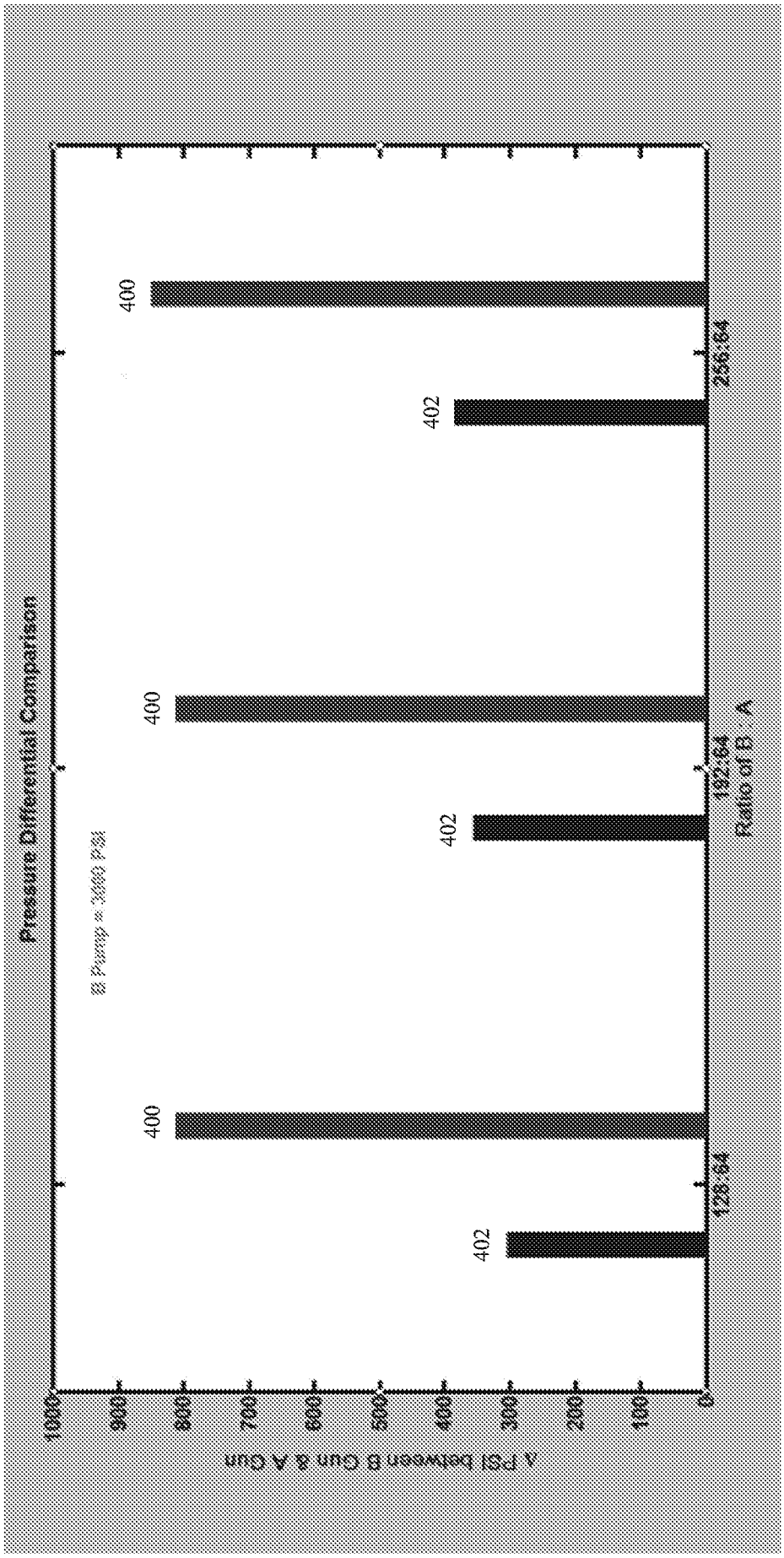

Pressure Differential Comparison
B Pump @ 3000 PSI
Δ PSI between B Gun & A Gun
1000
900
800
700
600
500
400
300
200
100
0
400
402
400
402
400
402
128.64
192.64
256.64
Ratio of B : A

