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(54) Title: CONE AND PLATE FLUIDIC OSCILLATOR INSERTS FOR USE WITH A SUBTERRANEAN WELL

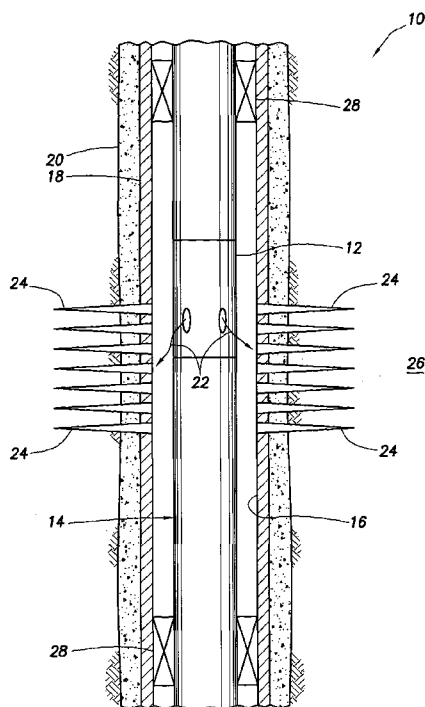


FIG. 1

(57) Abstract: A method of manufacturing a fluidic oscillator insert for use in a subterranean well can include forming the insert with a conical housing engagement surface thereon, and forming at least one fluidic oscillator on a substantially planar surface of the insert. A well tool can include a housing assembly, at least one insert received in the housing assembly, the insert having a fluidic oscillator formed on a first surface thereof, the insert being at least partially secured in the housing assembly by engagement of conical second and third surfaces formed on the insert and housing assembly, and a cover which closes off the first surface on the insert. An insert for use in a well tool can include a conical housing engagement surface, and at least one fluidic oscillator formed on a substantially planar surface. The fluidic oscillator produces oscillations in response to fluid flow through the fluidic oscillator.



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**CONE AND PLATE FLUIDIC OSCILLATOR INSERTS FOR USE WITH A
SUBTERRANEAN WELL**

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BACKGROUND

This disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in an example described below, more particularly provides improved configurations of fluidic oscillators.

There are many situations in which it would be desirable to produce oscillations in
10 fluid flow in a well. For example, in steam flooding operations, pulsations in flow of the injected steam can enhance sweep efficiency. In production operations, pressure fluctuations can encourage flow of hydrocarbons through rock pores, and pulsating jets can be used to clean well screens. In stimulation operations, pulsating jet flow can be used to initiate fractures in formations. These are just a few examples of a wide variety of possible
15 applications for oscillating fluid flow.

Therefore, it will be appreciated that improvements would be beneficial in the art of manufacturing fluidic oscillator inserts.

SUMMARY

20 In a first aspect, the present invention provides a method of manufacturing a fluidic oscillator insert for use in a subterranean well, the method comprising: forming the insert with a conical housing engagement surface thereon; and forming at least one fluidic oscillator on a substantially planar surface of the insert.

A side of the fluidic oscillator may be closed off by engagement between the insert
25 and a cover which engages the substantially planar surface. The cover may sealingly engage the substantially planar surface. The cover may also have the conical housing engagement surface formed thereon. The conical surface may comprise an exterior surface of the insert. The fluidic oscillator may comprise: a fluid input; first and second fluid outputs on opposite sides of a longitudinal axis of the fluidic oscillator, whereby a majority of fluid which flows
30 through the fluidic oscillator exits the fluidic oscillator alternately via the first and second fluid outputs; first and second fluid paths from the fluid input to the respective first and

second fluid outputs; and wherein the first and second fluid paths cross each other between the fluid input and the respective first and second fluid outputs.

In a second aspect, the present invention provides a well tool, comprising: a housing assembly; at least one insert received in the housing assembly, the insert having a fluidic oscillator formed on a first surface thereof; the insert being at least partially secured in the housing assembly by engagement of conical second and third surfaces formed on the insert and housing assembly; and a cover which closes off the first surface on the insert.

The first surface may be substantially planar. The conical second and third surfaces may comprise respective exterior and interior surfaces of the insert and housing assembly. The cover may sealingly engage the first surface. The cover may also have the conical second surface formed thereon. The fluidic oscillator may comprise: a fluid input; first and second fluid outputs on opposite sides of a longitudinal axis of the fluidic oscillator, whereby a majority of fluid which flows through the fluidic oscillator exits the fluidic oscillator alternately via the first and second fluid outputs; first and second fluid paths from the fluid input to the respective first and second fluid outputs; and wherein the first and second fluid paths cross each other between the fluid input and the respective first and second fluid outputs.

In a third aspect the present invention provides an insert for use in a well tool, the insert comprising: a conical housing engagement surface; at least one fluidic oscillator formed on a substantially planar surface, and wherein the fluidic oscillator produces oscillations in response to fluid flow through the fluidic oscillator.

A side of the fluidic oscillator may be closed off by engagement between the insert and a cover which engages the substantially planar surface. The cover may sealingly engage the substantially planar surface. The cover may also have the conical housing engagement surface formed thereon. The conical surface may comprise an exterior surface of the insert. The fluidic oscillator may comprise: a fluid input; first and second fluid outputs on opposite sides of a longitudinal axis of the fluidic oscillator, whereby a majority of fluid which flows through the fluidic oscillator exits the fluidic oscillator alternately via the first and second fluid outputs; first and second fluid paths from the fluid input to the respective first and second fluid outputs; and wherein the first and second fluid paths cross each other between the fluid input and the respective first and second fluid outputs.

In the disclosure below, a technique for forming a fluidic oscillator insert is provided which brings improvements to the art. One example is described below in which the insert has a fluidic oscillator formed on a planar surface thereof. Another example is described below in which the insert has a conical housing engagement surface formed thereon.

5 In one aspect, this disclosure provides to the art a method of manufacturing a fluidic oscillator insert for use in a subterranean well. The method can include forming the insert with a conical housing engagement surface thereon, and forming at least one fluidic oscillator on a substantially planar surface of the insert.

In another aspect, this disclosure provides to the art a well tool. The well tool can
10 include a housing assembly, at least one insert received in the housing assembly, the insert having a fluidic oscillator formed on a first surface thereof, the insert being at least partially secured in the housing assembly by engagement of conical second and third surfaces formed on the insert and housing assembly, and a cover which closes off the first surface on the insert.

15 In yet another aspect, a insert for use in a well tool is provided. The insert can include an exterior conical surface, and at least one fluidic oscillator formed on a substantially planar surface. The fluidic oscillator produces oscillations in response to fluid flow through the fluidic oscillator.

These and other features, advantages and benefits will become apparent to one of
20 ordinary skill in the art upon careful consideration of the detailed description of representative examples below and the accompanying drawings, in which similar elements are indicated in the various figures using the same reference numbers.

BRIEF DESCRIPTION OF THE DRAWINGS

25 FIG. 1 is a representative partially cross-sectional view of a well system and associated method which can embody principles of the present disclosure.

FIG. 2 is a representative partially cross-sectional isometric view of a well tool which may be used in the well system and method of FIG. 1.

FIG. 3 is a representative isometric view of an insert which may be used in the well
30 tool of FIG. 2.

FIG. 4 is a representative elevational view of a fluidic oscillator formed in the insert of FIG. 3, which fluidic oscillator can embody principles of this disclosure.

FIGS. 5-10 are additional configurations of the fluidic oscillator.

FIG. 11 is a representative partially cross-sectional view of the well tool.

FIGS. 12A & B are representative isometric views of another configuration of the insert.

5 FIGS. 13A & B are representative isometric views of yet another configuration of the insert.

DETAILED DESCRIPTION

Representatively illustrated in FIG. 1 is a well system 10 and associated method
10 which can embody principles of this disclosure. In this example, a well tool 12 is interconnected in a tubular string 14 installed in a wellbore 16. The wellbore 16 is lined with casing 18 and cement 20. The well tool 12 is used to produce oscillations in flow of fluid 22 injected through perforations 24 into a formation 26 penetrated by the wellbore 16.

The fluid 22 could be steam, water, gas, fluid previously produced from the
15 formation 26, fluid produced from another formation or another interval of the formation 26, or any other type of fluid from any source. It is not necessary, however, for the fluid 22 to be flowed outward into the formation 26 or outward through the well tool 12, since the principles of this disclosure are also applicable to situations in which fluid is produced from a formation, or in which fluid is flowed inwardly through a well tool.

20 Broadly speaking, this disclosure is not limited at all to the one example depicted in FIG. 1 and described herein. Instead, this disclosure is applicable to a variety of different circumstances in which, for example, the wellbore 16 is not cased or cemented, the well tool 12 is not interconnected in a tubular string 14 secured by packers 28 in the wellbore, etc.

Referring additionally now to FIG. 2, an example of the well tool 12 which may be
25 used in the system 10 and method of FIG. 1 is representatively illustrated. However, the well tool 12 could be used in other systems and methods, in keeping with the principles of this disclosure.

The well tool 12 depicted in FIG. 2 has an outer housing assembly 30 with a threaded connector 32 at an upper end thereof. This example is configured for attachment at a lower
30 end of a tubular string, and so there is not another connector at a lower end of the housing assembly 30, but one could be provided if desired.

Secured within the housing assembly 30 are three inserts 34, 36, 38. The inserts 34, 36, 38 produce oscillations in the flow of the fluid 22 through the well tool 12.

More specifically, the upper insert 34 produces oscillations in the flow of the fluid 22 outwardly through two opposing ports 40 (only one of which is visible in FIG. 2) in the housing assembly 30. The middle insert 36 produces oscillations in the flow of the fluid 22 outwardly through two opposing ports 42 (only one of which is visible in FIG. 2). The lower insert 38 produces oscillations in the flow of the fluid 22 outwardly through a port 44 in the lower end of the housing assembly 30.

Of course, other numbers and arrangements of inserts and ports, and other directions of fluid flow may be used in other examples. FIG. 2 depicts merely one example of a possible configuration of the well tool 12.

Referring additionally now to FIG. 3, an enlarged scale view of one example of the insert 34 is representatively illustrated. The insert 34 may be used in the well tool 12 described above, or it may be used in other well tools in keeping with the principles of this disclosure.

