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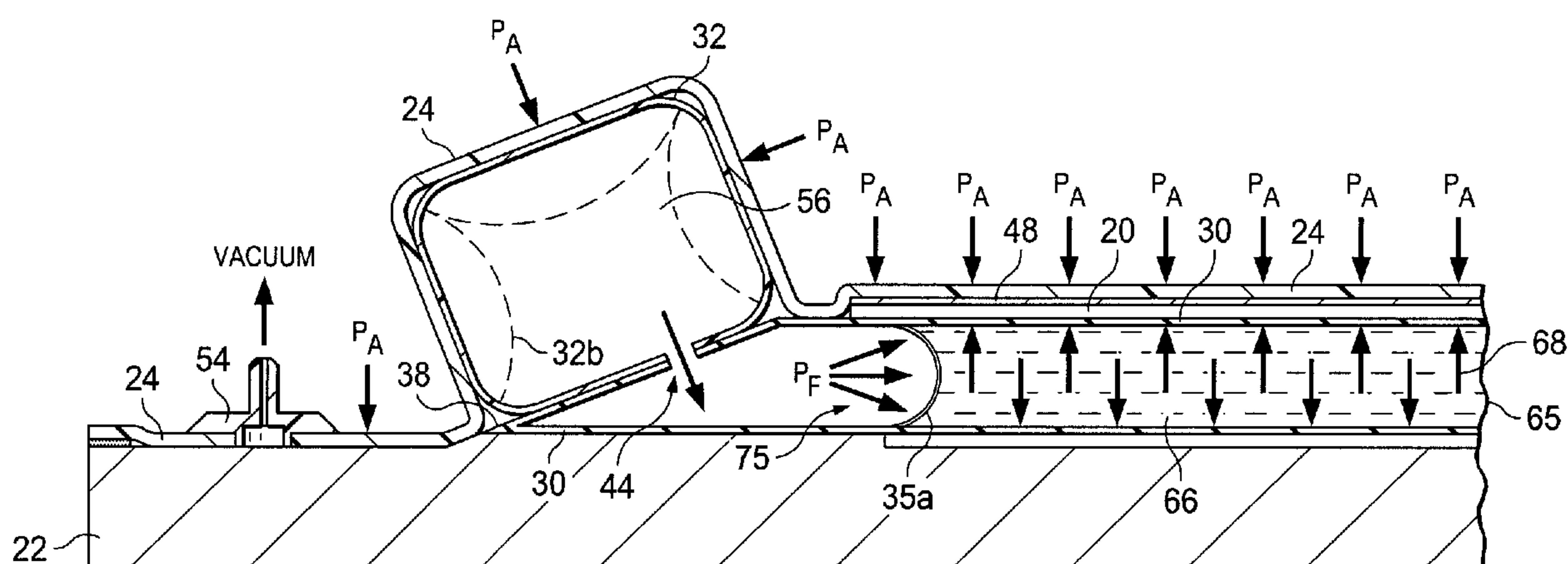
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(57) Abrégé/Abstract:

A composite part charge having an internal cavity is placed on a tool and covered by a vacuum bag for autoclave curing. A bladder is placed in the cavity to react autoclave pressure on the charge. The bladder is coupled with a flexible fluid reservoir located beneath the vacuum bag. The bladder is pressurized by autoclave pressure applied through the vacuum bag to the flexible fluid reservoir.

ABSTRACT

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A composite part charge having an internal cavity is placed on a tool and covered by a vacuum bag for autoclave curing. A bladder is placed in the cavity to react autoclave pressure on the charge. The bladder is coupled with a flexible fluid reservoir located beneath the vacuum bag. The bladder is pressurized by autoclave pressure applied through the vacuum bag to the flexible fluid reservoir.

NON-VENTED BLADDER SYSTEM FOR CURING COMPOSITE PARTS**BACKGROUND INFORMATION**

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1. Field:

The present disclosure generally relates to methods and equipment for fabricating composite resin parts, and deals more particularly with a bladder system used in curing composite parts within an autoclave.

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2. Background:

Composite resin parts may be cured within an autoclave that applies heat and pressure to the part during a cure cycle. Some part geometries include internal cavities that may cause the part to collapse under autoclave pressure unless a tool such as an inflatable bladder is placed in the cavity to react the autoclave pressure force applied to the part. For example, in the aircraft industry, inflatable bladders may be inserted into the cavities of composite stringer layups that are autoclave cured on mandrel-like cure tools. These bladders are pressurized by venting them to the autoclave pressure.

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There are several problems with the vented bladders described above that may lead to inconsistencies in the cured parts. For example, failure to properly vent the bladder may prevent the bladder from becoming pressurized sufficiently to react the applied autoclave pressures. Similarly, insufficient bladder pressurization may result from the failure of sealant tape used to seal a vent hole coupling the bladder with an outside vent. It is also possible for a bladder wall to fail or be penetrated, in which event autoclave gases may be forced into the part throughout the cure cycle. These issues may be particularly problematic where a relatively large number of stringers are cocured at the same time with other parts. For example, where a number of stringers are cocured with a fuselage skin, each of the bladders placed in the stringers is a potential source of leakage into the cocured structure that may cause the entire structure to be scrapped or extensively reworked.

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Accordingly, there is a need for a non-vented bladder system that may reduce or eliminate the adverse effects resulting from leaks in the bladder or failure to properly pressurize

the bladder. There is also a need for a bladder system and curing method that does not require venting to autoclave pressure, and which may eliminate the need for bladder vent hole seals.

SUMMARY

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The disclosed embodiments provide a non-vented bladder system that may substantially reduce or eliminate inconsistencies in cured parts due to bladder leakage, seal leakage and/or or failure of a bladder to properly vent to autoclave pressures. The disclosed system may reduce product scrap and/or the need for rework. Additionally, the disclosed method and non-vented bladder system may reduce labor costs and improve production flow. The embodiments eliminate the need for use of a sealant tape around a vent hole in the bladder. A fluid reservoir is permanently attached to the bladder vent hole and is sealed beneath a vacuum bag, thereby eliminating leak paths around the bladder vent. The reservoir pressurizes the bladder cavity when the autoclave is pressurized. In the event of a leak in the bladder, only the volume of the bladder is leaked into the part.

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According to one disclosed embodiment, apparatus is provided for use in autoclave curing of a composite part charge having an internal cavity. The apparatus comprises a flexible bladder adapted to be placed in the cavity for applying pressure on the composite part charge during the curing, and a reservoir of fluid for pressuring the bladder, the reservoir and the bladder being coupled together in a closed system. The apparatus may further comprise a flexible bag sealed over the flexible bladder and the fluid reservoir, wherein the flexible bag is in face-to-face contact with the fluid reservoir and transmits pressure from the autoclave to the fluid reservoir. The apparatus may also comprise a cure tool adapted to have the composite part charge placed thereon, and wherein the fluid reservoir is located on the cure tool and the flexible bag is sealed to the cured tool. The fluid reservoir is flexible. The bladder includes a vent hole, and a portion of the fluid reservoir is attached to the bladder and includes a fluid outlet coupled with the vent hole in the bladder. The fluid reservoir may include a vacuum port sealed beneath the flexible bag adapted to be coupled with a vacuum source for selectively relieving pressure within the fluid reservoir after the composite charge has been cured. The bladder includes a septum forming an interior chamber within the bladder, and a fill material filling the interior chamber which has a density that is sufficient to stiffen the bladder when the

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bladder is pressured by fluid from the fluid reservoir. The septum includes a flexible side that is exposed to fluid from the fluid reservoir. The flexible side flexes to apply pressure to the fill material when the fluid reservoir pressurizes the bladder.

According to another disclosed embodiment, a non-vented bladder system is provided for use in autoclave curing a composite part charge. The non-vented bladder system comprises a bladder adapted to apply pressure to the composite part charge, and a flexible fluid reservoir adapted to contain a quantity of fluid and compressible by pressure applied by the autoclave for supplying fluid pressure to the bladder, wherein the fluid reservoir is coupled with the bladder in a closed fluid system that is not vented to the autoclave. The fluid reservoir is attached to the bladder. The fluid reservoir includes a fluid outlet, and the bladder includes a vent hole coupled with the fluid outlet. The bladder includes flexible septum exposed to fluid from the fluid reservoir forming an internal chamber within the bladder, and a fill material within the internal chamber for stiffening the bladder.

In another embodiment, apparatus is provided for applying substantially uniform external air pressure on an uncured part having an internal cavity. The apparatus comprises a tool adapted to have the part placed thereon, a bladder adapted to be placed within the internal cavity and in contact with the part, the bladder being adapted to be pressurized with a fluid, a reservoir of the fluid coupled with the bladder, and a flexible bag sealed to the tool and covering the part, the bladder and the reservoir. The reservoir is attached to the bladder to form a single assembly that may be installed in and removed from the internal cavity. The reservoir includes flexible walls in face-to-face contact with the flexible bag allowing the external pressure to be applied to the reservoir through the flexible bag. The bladder includes fill material for stiffening the bladder, and a septum separating the fill material from the reservoir fluid. The reservoir and the bladder form a closed fluid system that is not vented to the external pressure.