FIG. 4H

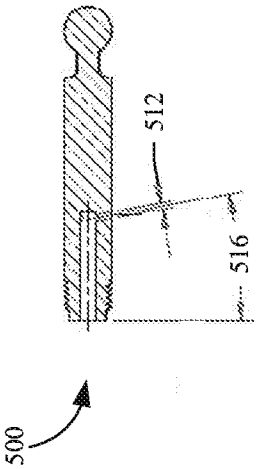


FIG. 5E

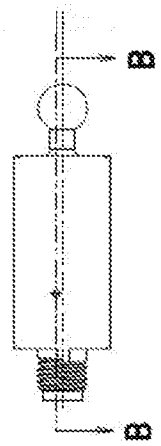


FIG. 5B

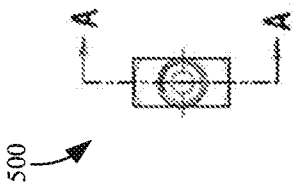


FIG. 5A

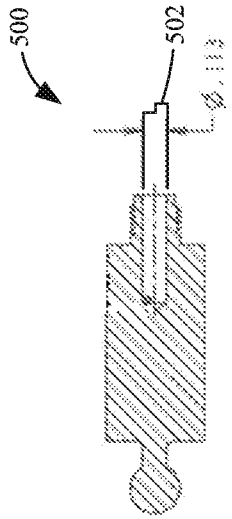


FIG. 5D

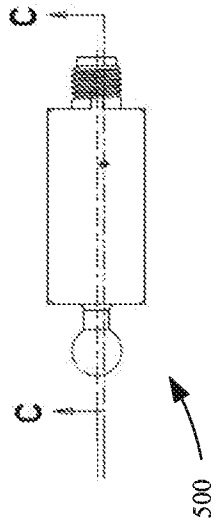


FIG. 5C

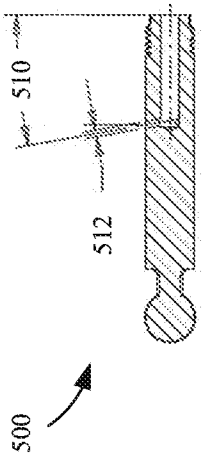


FIG. 5F

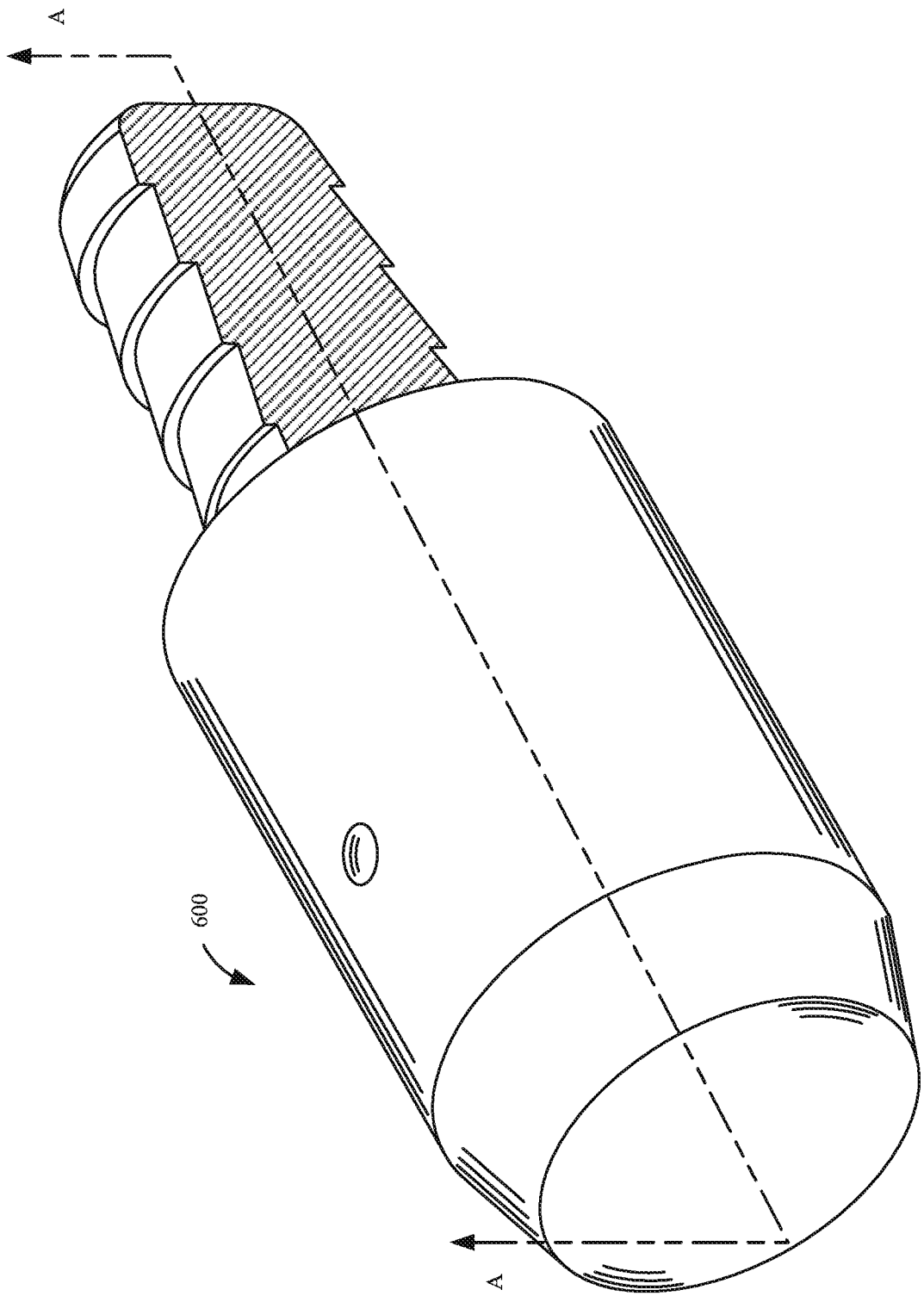


FIG. 6A