The insert 34 depicted in FIG. 3 has a fluidic oscillator 50 machined, molded, cast or otherwise formed therein. In this example, the fluidic oscillator 50 is formed into a generally planar side 52 of the insert 34, and that side is closed off when the insert is installed in the well tool 12, so that the fluid oscillator is enclosed between its fluid input 54 and two fluid outputs 56, 58.

The fluid 22 flows into the fluidic oscillator 50 via the fluid input 54, and at least a majority of the fluid 22 alternately flows through the two fluid outputs 56, 58. That is, the majority of the fluid 22 flows outwardly via the fluid output 56, then it flows outwardly via the fluid output 58, then it flows outwardly through the fluid output 56, then through the fluid output 58, etc., back and forth repeatedly.

In the example of FIG. 3, the fluid outputs 56, 58 are oppositely directed (e.g., facing about 180 degrees relative to one another), so that the fluid 22 is alternately discharged from the fluidic oscillator 50 in opposite directions. In other examples (including some of those described below), the fluid outputs 56, 58 could be otherwise directed.

It also is not necessary for the fluid outputs 56, 58 to be structurally separated as in the example of FIG. 3. Instead, the fluid outputs 56, 58 could be different areas of a larger output opening as in the example of FIG. 7 described more fully below.

Referring additionally now to FIG. 4, The fluidic oscillator 50 is representatively illustrated in an elevational view of the insert 34. However, it should be clearly understood that it is not necessary for the fluid oscillator 50 to be positioned in the insert 34 as depicted in FIG. 4, and the fluidic oscillator could be positioned in other inserts (such as the inserts 5 36, 38, etc.) or in other devices, in keeping with the principles of this disclosure.

The fluid 22 is received into the fluidic oscillator 50 via the inlet 54, and a majority of the fluid flows from the inlet to either the outlet 56 or the outlet 58 at any given point in time. The fluid 22 flows from the inlet 54 to the outlet 56 via one fluid path 60, and the fluid flows from the inlet to the other outlet 58 via another fluid path 62.

10 In one unique aspect of the fluidic oscillator 50, the two fluid paths 60, 62 cross each other at a crossing 65. A location of the crossing 65 is determined by shapes of walls 64, 66 of the fluidic oscillator 50 which outwardly bound the flow paths 60, 62.

When a majority of the fluid 22 flows via the fluid path 60, the well-known Coanda effect tends to maintain the flow adjacent the wall 64. When a majority of the fluid 22 flows 15 via the fluid path 62, the Coanda effect tends to maintain the flow adjacent the wall 66.

A fluid switch 68 is used to alternate the flow of the fluid 22 between the two fluid paths 60, 62. The fluid switch 68 is formed at an intersection between the inlet 54 and the two fluid paths 60, 62.

A feedback fluid path 70 is connected between the fluid switch 68 and the fluid path 20 60 downstream of the fluid switch and upstream of the crossing 65. Another feedback fluid path 72 is connected between the fluid switch 68 and the fluid path 62 downstream of the fluid switch and upstream of the crossing 65.

When pressure in the feedback fluid path 72 is greater than pressure in the other feedback fluid path 70, the fluid 22 will be influenced to flow toward the fluid path 60. 25 When pressure in the feedback fluid path 70 is greater than pressure in the other feedback fluid path 72, the fluid 22 will be influenced to flow toward the fluid path 62. These relative pressure conditions are alternated back and forth, resulting in a majority of the fluid 22 flowing alternately via the fluid paths 60, 62.

For example, if initially a majority of the fluid 22 flows via the fluid path 60 (with 30 the Coanda effect acting to maintain the fluid flow adjacent the wall 64), pressure in the feedback fluid path 70 will become greater than pressure in the feedback fluid path 72. This

will result in the fluid 22 being influenced (in the fluid switch 68) to flow via the other fluid path 62.

When a majority of the fluid 22 flows via the fluid path 62 (with the Coanda effect acting to maintain the fluid flow adjacent the wall 66), pressure in the feedback fluid path 72 will become greater than pressure in the feedback fluid path 70. This will result in the fluid 22 being influenced (in the fluid switch 68) to flow via the other fluid path 60.

Thus, a majority of the fluid 22 will alternate between flowing via the fluid path 60 and flowing via the fluid path 62. Note that, although the fluid 22 is depicted in FIG. 4 as simultaneously flowing via both of the fluid paths 60, 62, in practice a majority of the fluid 22 will flow via only one of the fluid paths at a time.

Note that the fluidic oscillator 50 of FIG. 4 is generally symmetrical about a longitudinal axis 74. The fluid outputs 56, 58 are on opposite sides of the longitudinal axis 74, the feedback fluid paths 70, 72 are on opposite sides of the longitudinal axis, etc.

Referring additionally now to FIG. 5, another configuration of the fluidic oscillator 50 is representatively illustrated. In this configuration, the fluid outputs 56, 58 are not oppositely directed.

Instead, the fluid outputs 56, 58 discharge the fluid 22 in the same general direction (downward as viewed in FIG. 5). As such, the fluidic oscillator 50 of FIG. 5 would be appropriately configured for use in the lower insert 38 in the well tool 12 of FIG. 2.

Referring additionally now to FIG. 6, another configuration of the fluidic oscillator 50 is representatively illustrated. In this configuration, a structure 76 is interposed between the fluid paths 60, 62 just upstream of the crossing 65.

The structure 76 beneficially reduces a flow area of each of the fluid paths 60, 62 upstream of the crossing 65, thereby increasing a velocity of the fluid 22 through the crossing and somewhat increasing the fluid pressure in the respective feedback fluid paths 70, 72.

This increased pressure is alternately present in the feedback fluid paths 70, 72, thereby producing more positive switching of fluid paths 60, 62 in the fluid switch 68. In addition, when initiating flow of the fluid 22 through the fluidic oscillator 50, an increased pressure difference between the feedback fluid paths 70, 72 helps to initiate the desired switching back and forth between the fluid paths 60, 62.

Referring additionally now to FIG. 7, another configuration of the fluidic oscillator 50 is representatively illustrated. In this configuration, the fluid outputs 56, 58 are not separated by any structure.

However, a majority of the fluid 22 will exit the fluidic oscillator 50 of FIG. 7 via either the fluid path 60 or the fluid path 62 at any given time. Therefore, the fluid outputs 56, 58 are defined by the regions of the fluidic oscillator 50 via which the fluid 22 exits the fluidic oscillator along the respective fluid paths 60, 62.

Referring additionally now to FIG. 8, another configuration of the fluidic oscillator is representatively illustrated. In this configuration, the fluid outputs 56, 58 are oppositely directed, similar to the configuration of FIG. 4, but the structure 76 is interposed between the fluid paths 60, 62, similar to the configuration of FIGS. 6 & 7.

Thus, the FIG. 8 configuration can be considered a combination of the FIGS. 4, 6 & 7 configurations. This demonstrates that any of the features of any of the configurations described herein can be used in combination with any of the other configurations, in keeping with the principles of this disclosure.

Referring additionally now to FIG. 9, another configuration of the fluidic oscillator 50 is representatively illustrated. In this configuration, another structure 78 is interposed between the fluid paths 60, 62 downstream of the crossing 65.

The structure 78 reduces the flow areas of the fluid paths 60, 62 just upstream of a fluid path 80 which connects the fluid paths 60, 62. The velocity of the fluid 22 flowing through the fluid paths 60, 62 is increased due to the reduced flow areas of the fluid paths.

The increased velocity of the fluid 22 flowing through each of the fluid paths 60, 62 can function to draw some fluid from the other of the fluid paths. For example, when a majority of the fluid 22 flows via the fluid path 60, its increased velocity due to the presence of the structure 78 can draw some fluid through the fluid path 80 into the fluid path 60. When a majority of the fluid 22 flows via the fluid path 62, its increased velocity due to the presence of the structure 78 can draw some fluid through the fluid path 80 into the fluid path 62.

It is possible that, properly designed, this can result in more fluid being alternately discharged from the fluid outputs 56, 58 than fluid 22 being flowed into the input 54. Thus, fluid can be drawn into one of the outputs 56, 58 while fluid is being discharged from the other of the outputs.

Referring additionally now to FIG. 10, another configuration of the fluidic oscillator 50 is representatively illustrated. In this configuration, computational fluid dynamics modeling has shown that a flow rate of fluid discharged from one of the outputs 56, 58 can be greater than a flow rate of fluid 22 directed into the input 54.

5 Fluid can be drawn from one of the outputs 56, 58 to the other output via the fluid path 80. Thus, fluid can enter one of the outputs 56, 58 while fluid is being discharged from the other output.

This is due in large part to the increased velocity of the fluid 22 caused by the structure 78 (e.g., the increased velocity of the fluid in one of the fluid paths 60, 62 causes
10 eduction of fluid from the other of the fluid paths 60, 62 via the fluid path 80). At the intersections between the fluid paths 60, 62 and the respective feedback fluid paths 70, 72, pressure can be significantly reduced due to the increased velocity, thereby reducing pressure in the respective feedback fluid paths.

In the FIG. 10 example, a reduction in pressure in the feedback fluid path 70 will
15 influence the fluid 22 to flow via the fluid path 62 from the fluid switch 68 (due to the relatively higher pressure in the other feedback fluid path 72). Similarly, a reduction in pressure in the feedback fluid path 72 will influence the fluid 22 to flow via the fluid path 60 from the fluid switch 68 (due to the relatively higher pressure in the other feedback fluid path 70).

20 One difference between the FIGS. 9 & 10 configurations is that, in the FIG. 10 configuration, the feedback fluid paths 70, 72 are connected to the respective fluid paths 60, 62 downstream of the crossing 65. Computational fluid dynamics modeling has shown that this arrangement produces desirably low frequency oscillations of flow from the outputs 56, 58, although such low frequency oscillations are not necessary in keeping with the principles
25 of this disclosure.

Referring additionally now to FIG. 11, another configuration of the well tool 12 is representatively illustrated. In this configuration, the housing assembly 30 has an upper connector 32 for interconnecting the well tool 12 at a lower end of the tubular string 14 (as in the configuration of FIG. 2). In other examples, the housing assembly 30 could be
30 configured for connection between other components of the tubular string 14 (e.g., with connectors 32 at both of its opposite ends).