According to still another embodiment, a method is provided of autoclave curing a composite part charge having an internal cavity. The method comprises placing the composite part charge on a tool, installing a bladder within the cavity, coupling the bladder with a reservoir of fluid, sealing a flexible bag over the part and the reservoir, and using the flexible bag to transmit autoclave pressure to the reservoir to force fluid from the reservoir into the bladder. Coupling the bladder with the reservoir includes attaching the bladder to the reservoir

before the bladder is installed in the cavity. Sealing the bag includes sealing the bag to the tool. The method may further comprise stiffening the bladder by filling the bladder with a fill material, and separating the fill material from the fluid by placing a septum in the bladder. The method may also comprise using a vacuum to draw the flexible bag down against sides of the reservoir.

5 According to a further embodiment, a method is provided of autoclave curing a composite part charge having an internal cavity. The method comprises supporting the composite part charge within the autoclave, and pressurizing a bladder within the internal cavity using autoclave pressure to force fluid from a fluid reservoir into the bladder. Using the autoclave pressure to force the fluid from the fluid reservoir into the bladder includes evacuating a vacuum bag sealed over the 10 fluid reservoir, and using the bag to transmit the autoclave pressure to the fluid reservoir.

In accordance with one aspect of the invention there is provided an apparatus for use in autoclave curing of a composite charge having an internal cavity. The apparatus includes a flexible bladder adapted to be placed in the cavity for applying pressure on the composite charge during the curing, and a flexible fluid reservoir for pressuring the bladder in response to a pressure 15 applied to the fluid reservoir, the reservoir and the bladder being coupled together in a closed system.

The apparatus may include a flexible bag sealed over the flexible bladder and the fluid reservoir, and the flexible bag may be in face-to-face contact with the fluid reservoir.

The flexible bag may transmit pressure from the autoclave to the fluid reservoir.

20 The apparatus may include a cure tool adapted to have the composite charge placed thereon, and the fluid reservoir may be located on the cure tool and the flexible bag may be sealed to the cured tool.

The bladder may include a vent hole, and a portion of the fluid reservoir may be attached to the bladder and may include a fluid outlet coupled with the vent hole in the bladder.

25 The reservoir may include a vacuum port adapted to be coupled with a vacuum source for selectively relieving pressure within the fluid reservoir.

The bladder may include a septum forming an interior chamber within the bladder, and a fill material filling the interior chamber and having a density that is sufficient to stiffen the bladder when the bladder is pressured by fluid from the fluid reservoir.

The septum may include a flexible side that is exposed to fluid from the fluid of the fluid reservoir, and the flexible side may flex to apply pressure to the fill material when the fluid reservoir pressurizes the bladder.

In accordance with another aspect of the invention there is provided an apparatus for applying substantially uniform external air pressure on a part having an internal cavity. The apparatus includes a tool adapted to have the part placed thereon, a bladder adapted to be placed within the internal cavity and in contact with the part, and a fluid reservoir coupled with the bladder for supplying pressurized fluid to the bladder in response to a pressure applied to the fluid reservoir. The apparatus also includes a flexible bag sealed to the tool and covering the part, the bladder and the reservoir.

The reservoir may be attached to the bladder to form a single assembly that may be installed in and removed from the internal cavity.

The reservoir may include flexible walls in face-to-face contact with the flexible bag allowing the external pressure to be applied to the reservoir through the flexible bag.

The bladder may include fill material for stiffening the bladder, and a septum separating the fill material from the reservoir fluid.

The reservoir and the bladder may form a closed fluid system that is not vented to the external pressure.

In accordance with another aspect of the invention there is provided a method of autoclave curing a composite charge having an internal cavity. The method involves placing the composite charge on a tool, installing a bladder within the cavity, coupling the bladder with a reservoir of fluid, sealing a flexible bag over the composite charge and the reservoir, and using the flexible bag to transmit autoclave pressure to the reservoir to force fluid from the reservoir into the bladder.

Coupling the bladder with the reservoir may include attaching the bladder to the reservoir before the bladder is installed in the cavity.

Sealing the bag may include sealing the bag to the tool.

The method may involve stiffening the bladder by filling the bladder with a fill material, and separating the fill material from the fluid by placing a septum in the bladder.

5 The method may involve using a vacuum to draw the flexible bag down against sides of the reservoir.

The method may involve removing the flexible bag from the composite charge and the reservoir after the composite charge has been cured, and relieving pressure within the bladder by porting the reservoir to a vacuum source after the flexible bag has been removed.

The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

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The novel features believed characteristic of the advantageous embodiments are set forth in the appended claims. The advantageous embodiments, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an advantageous embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is an illustration of a functional block diagram of a non-vented bladder system according to the disclosed embodiments.

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FIG. 2 is an illustration of a perspective view of a composite resin stringer cured using the non-vented bladder system shown in FIG. 1.

FIG. 3 is an illustration of a perspective view of a cure tool used in curing a composite stringer charge.

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FIG. 4 is an illustration similar to FIG. 3 but showing a stringer charge having been placed on the tool.

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FIG. 5 is an illustration similar to FIG. 4 but showing an inflatable bladder having been placed within the cavity of the stringer charge.

FIG. 6 is an illustration similar to FIG. 5 but additionally showing a skin charge having been placed on the stringer charge.

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FIG. 7 is an illustration similar to FIG. 6 but showing a caul plate having been installed over the skin charge.

FIG. 8 is an illustration similar to FIG. 7 but showing sealant tape having been applied around the periphery of the cure tool.

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FIG. 9 is an illustration of a perspective view of one end of the cure tool shown in FIG. 8, a flexible fluid reservoir having been installed on the cure tool and coupled with the flexible bladder.

FIG. 10 is an illustration of a sectional view taken along the line 10-10 in FIG. 9, but additionally showing a vacuum bag having been installed over and sealed to the cure tool.

5 FIG. 11 is an illustration of a sectional view similar to FIG. 10 but showing an alternate embodiment employing a septum within the bladder, the bladder being shown in its unpressurized state.

FIG. 12 is an illustration similar to FIG. 11 but showing the bladder having been pressurized through autoclave pressure applied to the fluid reservoir through the vacuum bag.

10 FIG. 13 is an illustration of a diagrammatic view showing the volumes of fluid reaching the composite charge in the event of a leak in the non-vented bladder system.

FIG. 14 is an illustration of a flow diagram of a method of autoclave curing a composite part charge having an internal cavity using a non-vented bladder system.

15 FIG. 15 is an illustration of a flow diagram of an alternate method of autoclave curing a composite part charge using a non-vented bladder system.

FIG. 16 is an illustration of a flow diagram of aircraft production and service methodology.

15 FIG. 17 is an illustration of a block diagram of an aircraft.

DETAILED DESCRIPTION

20 Referring first to FIG. 1, an uncured composite resin part 20, hereafter referred to as a “charge”, a “composite charge”, a “composite part charge” or a “stringer charge”, is cured on a cure tool 22 placed in an autoclave 26 in which autoclave heat and pressure are applied to the composite charge 20. The composite charge 20 includes one or more internal voids, trapped or enclosed areas, or cavities, which for ease of description, will collectively be referred hereinafter as a cavity 28. A flexible, inflatable bladder 30 is placed within the cavity 28 prior to a cure cycle in order to react autoclave pressures applied to the charge 20 during curing. A flexible fluid reservoir 32 is mounted on the cure tool 22 and is coupled with the bladder 30 in an manner that forms a closed bladder system 25 which is not vented to the atmosphere within the autoclave 26. In other words, the bladder 30 and the fluid reservoir 32 form a closed fluid system that is not directly exposed to the internal atmosphere of the autoclave 26. A flexible bag, such as a vacuum bag 24, is placed over and sealed to the cure tool 22, covering the

composite charge **20**, the bladder **30** and the fluid reservoir **32**. The flexible bag **24** is adapted to be coupled with a suitable vacuum source **64** for evacuating the flexible bag **24**. During curing, the bladder **30** is pressurized using a substantially non-compressible fluid (not shown) supplied from the fluid reservoir **32**.

As will be discussed in more detail below, because both the bladder **30** and the fluid reservoir **32** are located beneath the vacuum bag **24**, the bladder **30** is not vented to the internal atmosphere of the autoclave **26**, i.e. the bladder **30** is non-vented. Rather, the combination of the bladder **30** and the fluid reservoir **32** form a closed, non-vented bladder system **25** that is controlled by autoclave air pressure exerted on the vacuum bag **24**. Optionally, the bladder **30** may include an internal septum **35** that separates substantially the full internal volume of the bladder **30** from the fluid supplied from the fluid reservoir **32**. Reduction of the pressure within the fluid reservoir **32** allows the bladder **30** to partially collapse slightly, thereby preventing the bladder **30** from becoming “locked” in the composite charge **20** and facilitating easy removal of the bladder **30** from the cured composite charge **20**.