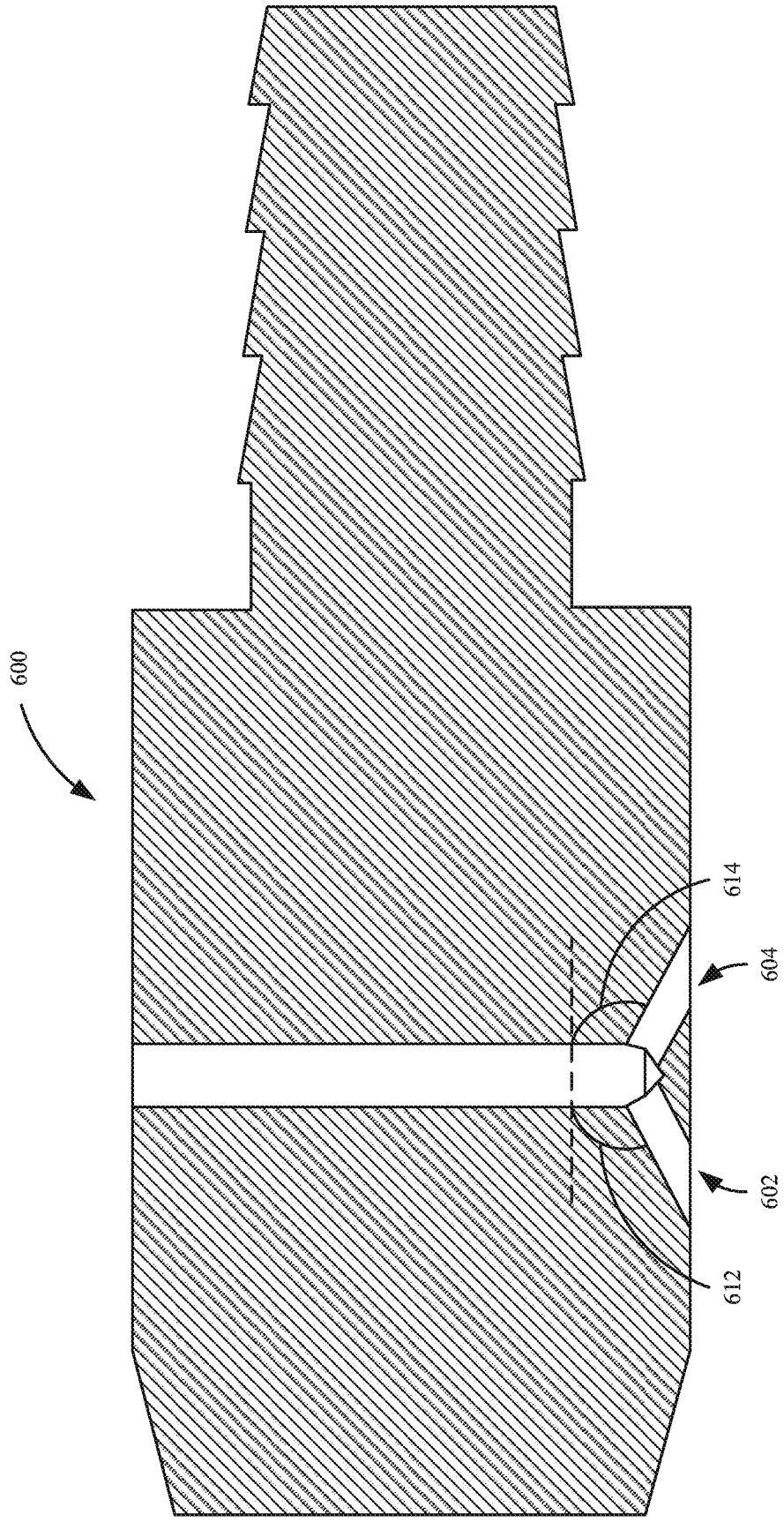


FIG. 6B

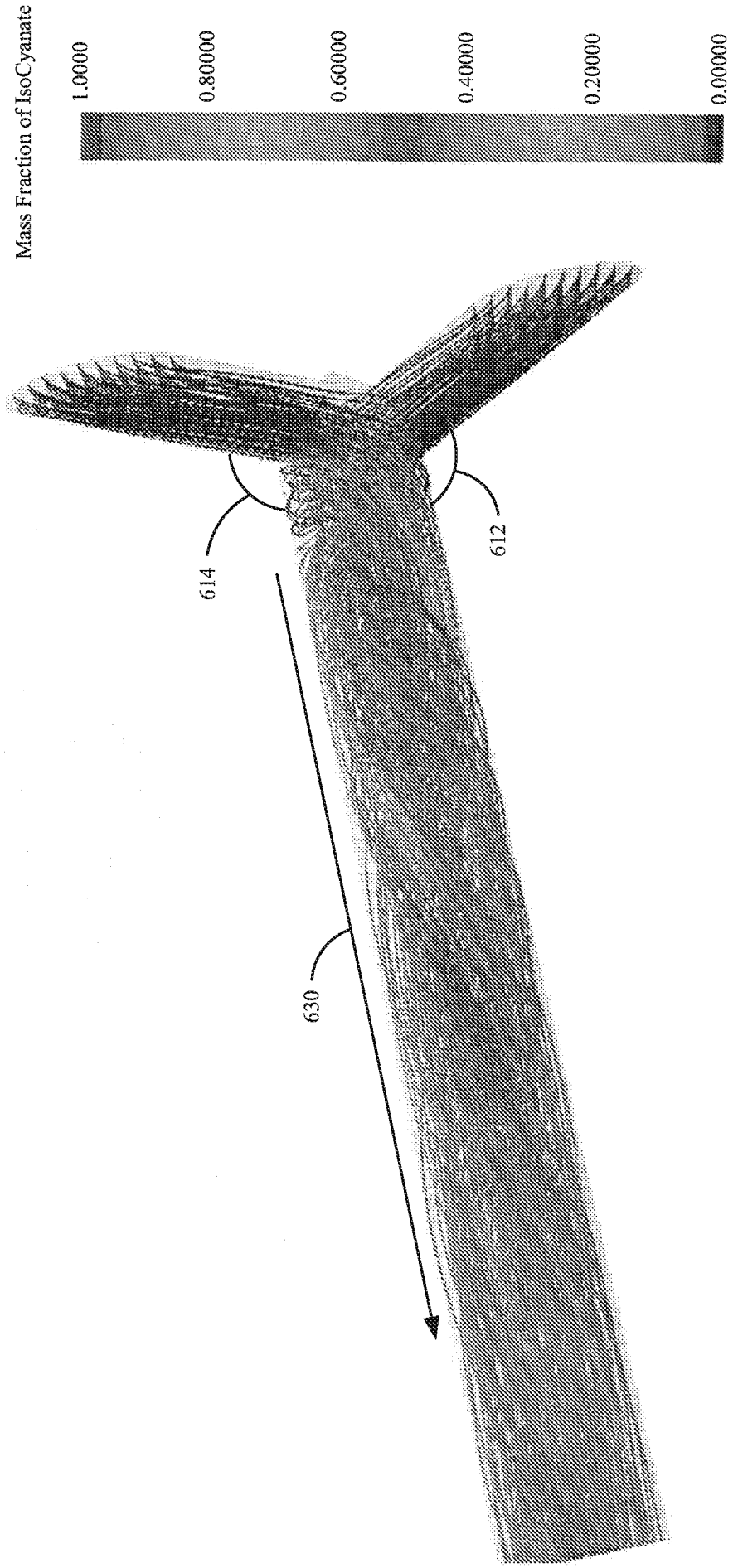

Mass Fraction of IsoCyanate
1.0000
0.80000
0.60000
0.40000
0.20000
0.00000
614
612
630