In the configuration of FIG. 11, the inserts 34, 36 are similarly constructed, in that each is arranged to discharge the fluid 22 laterally outward. The insert 38 is configured to discharge the fluid 22 in alternating somewhat downward directions. In other examples, the inserts may not differ from each other, other numbers of inserts (including one) may be used, etc.

In one unique aspect of the well tool 12, an exterior conical housing engagement surface 80 is formed on each of the inserts 34, 36, 38. The conical surfaces 80 engage respective interior conical surfaces 82 formed in the housing assembly 30.

The engagement between the conical surfaces 80, 82 is enhanced by pressure differentials longitudinally across the inserts 34, 36, 38 due to flow of the fluid 22 through the well tool 12, thereby further securing the inserts in the housing assembly. The use of conical surfaces 80, 82 also provides for convenient assembly of the well tool 12.

Note that the term "conical" is used herein to indicate a surface which is at least partially in the form of a cone. The surfaces 80, 82 are more precisely frusto-conical in form, and so it should be understood that the term "conical" as used herein encompasses frusto-conical surfaces.

The fluidic oscillators 50 are formed on a substantially planar surface 84 of each insert 34, 36, 38. A cover 86 encloses each of the fluidic oscillators 50 by closing off an outer side of the fluidic oscillator. However, it is not necessary for the cover 86 to fully sealingly engage the planar surface 84 (for example, partial sealing engagement could be adequate in some examples, etc.).

Referring additionally now to FIGS. 12A & B, one of the inserts 38 is representatively illustrated apart from the remainder of the well tool 12. In this view, it may be clearly seen that one fluidic oscillator 50 is formed on the planar surface 84. However, the insert 38 can have any number of fluidic oscillators 50 formed thereon in keeping with the principles of this disclosure.

The fluidic oscillator 50 depicted in FIG. 12A is of the FIG. 5 configuration. However, any type, or combination of types, of fluidic oscillators 50 may be used in other examples.

The cover 86 has the conical surface 80 formed thereon, so that the cover "completes" the conical exterior surface of the insert 38. Together, the insert 38 with the

cover 86 fully engage the surface 82 formed in the housing assembly 30 to secure the insert 38 therein.

Referring additionally now to FIGS. 13A & B, another configuration of the insert 38 is representatively illustrated. In this configuration, the cover 86 does not have the conical surface 80 formed thereon, but is instead in the shape of a flat plate. This demonstrates that a variety of different configurations may be used, in keeping with the principles of this disclosure.

In other examples, a longitudinal flow passage can be provided in the inserts 34, 36 to allow the fluid 22 to flow past the inserts to other inserts downstream, without flowing through the fluidic oscillators 50.

It can now be fully appreciated that the above disclosure provides several advancements to the art of manufacturing fluidic oscillator inserts. The inserts 34, 36, 38 described above allow for convenient assembly into the housing assembly 30 of the well tool 12, and allow for the fluidic oscillators 50 to be formed on each insert using conventional machining techniques (such a milling, etc.). In the configurations of FIGS. 11-13A, the fluidic oscillators 50 can be conveniently machined into the planar surfaces 84.

The above disclosure provides to the art a method of manufacturing a fluidic oscillator insert 38 for use in a subterranean well. The method can include forming the insert 38 with a conical housing engagement surface 80 thereon, and forming at least one fluidic oscillator 50 on a substantially planar surface 84 of the insert 38.

A side of the fluidic oscillator 50 may be closed off by engagement between the insert 38 and a cover 86 which engages the substantially planar surface 84. The cover 86 may sealingly engage the substantially planar surface 84. The cover 86 may also have the conical housing engagement surface 80 formed thereon.

The conical surface 80 may comprise an exterior surface of the insert 38.

Also provided by the above disclosure is a well tool 12 which may comprise a housing assembly 30, at least one insert 38 received in the housing assembly 30, the insert 38 having a fluidic oscillator 50 formed on a first surface 84 thereof, the insert 38 being at least partially secured in the housing assembly 30 by engagement of conical second and third surfaces 80, 82 formed on the insert 38 and housing assembly 30, and a cover 86 which closes off the first surface 84 on the insert 38.

The first surface 84 can be substantially planar.

The conical second and third surfaces 80, 82 may comprise respective exterior and interior surfaces of the insert 38 and housing assembly 30.

Also described above is an insert 38 for use in a well tool 12. The insert 38 can comprise a conical housing engagement surface 80, and at least one fluidic oscillator 50
5 formed on a substantially planar surface 84. The fluidic oscillator 50 produces oscillations in response to fluid 22 flow through the fluidic oscillator 50.

The fluidic oscillator 50 can include a fluid input 54, and first and second fluid outputs 56, 58 on opposite sides of a longitudinal axis 74 of the fluidic oscillator 50, whereby a majority of fluid 22 which flows through the fluidic oscillator 50 exits the fluidic
10 oscillator 50 alternately via the first and second fluid outputs 56, 58. The fluidic oscillator 50 can also include first and second fluid paths 60, 62 from the input 54 to the respective first and second fluid outputs 56, 58, with the first and second fluid paths 60, 62 crossing each other between the fluid input 54 and the respective first and second fluid outputs 56, 58.

15 It is to be understood that the various examples described above may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present disclosure. The embodiments illustrated in the drawings are depicted and described merely as examples of useful applications of the principles of the disclosure, which are not limited to any specific
20 details of these embodiments.

In the above description of the representative examples of the disclosure, directional terms, such as "above," "below," "upper," "lower," etc., are used for convenience in referring to the accompanying drawings.

Of course, a person skilled in the art would, upon a careful consideration of the above
25 description of representative embodiments, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to these specific embodiments, and such changes are within the scope of the principles of the present disclosure. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the present
30 invention being limited solely by the appended claims and their equivalents.

CLAIMS:

1. A method of manufacturing a fluidic oscillator insert for use in a subterranean well, the method comprising:

forming the insert with a conical housing engagement surface thereon; and

5 forming at least one fluidic oscillator on a substantially planar surface of the insert.

2. A method according to claim 1, wherein a side of the fluidic oscillator is closed off by engagement between the insert and a cover which engages the substantially planar surface.

3. A method according to claim 2, wherein the cover sealingly engages the
10 substantially planar surface.

4. A method according to claim 2 or 3, wherein the cover also has the conical housing engagement surface formed thereon.

5. A method according to any preceding claim, wherein the conical surface comprises an exterior surface of the insert.

15 6. A method according to any preceding claim, wherein the fluidic oscillator comprises:

a fluid input;

first and second fluid outputs on opposite sides of a longitudinal axis of the fluidic oscillator, whereby a majority of fluid which flows through the fluidic oscillator exits the
20 fluidic oscillator alternately via the first and second fluid outputs;

first and second fluid paths from the fluid input to the respective first and second fluid outputs; and

wherein the first and second fluid paths cross each other between the fluid input and the respective first and second fluid outputs.

25 7. A well tool, comprising:

a housing assembly;

at least one insert received in the housing assembly, the insert having a fluidic oscillator formed on a first surface thereof;

the insert being at least partially secured in the housing assembly by engagement of
30 conical second and third surfaces formed on the insert and housing assembly; and

a cover which closes off the first surface on the insert.

8. A well tool according to claim 7, wherein the first surface is substantially planar.

9. A well tool according to claim 7 or 8, wherein the conical second and third surfaces comprise respective exterior and interior surfaces of the insert and housing
5 assembly.

10. A well tool according to any one of claims 7 to 9, wherein the cover sealingly engages the first surface.

11. A well tool according to any one of claims 7 to 10, wherein the cover also has the conical second surface formed thereon.

10 12. A well tool according to any one of claims 7 to 11, wherein the fluidic oscillator comprises:

a fluid input;

first and second fluid outputs on opposite sides of a longitudinal axis of the fluidic oscillator, whereby a majority of fluid which flows through the fluidic oscillator exits the
15 fluidic oscillator alternately via the first and second fluid outputs;

first and second fluid paths from the fluid input to the respective first and second fluid outputs; and

wherein the first and second fluid paths cross each other between the fluid input and the respective first and second fluid outputs.

20 13. An insert for use in a well tool, the insert comprising:

a conical housing engagement surface;

at least one fluidic oscillator formed on a substantially planar surface, and

wherein the fluidic oscillator produces oscillations in response to fluid flow through the fluidic oscillator.

25 14. An insert according to claim 13, wherein a side of the fluidic oscillator is closed off by engagement between the insert and a cover which engages the substantially planar surface.

15. An insert according to claim 14, wherein the cover sealingly engages the substantially planar surface.

30 16. An insert according to claim 14 or 15, wherein the cover also has the conical housing engagement surface formed thereon.

17. An insert according to any one of claims 13 to 16, wherein the conical surface comprises an exterior surface of the insert.

18. An insert according to any one of claims 13 to 17, wherein the fluidic oscillator comprises:

5 a fluid input;

first and second fluid outputs on opposite sides of a longitudinal axis of the fluidic oscillator, whereby a majority of fluid which flows through the fluidic oscillator exits the fluidic oscillator alternately via the first and second fluid outputs;

10 first and second fluid paths from the fluid input to the respective first and second fluid outputs; and

wherein the first and second fluid paths cross each other between the fluid input and the respective first and second fluid outputs.