Referring now to FIG. 2, the disclosed non-vented bladder system and curing method may be employed to cure any of a variety of composite resin parts of various geometries, having one or more internal cavities. For example, and without limitation, the disclosed system and method may be used in the fabrication of a fiber reinforced composite resin stringer **23**, which may comprise a multi-ply layup of prepreg. The stringer **23** includes a hat section **27** forming an internal cavity **31**, a pair of laterally extending flange sections **29** and a substantially flat skin section **33** that is consolidated together with the flange sections **29** during curing. Other stringer geometries are possible.

FIGS. **3-10** respectively illustrate successive stages in the preparation of the apparatus shown in FIG. 1 for curing of the stringer **23** shown in FIG. 2. Referring particularly to FIG. 3, a cure tool **22** made of any suitable material includes an internal cavity **28** defining a hat section tool face **32**, and a pair of laterally extending, flange section tool faces **34**. Tool faces **32, 34** are configured to respectively match the geometry of the hat section and flange sections **27, 29** respectively of the stringer **23**. The cure tool **22** has a substantially flat upper tool surface **36** surrounding the internal cavity **28**, a chamfered surface **38** at one end of the cavity **28**, and a substantially flat end section **40**. One end of the internal cavity **28** is open at **42**. As will be discussed below, the cure tool **22** may be used to assemble composite stringer charges,

and to cure the assembled charges within an autoclave **26** (FIG. 1). While the illustrated cure tool **22** has a geometry that is adapted to match features of the stringer **23**, it should be noted that the disclosed non-vented bladder system **25** may be used with cure tools having any of various other geometries, depending on the application and the particular composite part charge to be cured.

Referring to FIG. 4, a composite stringer charge **20** is placed on the cure tool **22**. The stringer charge **20** comprises a hat **20a** filling the cavity **28** and engaging the tool face **32** (FIG. 3), and a pair of laterally extending flanges **20b** respectively engaging the tool faces **34**. The stringer charge **20** may be laid up on a separate layup tool (not shown) and then transferred to the cure tool **22**, or alternatively, depending on the geometry of the part charge, it may be possible to layup the stringer directly on the cure tool **22**.

Referring now to FIG. 5, after the stringer charge **20** has been placed in the cure tool **22**, a flexible bladder **30** is placed within the cavity **28** (FIG. 4) of the stringer charge **20** in order to react autoclave pressures that are applied during a curing cycle. The bladder **30** may be formed of any suitable material such, for example and without limitation, an elastomer. A release agent may be applied to the bladder **30** before it is installed to facilitate later removal of the bladder from the cavity **28** following curing. The bladder **30** includes a bladder vent hole **44** that is adapted to be coupled with the fluid reservoir **32** shown in FIG 1, as will be discussed below. In this example, the bladder **30** is configured to substantially match the geometry of the cavity **28** and has a substantially flat upper surface **30a** that is substantially flush with the flat tool surfaces **36** of the cure tool **22**.

Referring now to FIG. 6, after the bladder **30** has been installed as shown in FIG. 5, a substantially flat composite skin charge **46** is placed on the cure tool **22**, overlying the bladder **30** and in face-to-face contact with the flanges **20b** (FIG. 5) of the stringer charge **20** and the flat tool surfaces **36**. Next, as shown in FIG. 7, a caul plate **48** may be installed over the flat composite skin charge **46** in order to apply substantially even pressure over the skin charge **46** during the curing process. Also, although not shown in FIG. 7, peel plies, release films and/or breathers or other components may be installed along with the caul plate **48**, depending on the application. As shown in FIG. 8, a suitable sealant tape **50** or other suitable sealant is applied to the perimeter of the cure tool **22** in preparation for vacuum bagging the tool **22**. At this point, a vacuum probe base **52** may be applied to the flat end section **40** of the cure tool **22**.

Next, as shown in FIG. 9, a flexible fluid reservoir 32 is attached to the bladder 30 such that the bladder 30 and the fluid reservoir 32 may be installed and removed as a single assembly, if desired. The fluid reservoir 32 is coupled with the vent hole 44 (FIG. 8) in the bladder 30 and is supported on the chamfered surface 38 of the cure tool 22 when the bladder 30 is in place within the composite charge cavity 28. The fluid reservoir 32 may be permanently attached and sealed to the bladder 30, thus obviating the need to reconnect the bladder 30 to a pressure source each time the bladder 30 is installed in a composite charge 20 in preparation for a curing process. This arrangement also eliminates the need for placing a sealant around the vent hole 44 each time the bladder is installed in a composite charge 20. The fluid reservoir 32 may be fabricated from any suitable material such as, without limitation, an elastomer. A vacuum probe 54 is mounted on the vacuum probe base 52, and is adapted to be coupled with a vacuum source (not shown) for evacuating the vacuum bag 24 during a cure cycle.

Referring now to FIG. 10, the fluid reservoir 32 may have a generally rectangular or square cross sectional shape with sides 32a that are flexible and may plastically deform inwardly as shown by the dashed lines 32b when external pressure is applied to the fluid reservoir 32. A portion 32b of the fluid reservoir 32 is attached in face-to-face contact to one end of the bladder 30 and includes a fluid outlet 41 that is aligned and coupled with the vent hole 44 in the bladder 30, allowing fluid to flow between the fluid reservoir 32 and the bladder 30. In other embodiments, the fluid reservoir 32 may have a different shape, and may or may not be attached to the bladder 30. Following installation of the fluid reservoir 32 shown in FIG. 9, flexible bag 24, sometimes referred to as a vacuum bag 24, formed of any suitable material such as polyester or nylon, is installed over the tool 22, covering the fluid reservoir 32, the stringer charges 20, 46, and the bladder 30. The vacuum bag 24 is in face-to-face contact with the fluid reservoir 32. The vacuum bag 24 is sealed to the periphery of the cure tool 22 and around the vacuum probe 54 using sealing tape 50 or other suitable sealants. Evacuation of vacuum bag 24 draws the vacuum bag 24 down in face-to-face contact with the sides of the fluid reservoir 32, allowing autoclave pressure P_A to be applied to the fluid reservoir 32.

Optionally, the fluid reservoir 32 may include a vacuum port 60 that is adapted to be coupled with a vacuum source (not shown) after the vacuum bag 24 has been removed following a cure cycle. The vacuum port 60 is closed and sealed beneath the vacuum bag 24

5 during curing, but includes a valve or other device (not shown) that allows connection of the internal volume **56** of the fluid reservoir **32** to the vacuum source after curing is completed and the vacuum bag has been removed. Coupling the fluid reservoir **32** to the vacuum source in this manner relieves fluid pressure within the fluid reservoir **32**, which in turn reduces the pressure within the bladder **30**, allowing the bladder **30** to deflate or collapse slightly. Deflation of the bladder **30** in this manner reduces the maximum cross sectional dimension (not shown) of the bladder **30** an amount that is sufficient to allow the bladder **30** to be removed from the cured stringer.

10 During curing carried out within an autoclave, autoclave pressure P_A forces the vacuum bag **24** against the cure tool **22**, thereby compacting the composite charge **20** while also applying pressure to the fluid reservoir **32**. The autoclave pressure P_A applied to the fluid reservoir **32** causes fluid to flow **45** from the internal volume **56** of the fluid reservoir **32** through the bladder vent hole **44** into the bladder **30**, thereby internally pressurizing the bladder **30**. This pressurization of the bladder **30** causes a force **55** to be applied to composite charge **20** that reacts the autoclave pressure P_A applied to the composite charge **20**. When curing is completed, the autoclave pressure P_A is removed from the vacuum bag **22**, and thus is removed from the fluid reservoir **32**. The resulting decrease in fluid pressure within the fluid reservoir **32** allows fluid to flow from the bladder **58** through the vent hole **44** back into the fluid reservoir **32**.

20 As previously discussed, the fluid reservoir **32** may be permanently sealed to the bladder **30**, thus obviating the need to place a sealant around the vent hole **44** (FIG. 8) each time the bladder **30** is installed in a composite charge **20**. Permanently sealing the fluid reservoir **32** to the bladder **30** may therefore eliminate leakage around the vent hole **44** into the composite charge **20**. In the event of a leak in either the bladder **30** or the fluid reservoir **32**, fluid leakage into the composite charge **20** is limited to the total volume of the bladder **30** and the fluid reservoir **32** since the bladder system **25** (FIG. 1) is a closed system and does not allow air from the autoclave to enter into the composite charge cavity **28** (FIG. 4).