FIG. 6C

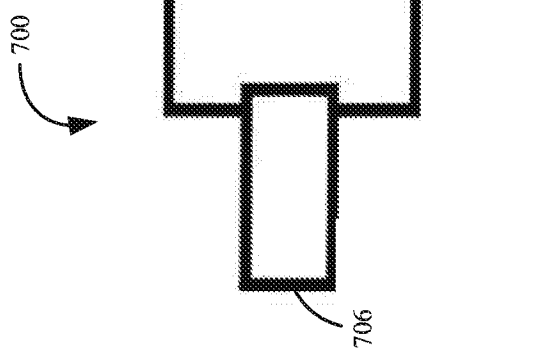


FIG. 7A

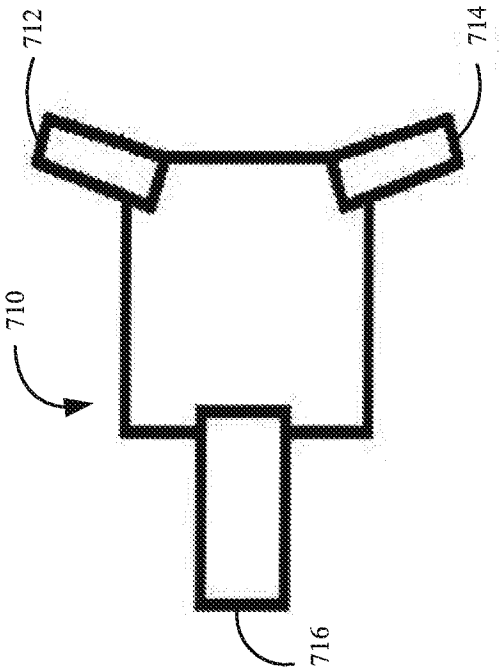


FIG. 7B

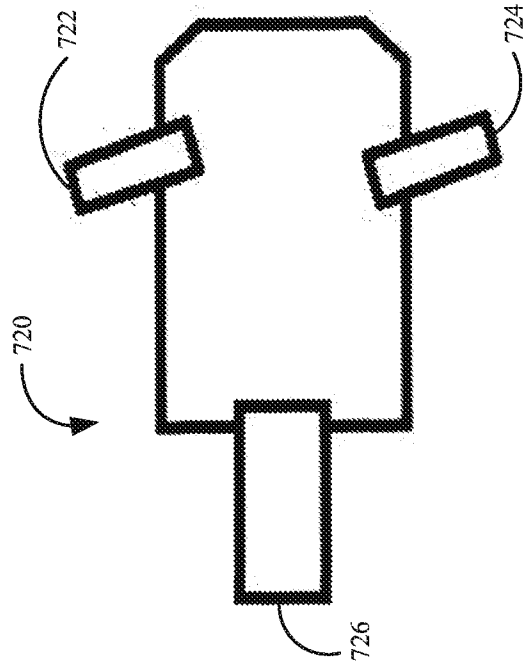


FIG. 7C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/030130

A. CLASSIFICATION OF SUBJECT MATTER

B05B 7/04(2006.01)i, B05B 7/00(2006.01)i, B05B 12/00(2006.01)i

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 7/04; A62C 5/00; B05B 7/00; A62C 31/00; B05B 12/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: plural, component, spray gun, mixer, chamber, offset, angle

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3437273 A1 (HAGFORS, G. D.) 08 April 1969 See column 6, line 54 - column 7, line 51; claim 1; figures 2, 4-6.	1,3-12,14,22-24
Y		2,13,15-21
Y	US 2013-0015262 A1 (MONCHAMP et al.) 17 January 2013 See paragraphs [0075]-[0082]; and figures 7-8.	2,13,15-21
A	US 2004-0124268 A1 (FRAZIER et al.) 01 July 2004 See paragraphs [0024]-[0026]; and figures 4-6.	1-24
A	US 2011-0011950 A1 (WALTER, BRADLEY P.) 20 January 2011 See paragraphs [0041]-[0043]; and figures 8-9.	1-24
A	JP 2006-511343 A (GRACO MINNESOTA INC.) 06 April 2006 See paragraphs [0013]-[0015]; and figures 7-11.	1-24

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 August 2018 (14.08.2018)	**14 August 2018 (14.08.2018)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/030130

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