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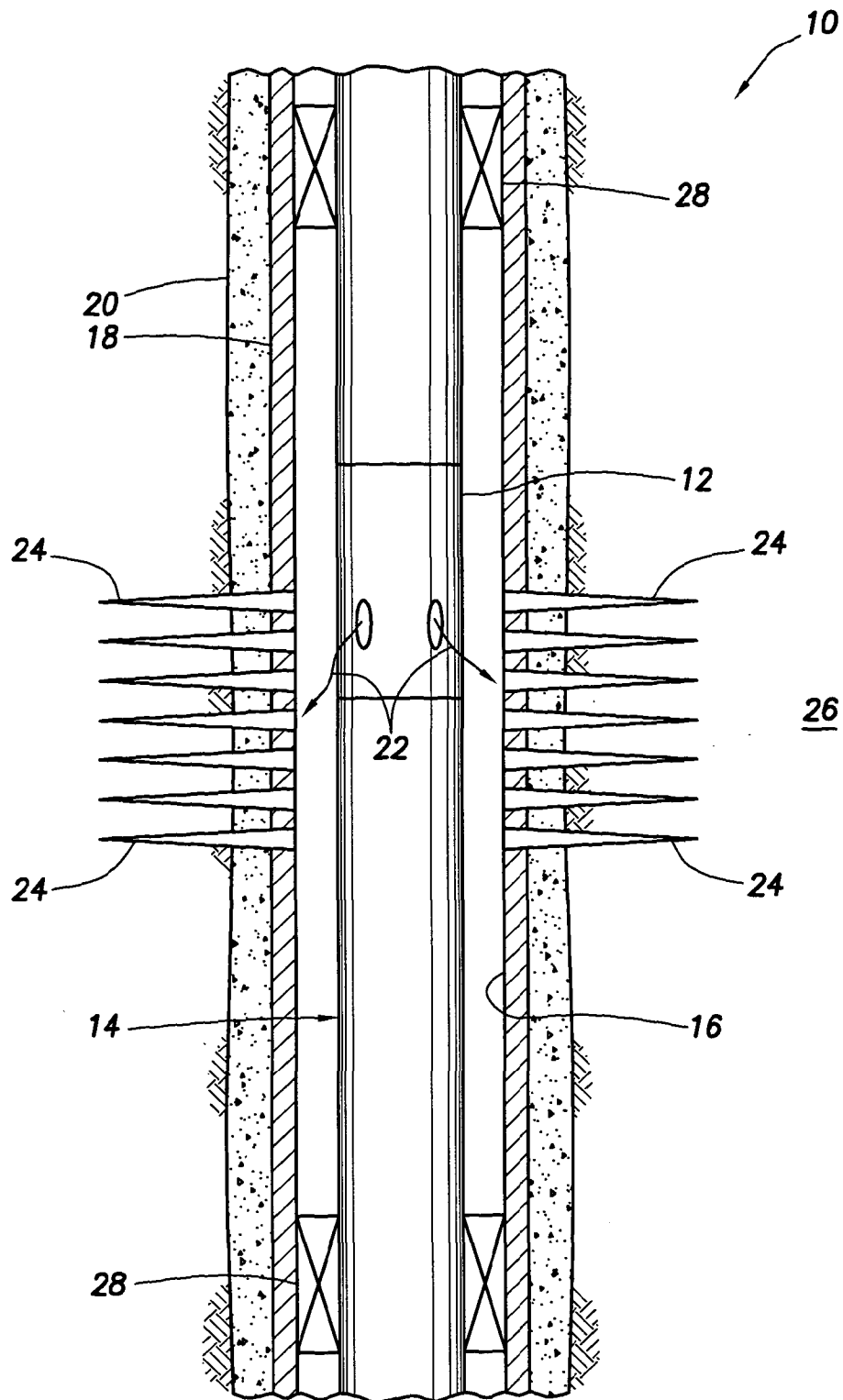
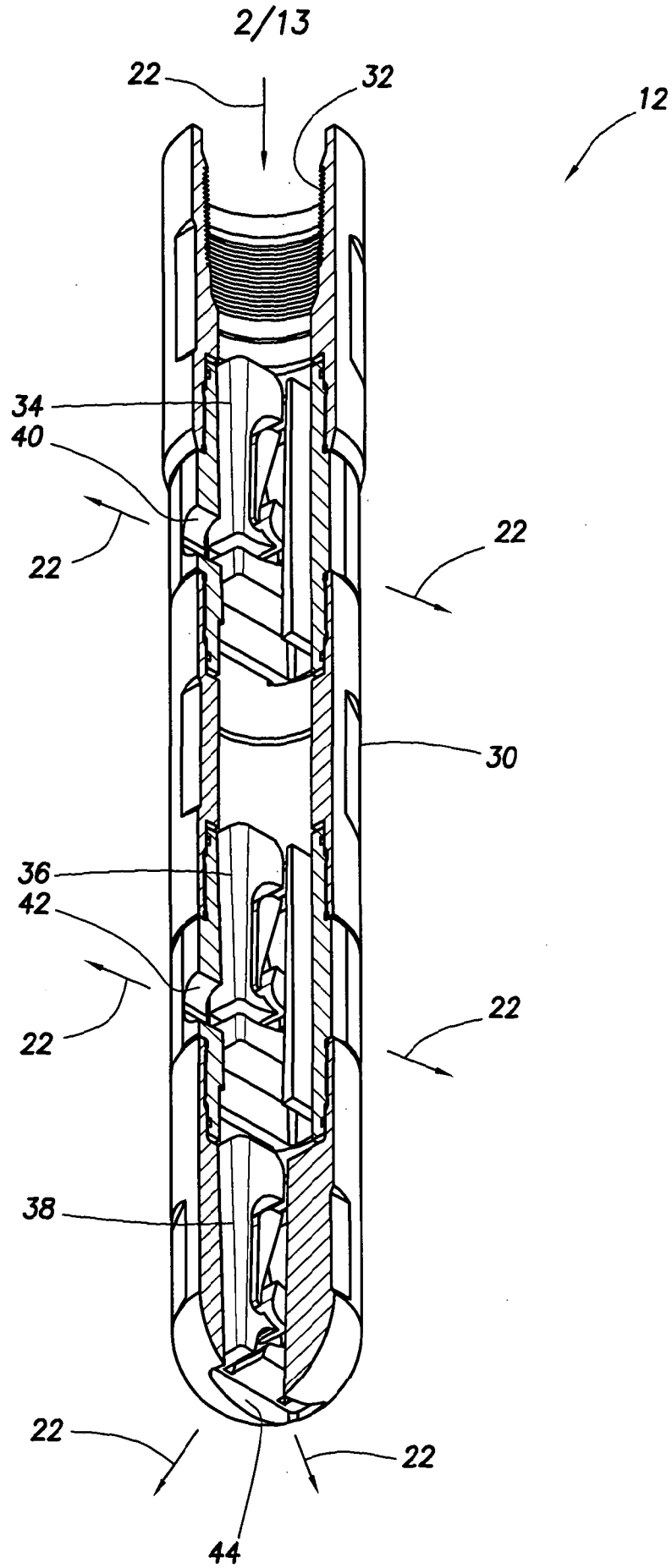


FIG. 1

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FIG.2



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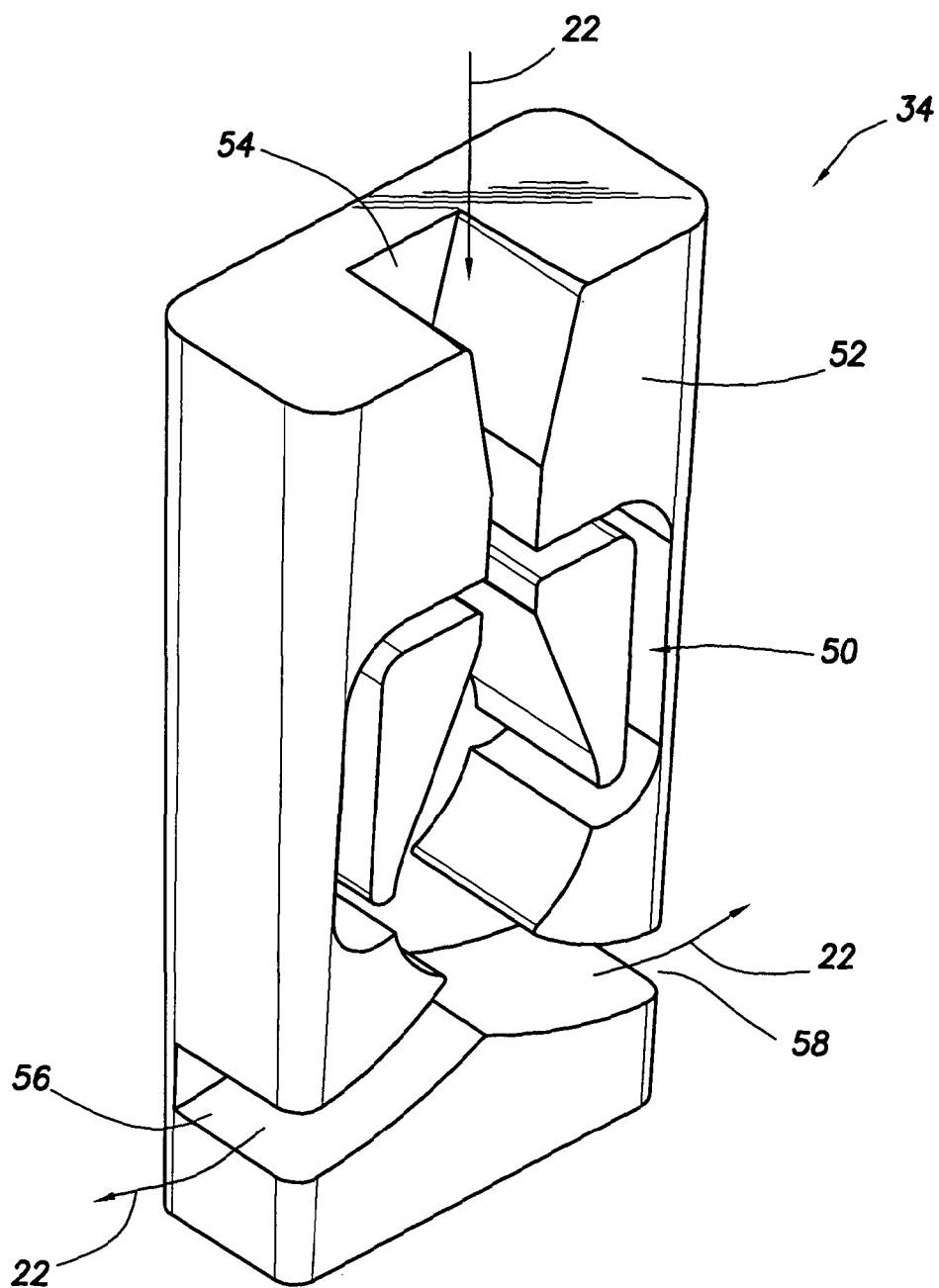