25 An alternate embodiment of the disclosed non-vented bladder system is shown in FIGS. **11** and **12**. In this embodiment, the bladder **30** includes an internal septum **35** that separates the interior chamber **65** of the bladder **30** from the fluid supplied by the fluid reservoir **32**. The septum **35** is made of a flexible material and may be formed integral with the bladder **30**. The

bladder chamber **65** is filled with a flowable fill material **66** having a relatively low CTE (coefficient of thermal expansion) and a density selected to provide the bladder **30** with a desired level of stiffness. One side **75** of the septum **35** is exposed to the fluid supplied by fluid reservoir **32**. Fluid from the reservoir **56** that is forced against the bladder **30** by the autoclave pressure P_A , exerts fluid pressure P_F (FIG. 12) against the septum **35**, causing the septum **35** to flex inwardly to the position **35a** shown in FIG. 12, thereby pressurizing the fill material **66**. Pressurization of the fill material **66** results in an outward pressure **68** being exerted against the composite charge **20**.

Referring now to FIG. 13, in the event of a leak in the non-vented bladder system **25** described above, the volume of air within the autoclave **26** (FIG. 1) does not reach the composite charge **20**, because the bladder system **25** is sealed beneath the vacuum bag **24**. Rather, the total amount of fluid possibly reaching the composite charge **20** in the event of a leak in either the bladder **30** or the fluid reservoir **32** (FIGS. 10-12) is limited to the fluid reservoir interior volume **56** plus the bladder chamber volume **65**.

Attention is now directed to FIG. 14 which broadly illustrates the steps of a method for autoclave curing using the non-vented bladder system **25** described above. Beginning at step **70**, a composite resin charge **20** is placed on a suitable tool, which may be a cure tool. At **72**, a flexible, inflatable bladder **30** is installed in an internal cavity **28** of the charge **20**. At **74**, the flexible bladder **30** is coupled with a flexible fluid reservoir **32** containing a quantity of fluid. At **76**, the composite charge **20** along with the fluid reservoir **32** are covered with a flexible bag **24** such as a vacuum bag, which is then sealed to the cure tool **22**. At **78**, autoclave pressure P_A is applied to the bag **24** in order to compress the fluid reservoir **32** and force fluid from the reservoir **32** into the bladder **30**, thereby pressuring the bladder **30** to react forces applied to the composite charge **20** by autoclave pressure. Optionally, at step **80**, an internal septum **35** within the bladder **30** may be employed to transmit pressure to the bladder **30** using the fluid pressure generated by the fluid reservoir **32**. Also, optionally at step **82**, following curing and removal of the vacuum bag **24**, pressure within the fluid reservoir **32** may be relieved to aid in bladder removal, by coupling the fluid reservoir **32** with a suitable vacuum source.

An alternate method of curing a composite part charge **20** is shown in FIG. 15. At **84**, a composite part charge **20** is placed on a tool **22**, and at **86**, a bladder **30** is installed in a cavity **28** of the composite part charge **20**. The bladder **60** is coupled with a reservoir of fluid **32** at

step **88**. Next, as shown at step **90**, a flexible bag **24** is sealed over the composite part charge **20** and the reservoir of fluid **32**. At step **92**, the flexible bag **24** is used to transmit autoclave pressure to the reservoir of fluid **32** to force fluid from the reservoir **32** into the bladder **60**.

Embodiments of the disclosure may find use in a variety of potential applications, 5 particularly in the transportation industry, including for example, aerospace, marine, automotive applications and other application where autoclave curing of composite parts may be used. Thus, referring now to FIGS. **16** and **17**, embodiments of the disclosure may be used in the context of an aircraft manufacturing and service method **94** as shown in Figure **16** and an aircraft **96** as shown in Figure **16**. Aircraft applications of the disclosed embodiments may include, for example, without 10 limitation, curing of stiffener members such as, without limitation beams, spars and stringers, to name only a few. During pre-production, exemplary method **94** may include specification and design **98** of the aircraft **96** and material procurement **100**. During production, component and subassembly manufacturing **102** and system integration **104** of the aircraft **96** takes place. Thereafter, the aircraft **96** may go through certification and delivery **106** in order to be placed in 15 service **108**. While in service by a customer, the aircraft **96** is scheduled for routine maintenance and service **110**, which may also include modification, reconfiguration, refurbishment, and so on.

Each of the processes of method **94** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and 20 major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

As shown in FIG. **17**, the aircraft **96** produced by exemplary method **94** may include an airframe **112** with a plurality of systems **114** and an interior **116**. Examples of high-level systems 25 **114** include one or more of a propulsion system **118**, an electrical system **120**, a hydraulic system **122**, and an environmental system **124**. Any number of other systems may be included. Although an aerospace example is shown, the principles of the disclosure may be applied to other industries, such as the marine and automotive industries.

Systems and methods embodied herein may be employed during any one or more of the 30 stages of the production and service method **94**. For example, components or subassemblies

corresponding to production process 102 may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft 96 is in service. Also, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during the production stages 102 and 104, for example, by substantially expediting assembly of or reducing the cost of an aircraft 96. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof may be utilized while the aircraft 96 is in service, for example and without limitation, to maintenance and service 110.

The description of the different advantageous embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different advantages as compared to other advantageous embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An apparatus for use in autoclave curing of a composite charge having an internal cavity, comprising:

5 a flexible bladder adapted to be placed in the cavity for applying pressure on the composite charge during the curing; and

10 a flexible fluid reservoir for pressuring the bladder in response to a pressure applied to the fluid reservoir, the reservoir and the bladder being coupled together in a closed system.

15 2. The apparatus of claim 1, further comprising:

a flexible bag sealed over the flexible bladder and the fluid reservoir, and

wherein the flexible bag is in face-to-face contact with the fluid reservoir.

20 3. The apparatus of claim 2, wherein the flexible bag transmits pressure from the autoclave to the fluid reservoir.

4. The apparatus of any one of claims 1 to 3, further comprising:

25 a cure tool adapted to have the composite charge placed thereon, and

wherein the fluid reservoir is located on the cure tool and the flexible bag is sealed to the cured tool.

5. The apparatus of any of claims **2** to **4**, wherein:

the bladder includes a vent hole, and

5 a portion of the fluid reservoir is attached to the bladder and includes a fluid outlet coupled with the vent hole in the bladder.

10 6. The apparatus of any one of claims **1** to **5**, wherein the reservoir includes a vacuum port adapted to be coupled with a vacuum source for selectively relieving pressure within the fluid reservoir.

15 7. The apparatus of any one of claims **1** to **6**, wherein the bladder includes:

a septum forming an interior chamber within the bladder, and

15 a fill material filling the interior chamber and having a density that is sufficient to stiffen the bladder when the bladder is pressurized by fluid from the fluid reservoir.

20 8. The apparatus of claim **7**, wherein:

the septum includes a flexible side that is exposed to fluid from the fluid of the fluid reservoir, and

25 the flexible side flexes to apply pressure to the fill material when the fluid reservoir pressurizes the bladder.

9. An apparatus for applying substantially uniform external air pressure on a part having an internal cavity, the apparatus comprising:

5 a tool adapted to have the part placed thereon;

10 a bladder adapted to be placed within the internal cavity and in contact with the part;

15 a fluid reservoir coupled with the bladder for supplying pressurized fluid to the bladder in response to a pressure applied to the fluid reservoir; and

20 a flexible bag sealed to the tool and covering the part, the bladder and the reservoir.

25 10. The apparatus of claim 9, wherein the reservoir is attached to the bladder to form a single assembly that may be installed in and removed from the internal cavity.

30 11. The apparatus of claim 9, wherein the reservoir includes flexible walls in face-to-face contact with the flexible bag allowing the external pressure to be applied to the reservoir through the flexible bag.

35 12. The apparatus of claim 9, wherein the bladder includes:

25 fill material for stiffening the bladder, and

30 a septum separating the fill material from the reservoir fluid.

35 13. The apparatus of claim 9, wherein the reservoir and the bladder form a closed fluid system that is not vented to the external pressure.

14. A method of autoclave curing a composite charge having an internal cavity, comprising:

5 placing the composite charge on a tool;

installing a bladder within the cavity;

coupling the bladder with a reservoir of fluid;

10 sealing a flexible bag over the composite charge and the reservoir; and

using the flexible bag to transmit autoclave pressure to the reservoir to force fluid from the reservoir into the bladder.

15. The method of claim 14, wherein coupling the bladder with the reservoir includes attaching the bladder to the reservoir before the bladder is installed in the cavity.

16. The method of any one of claims 14 to 15, wherein sealing the bag includes sealing the bag to the tool.

20. The method of any of claims 14 to 16, further comprising:

stiffening the bladder by filling the bladder with a fill material, and

separating the fill material from the fluid by placing a septum in the bladder.

25. The method of any of claims 14 to 17, further comprising:

using a vacuum to draw the flexible bag down against sides of the reservoir.