FIG.3

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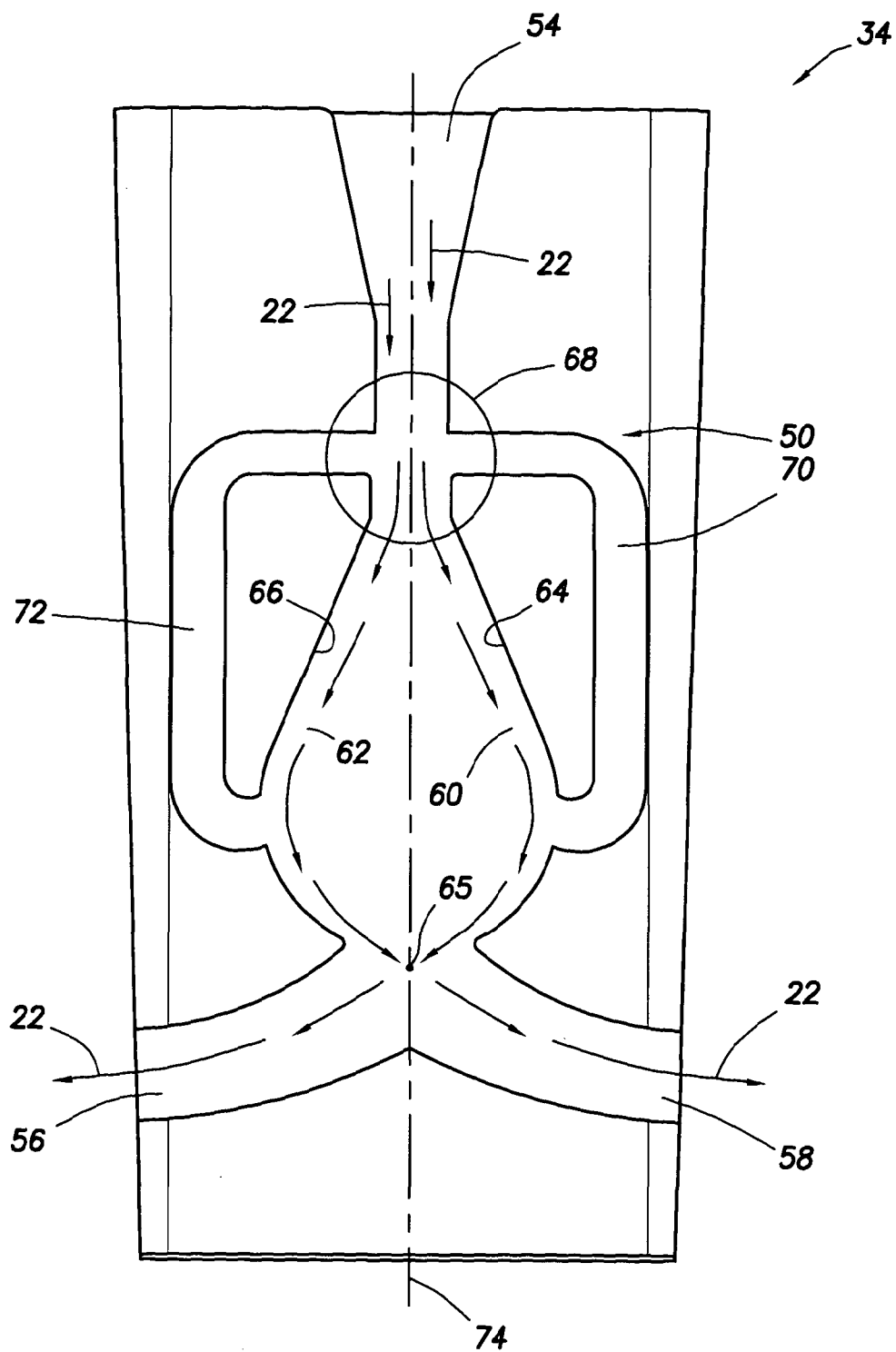


FIG. 4

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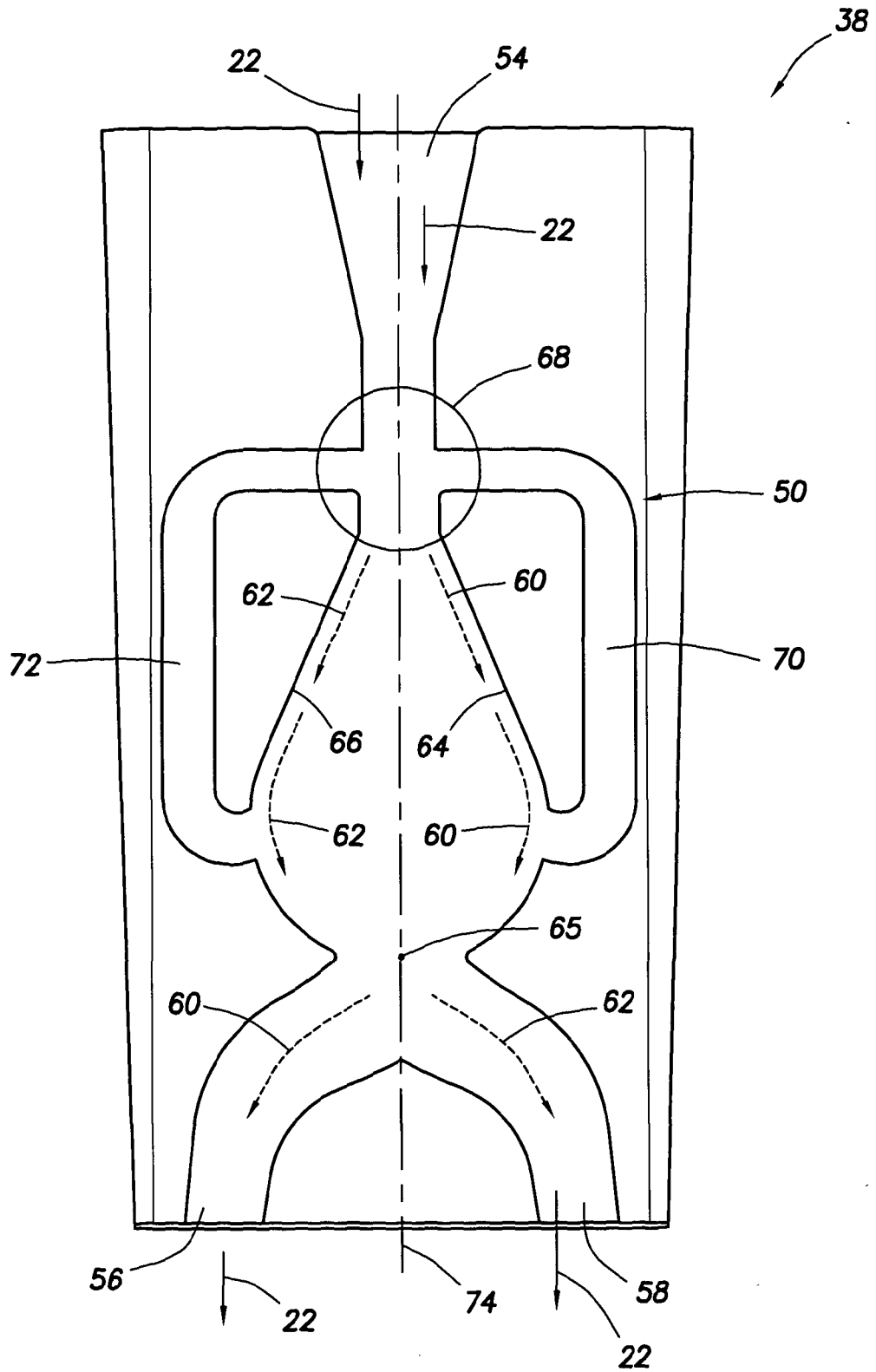


FIG.5

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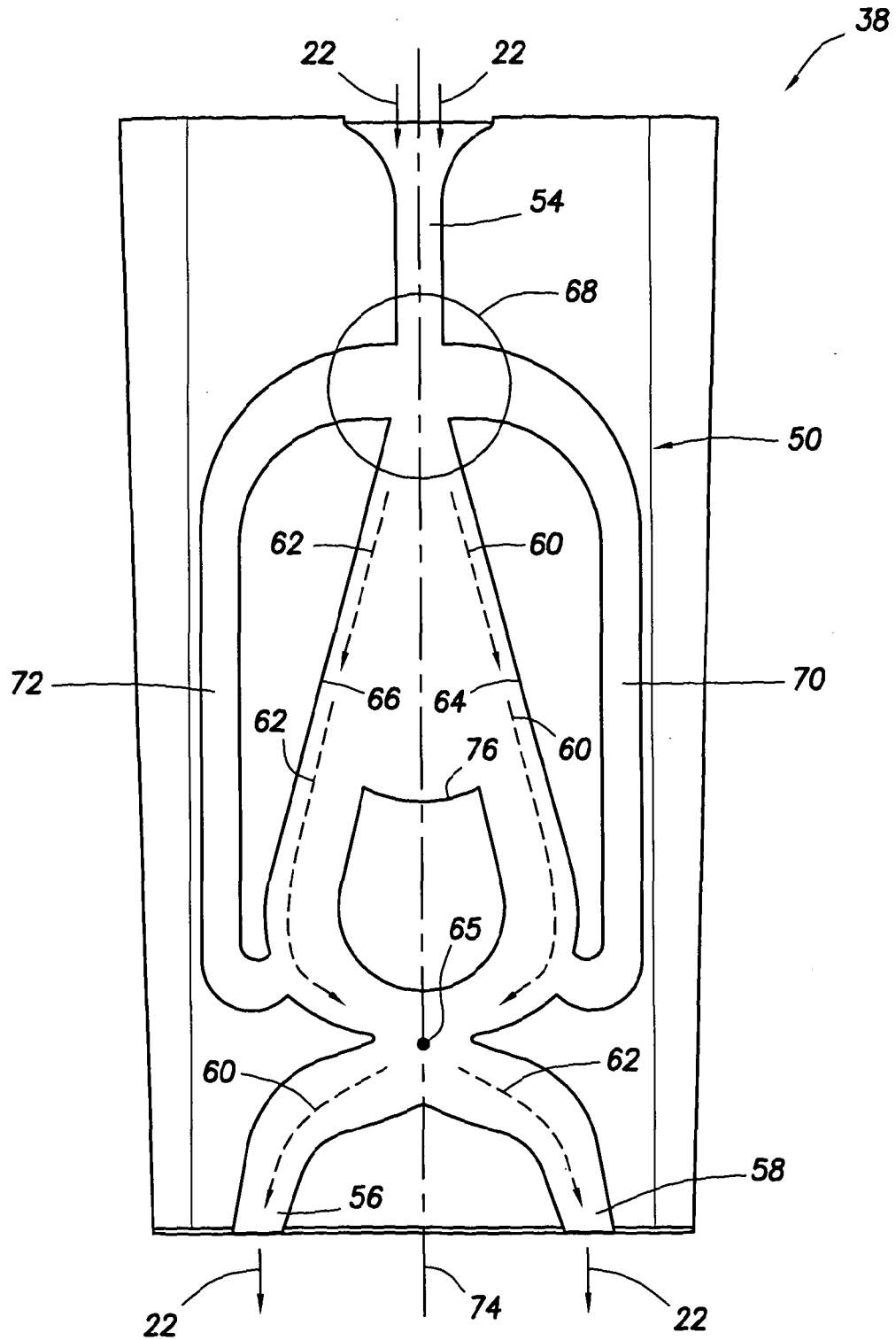