19. The method of any of claims 14 to 18, further comprising:

removing the flexible bag from the composite charge and the reservoir after the composite charge has been cured; and

5

relieving pressure within the bladder by porting the reservoir to a vacuum source after the flexible bag has been removed.

1/14

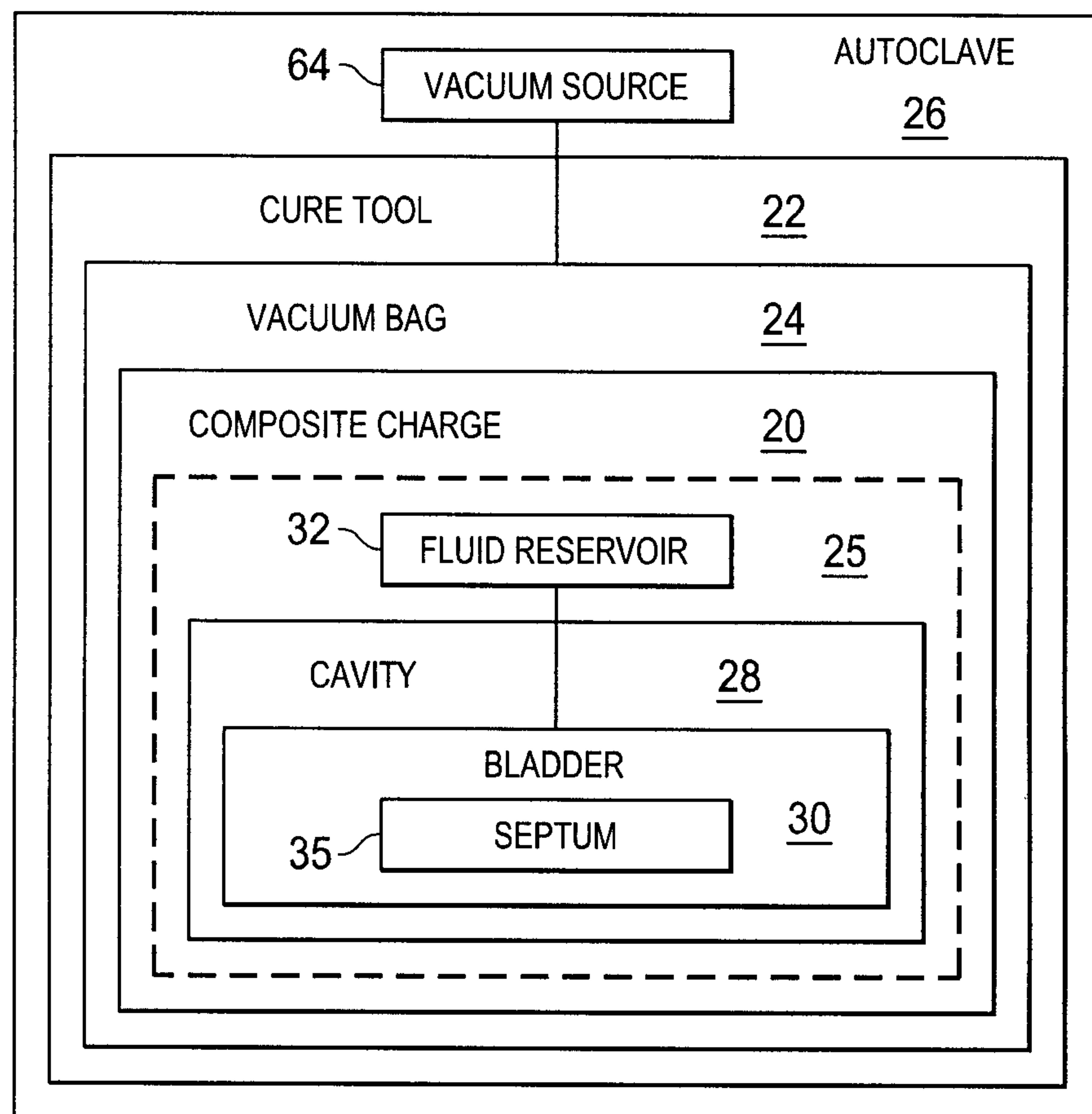


FIG. 1

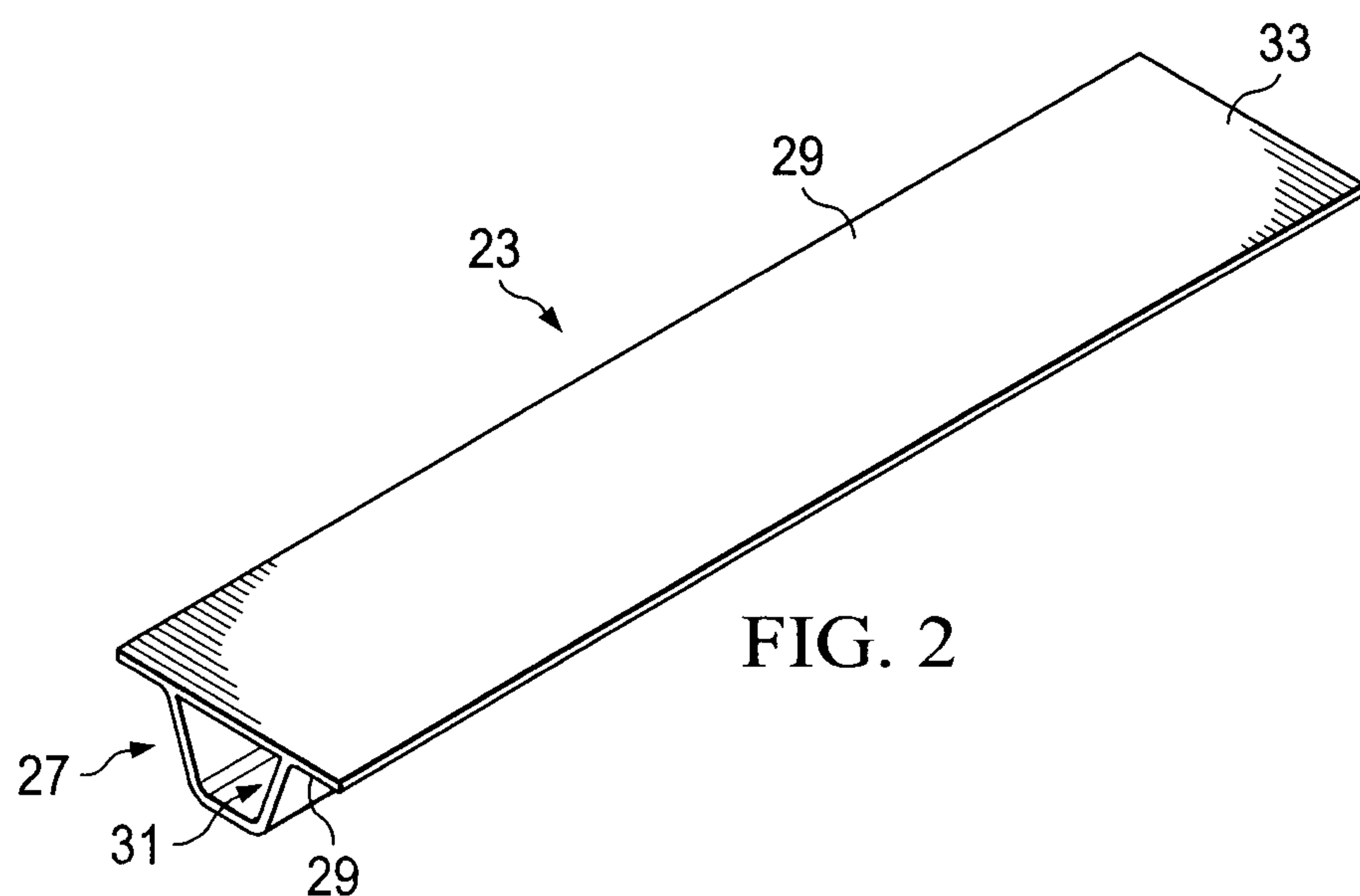
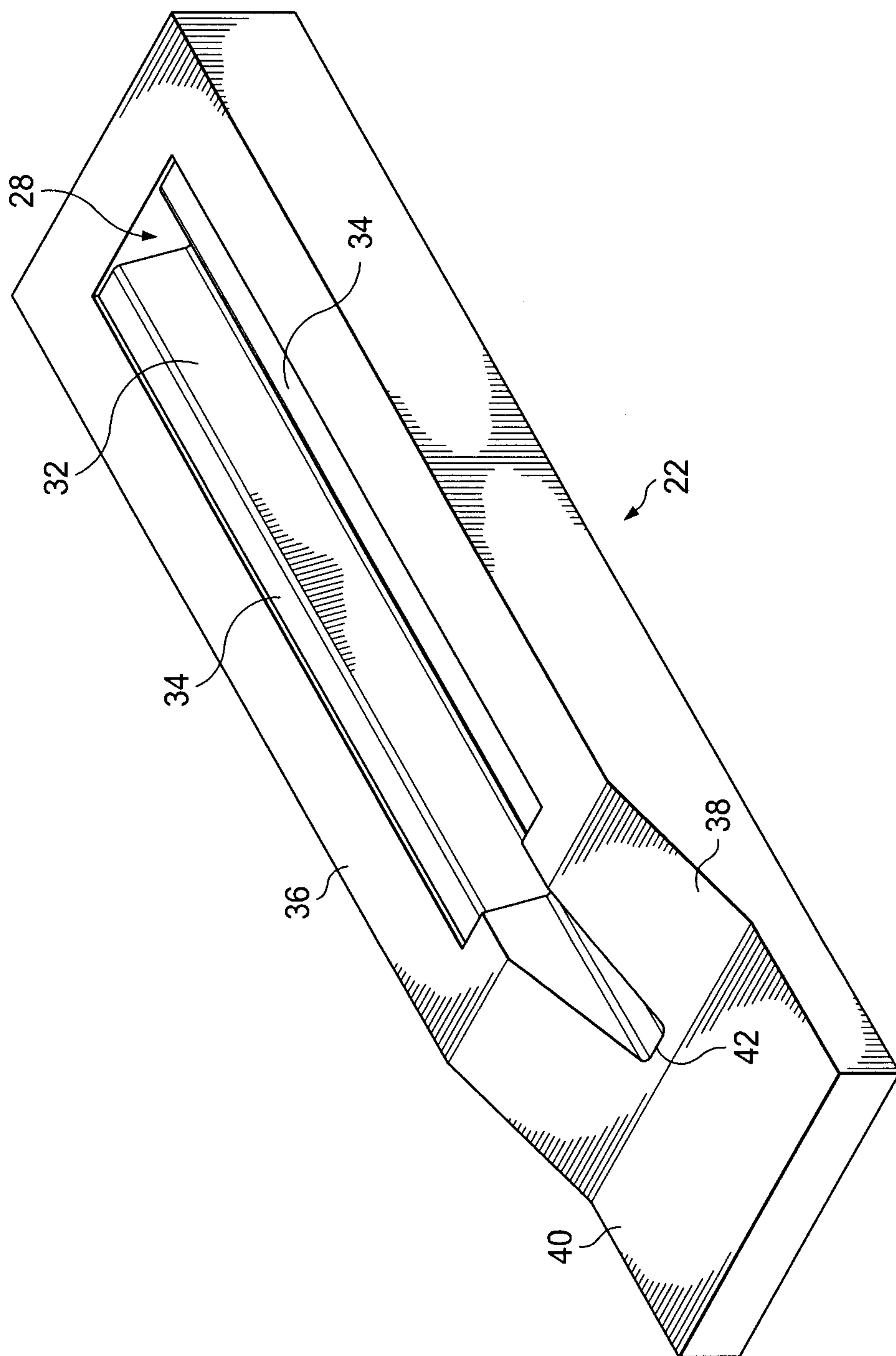


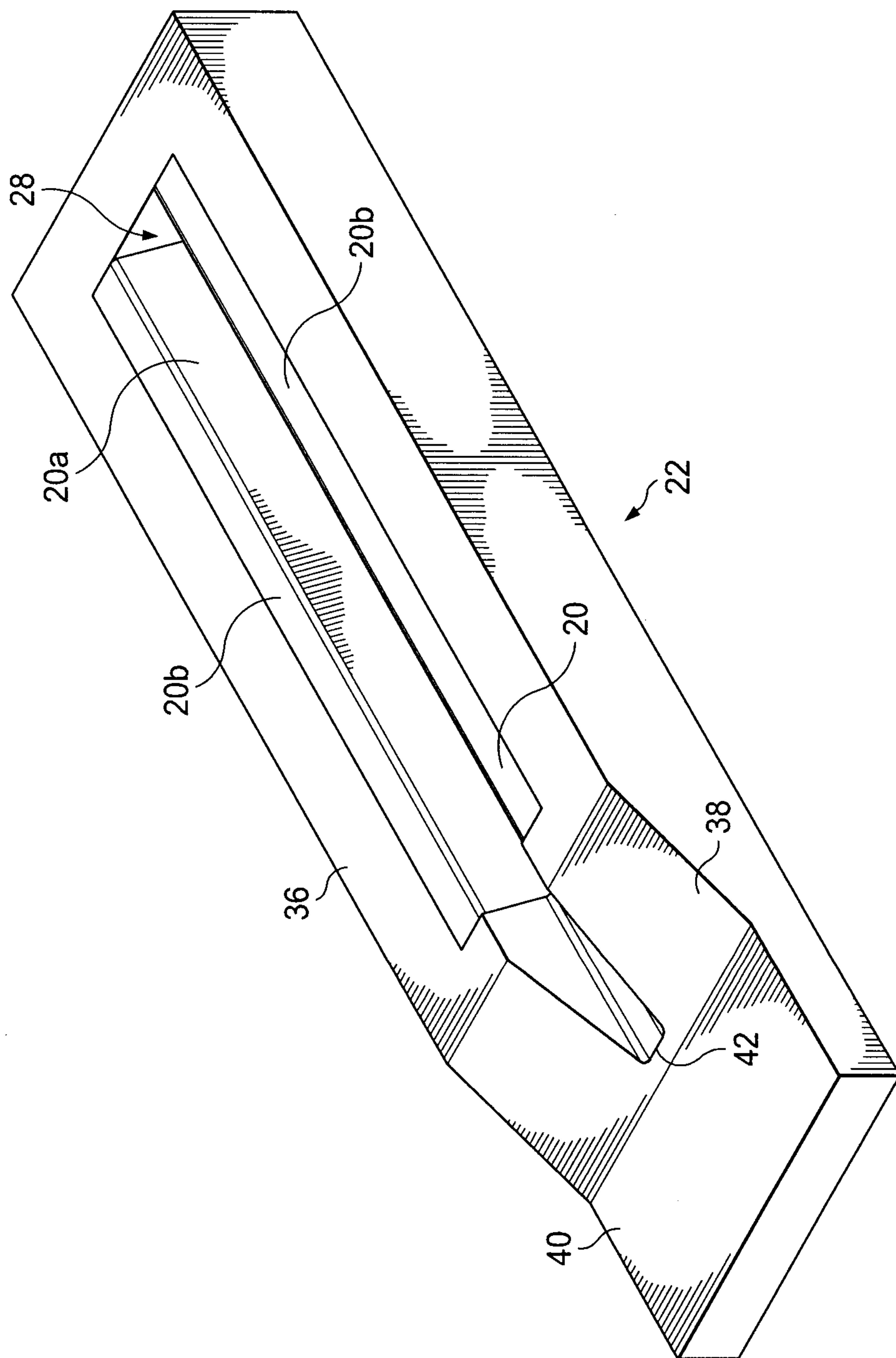
FIG. 2

FIG. 3



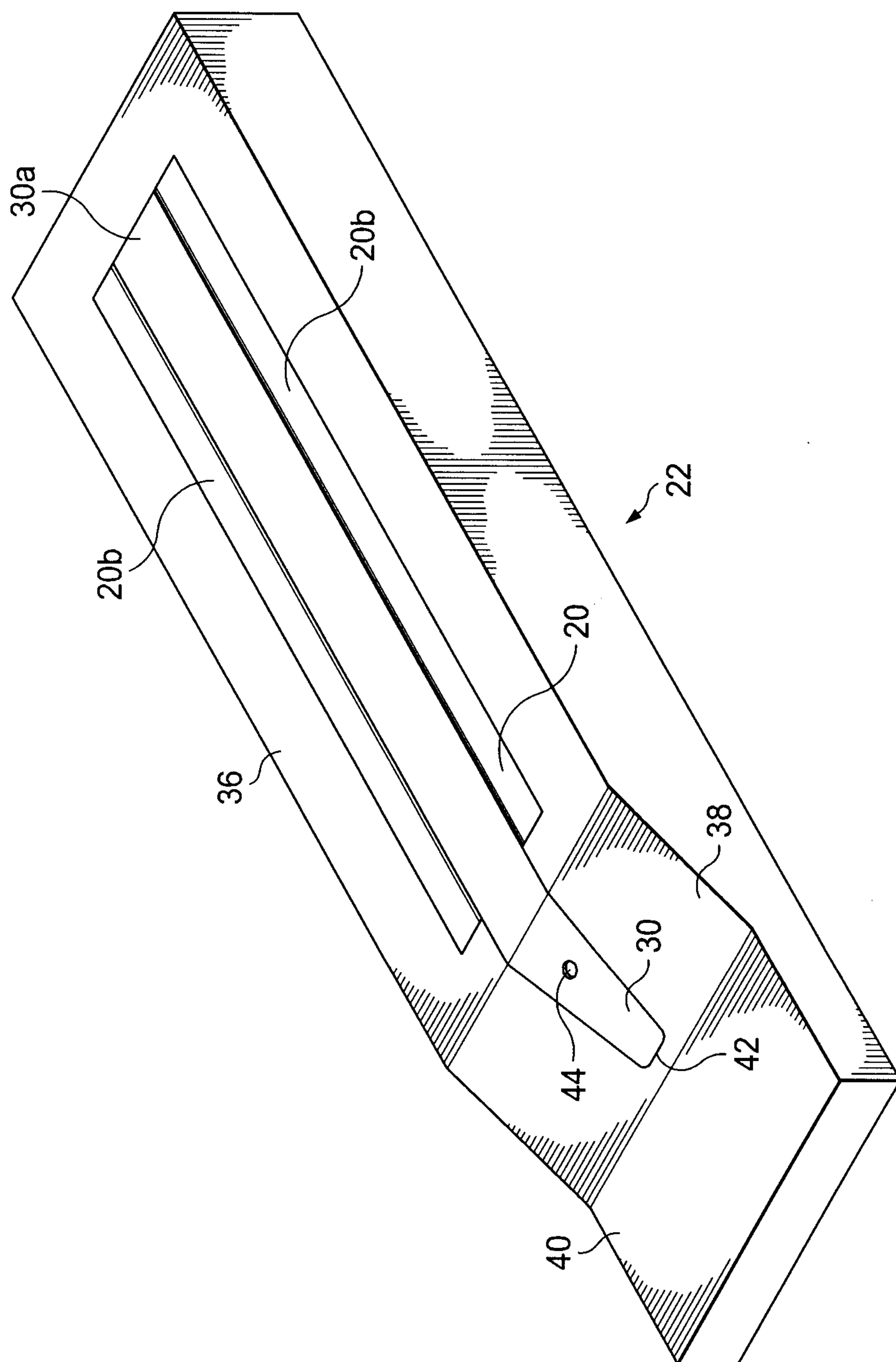
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FIG. 4