FIG. 6

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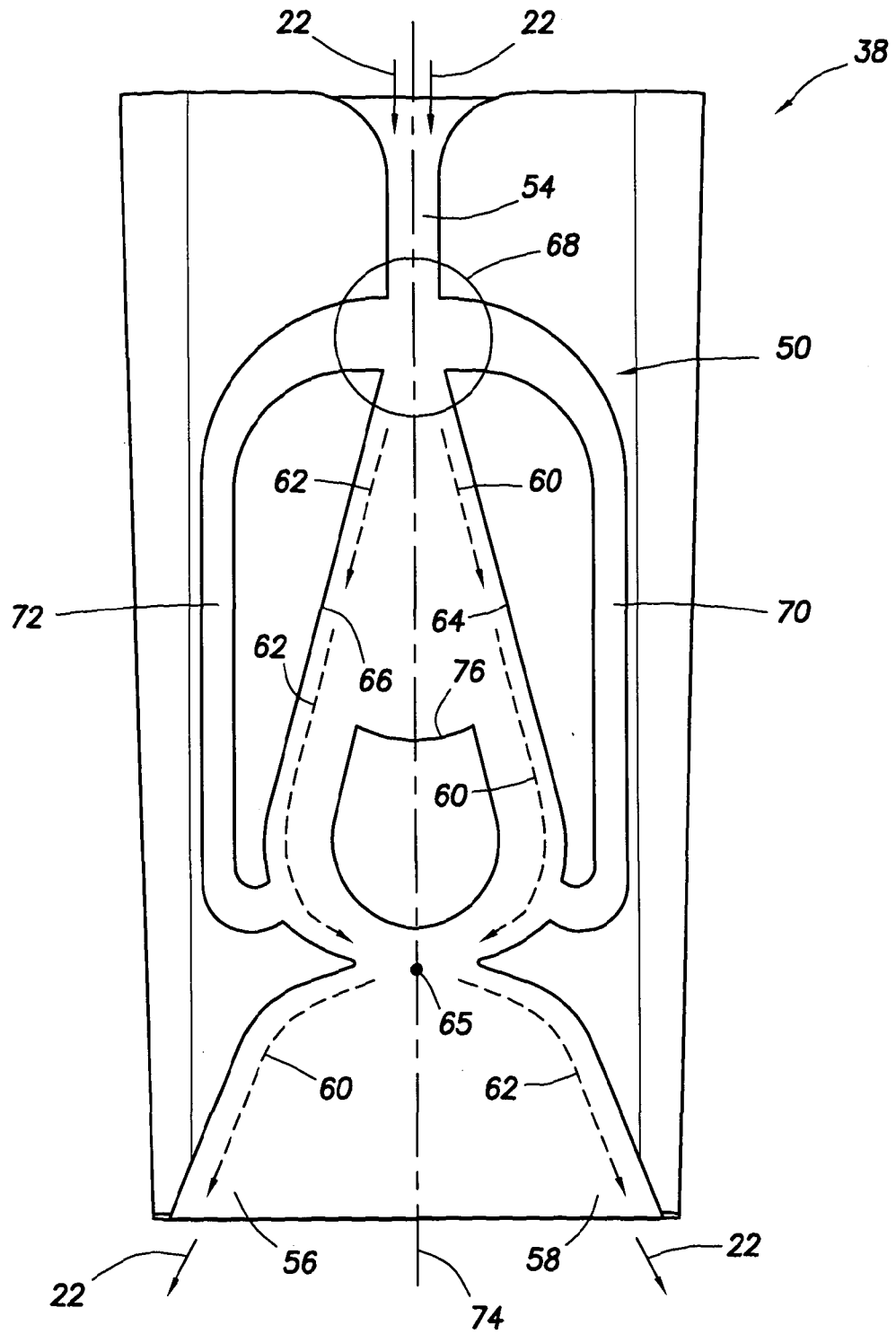


FIG. 7

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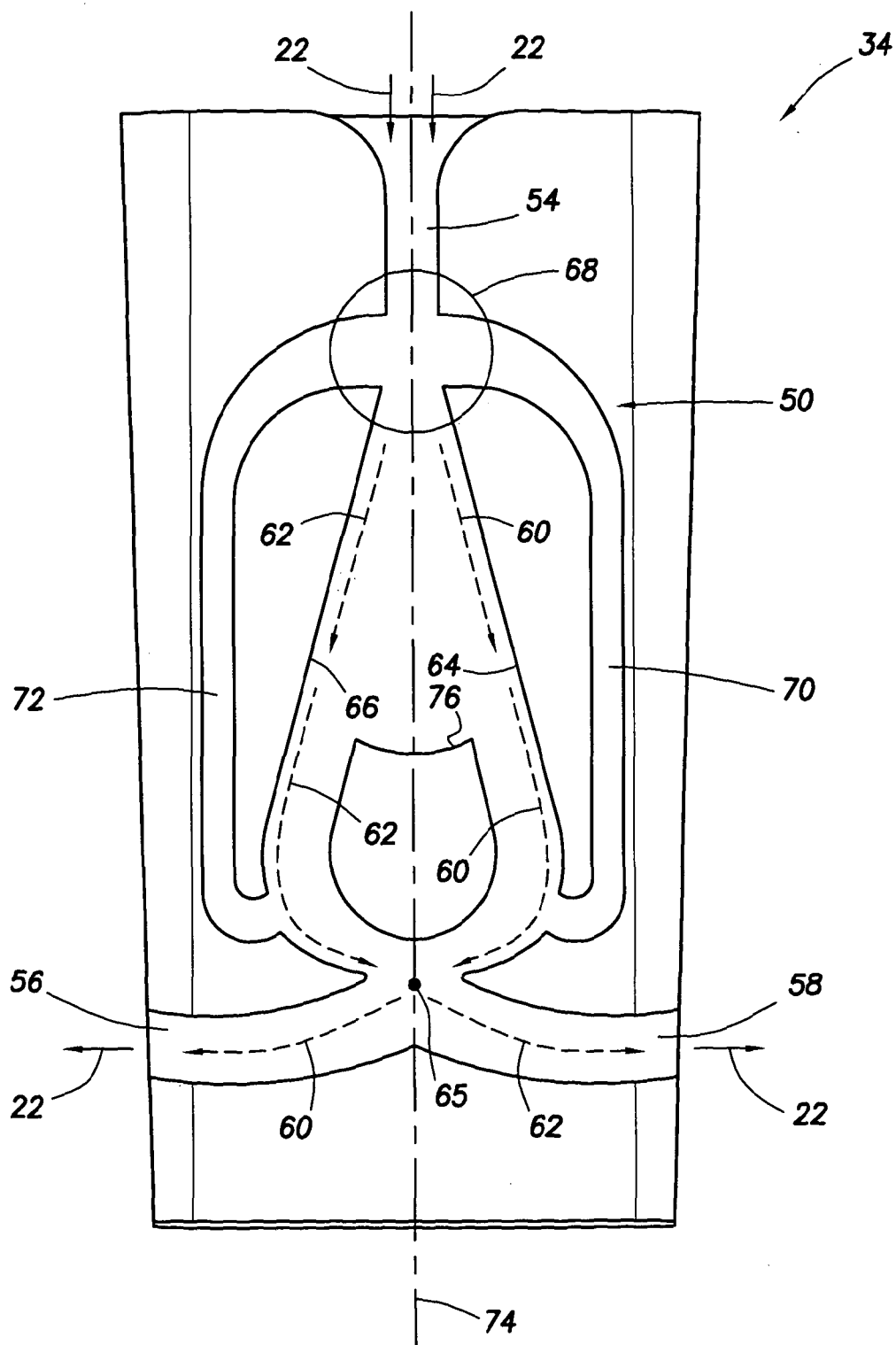