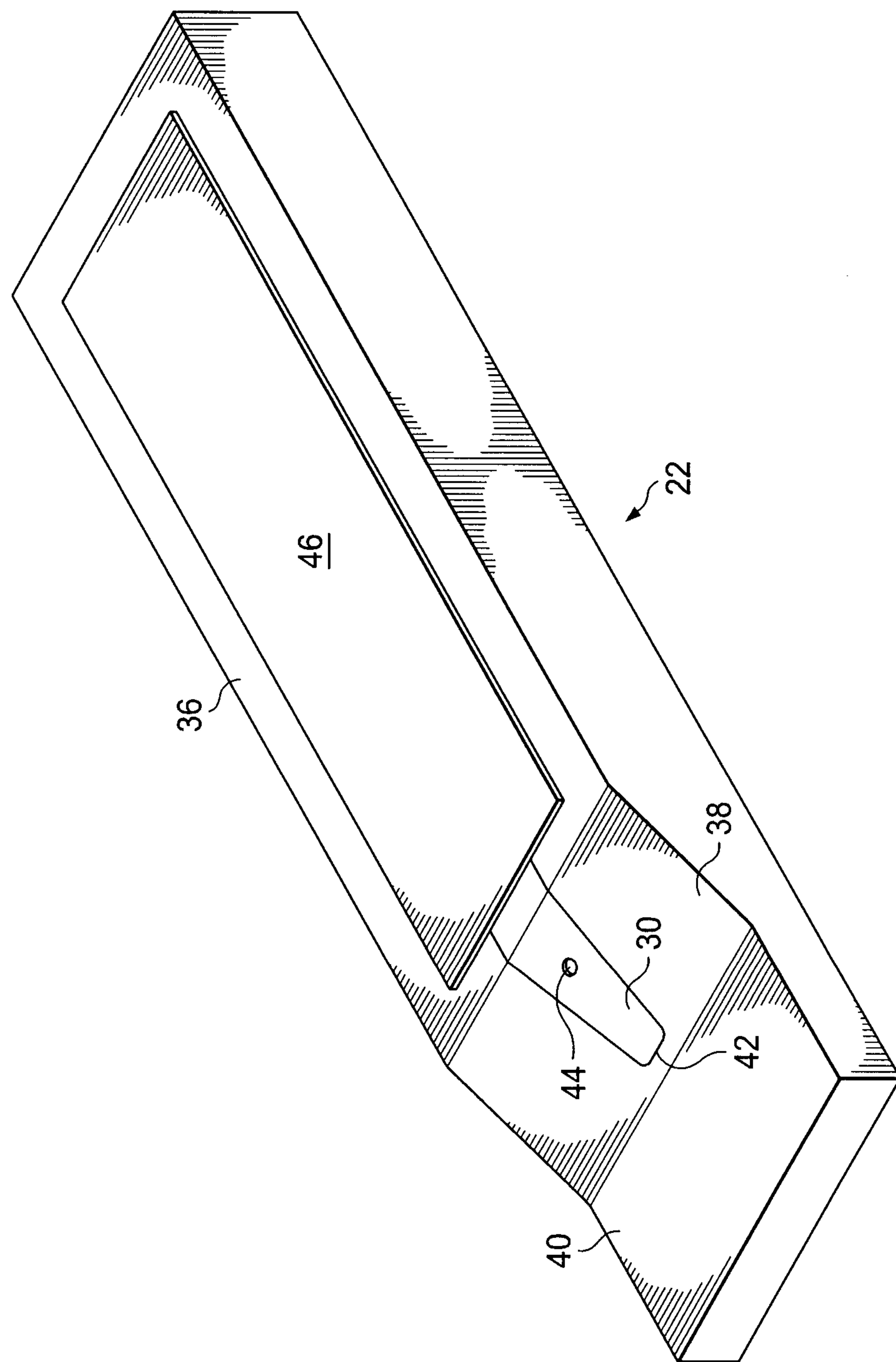
4/14

FIG. 5



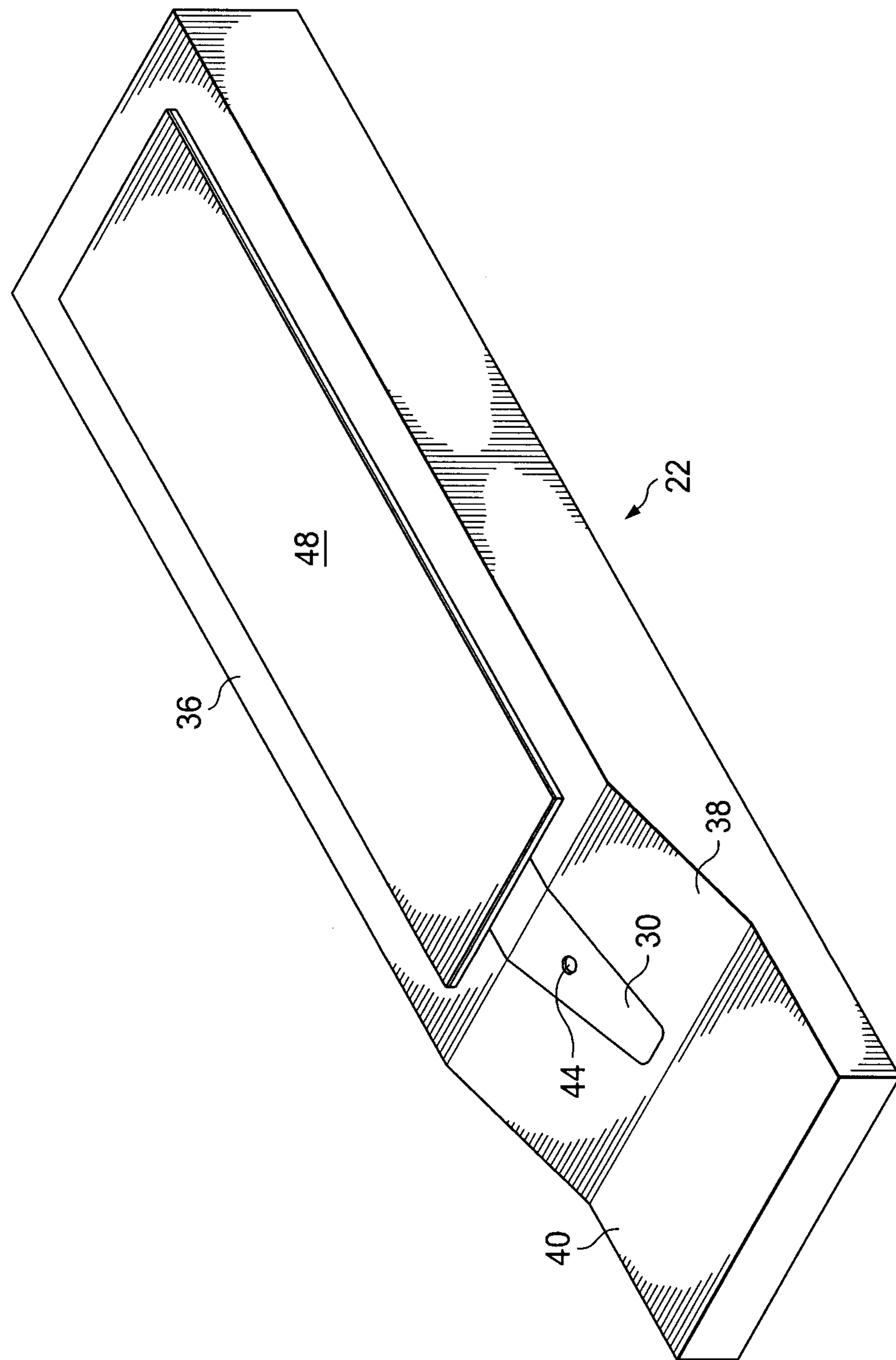
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FIG. 6