FIG. 8

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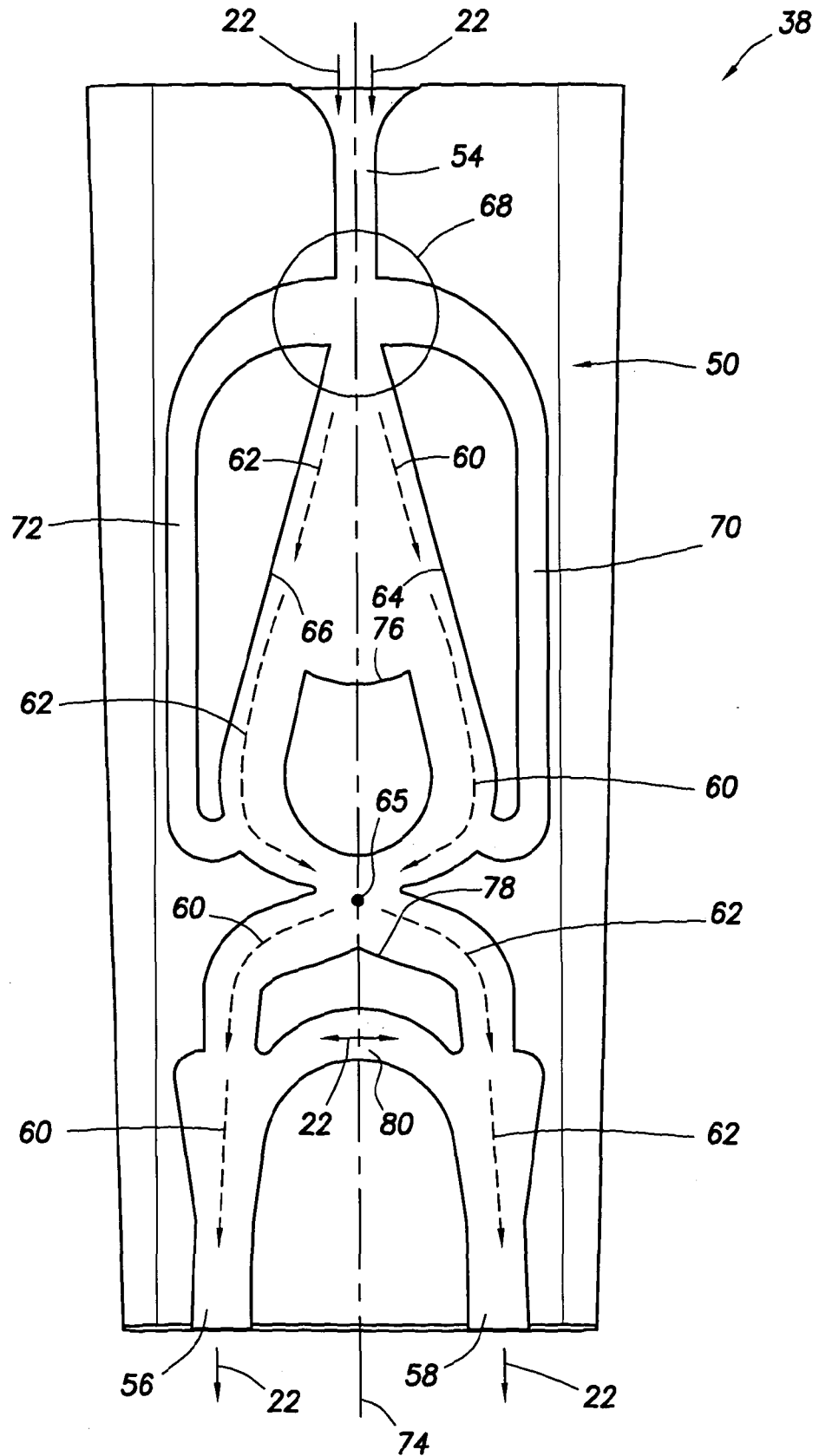


FIG. 9

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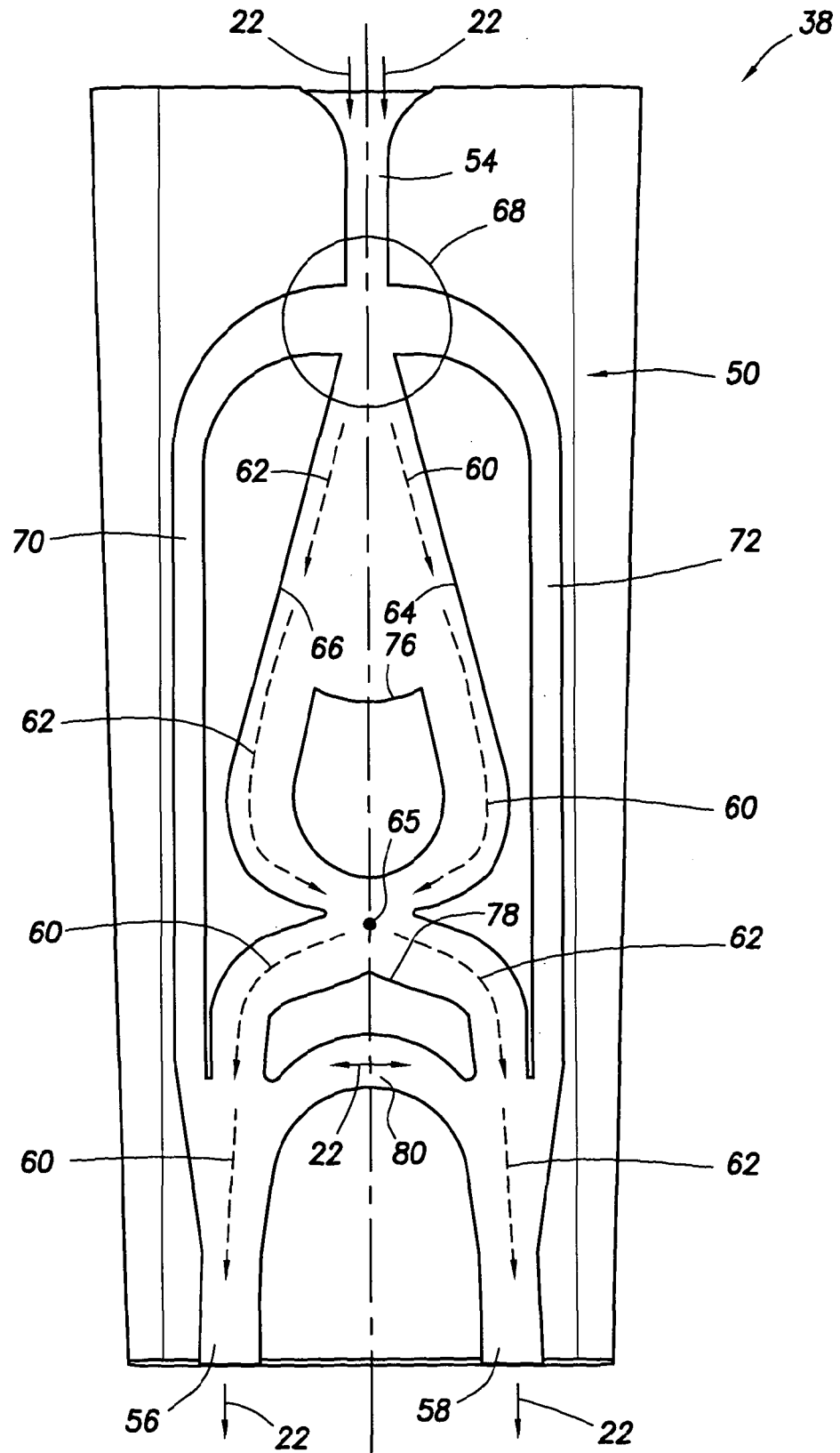


FIG. 10

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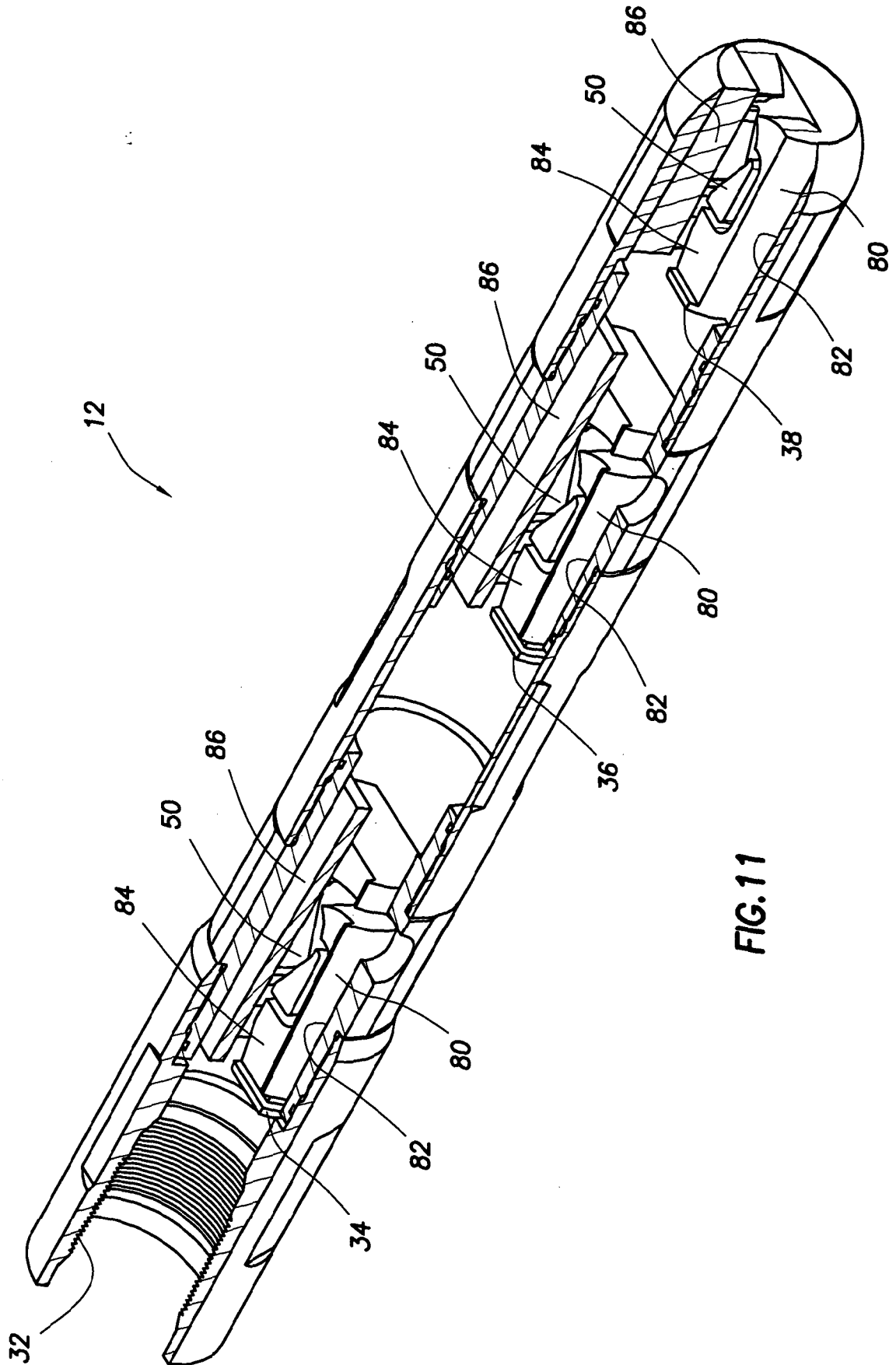


FIG. 11

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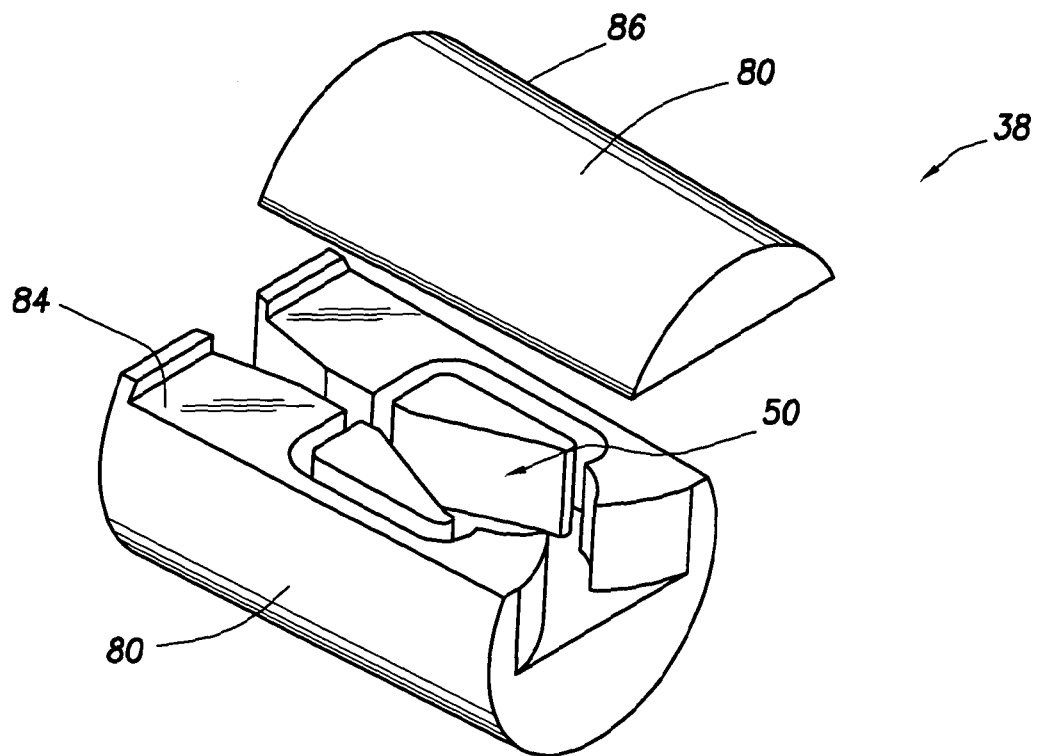


FIG. 12A

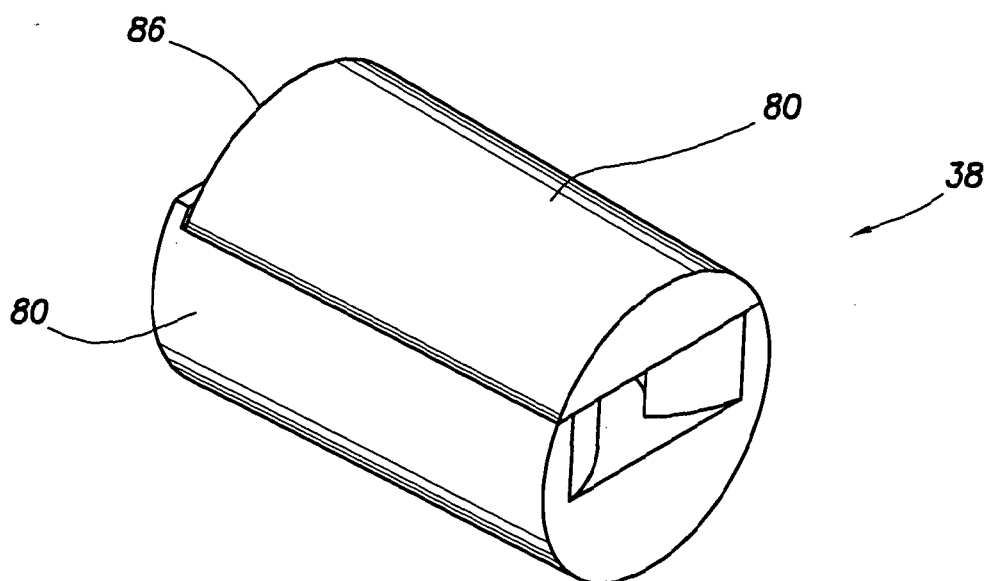


FIG. 12B

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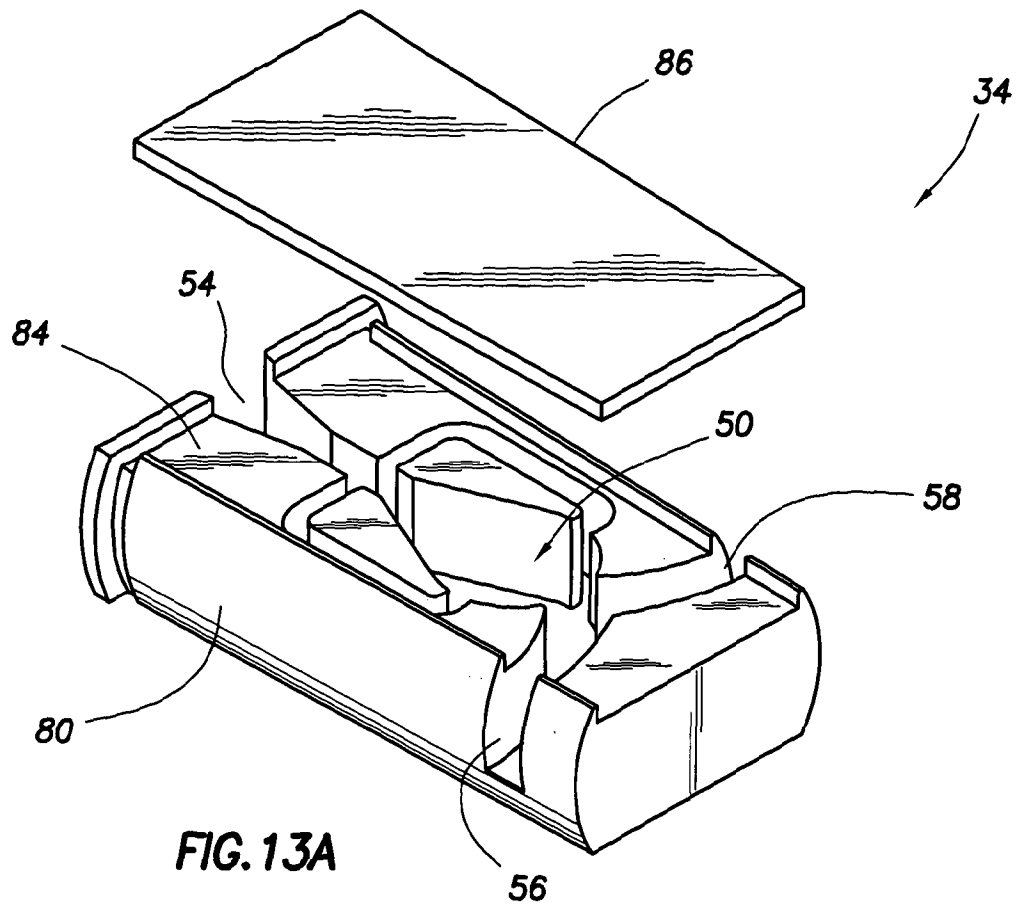


FIG. 13A

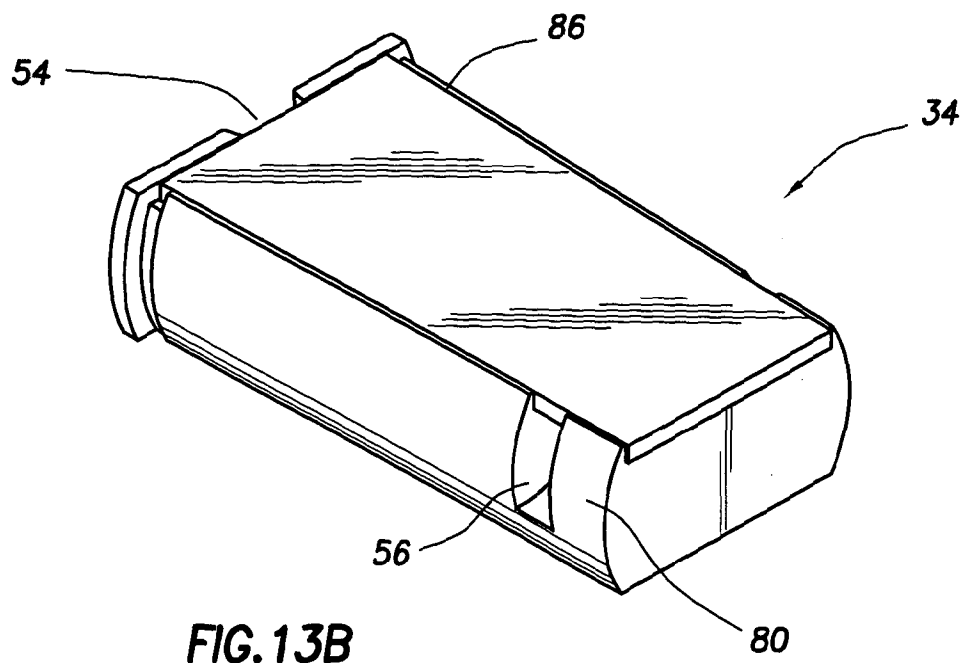


FIG. 13B

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