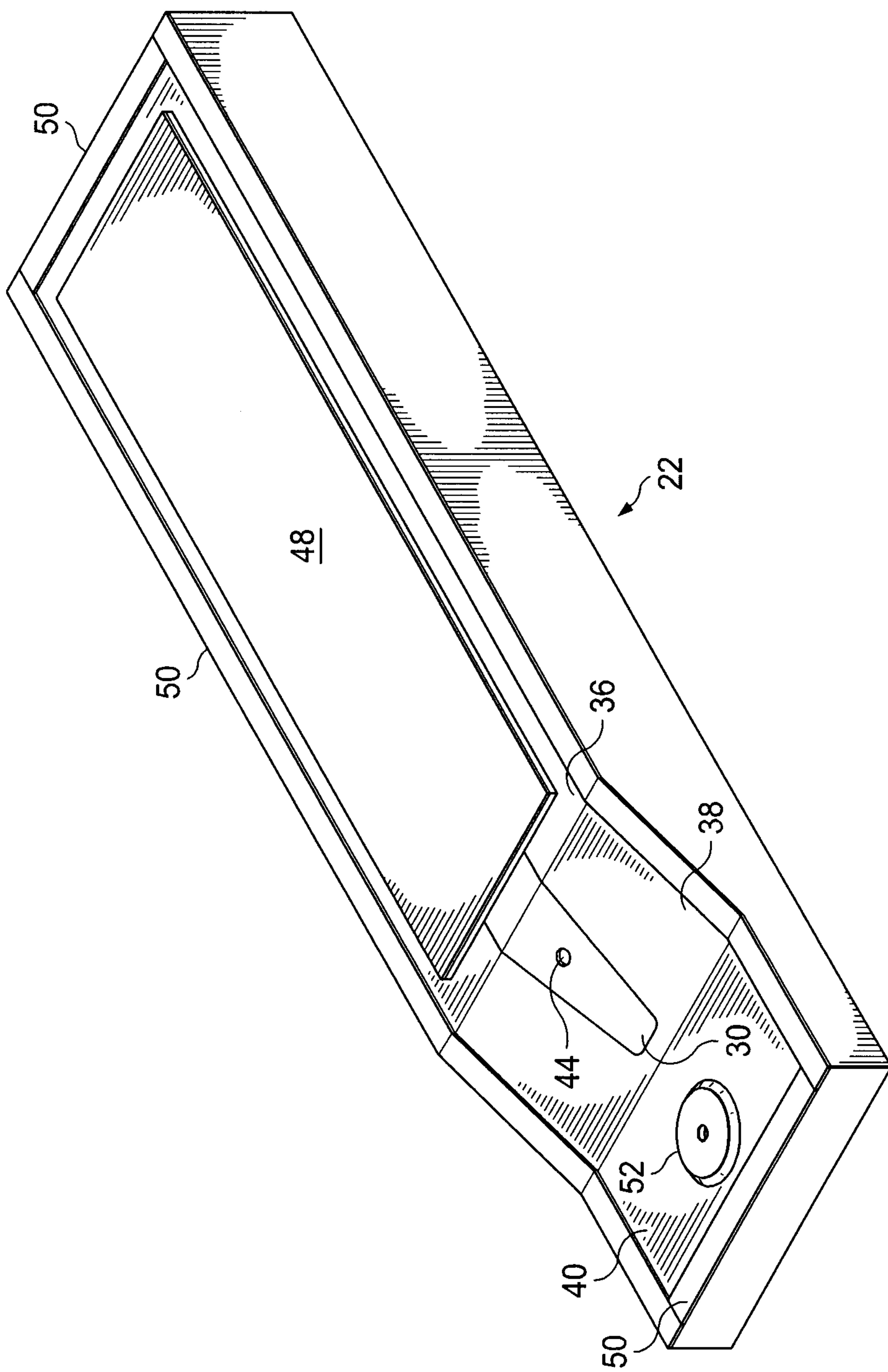
6/14

FIG. 7



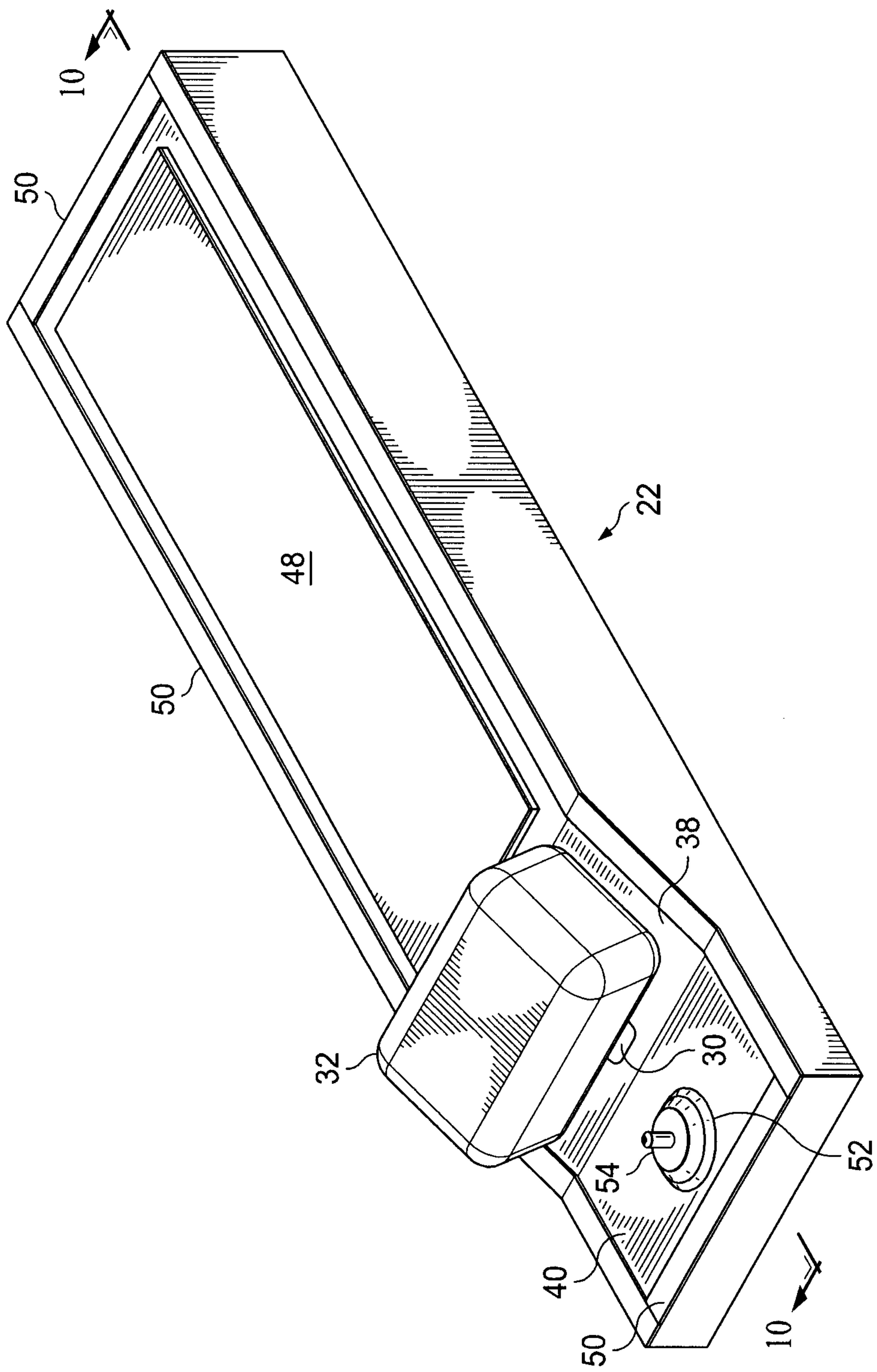
7/14

FIG. 8



8/14

FIG. 9



9/14

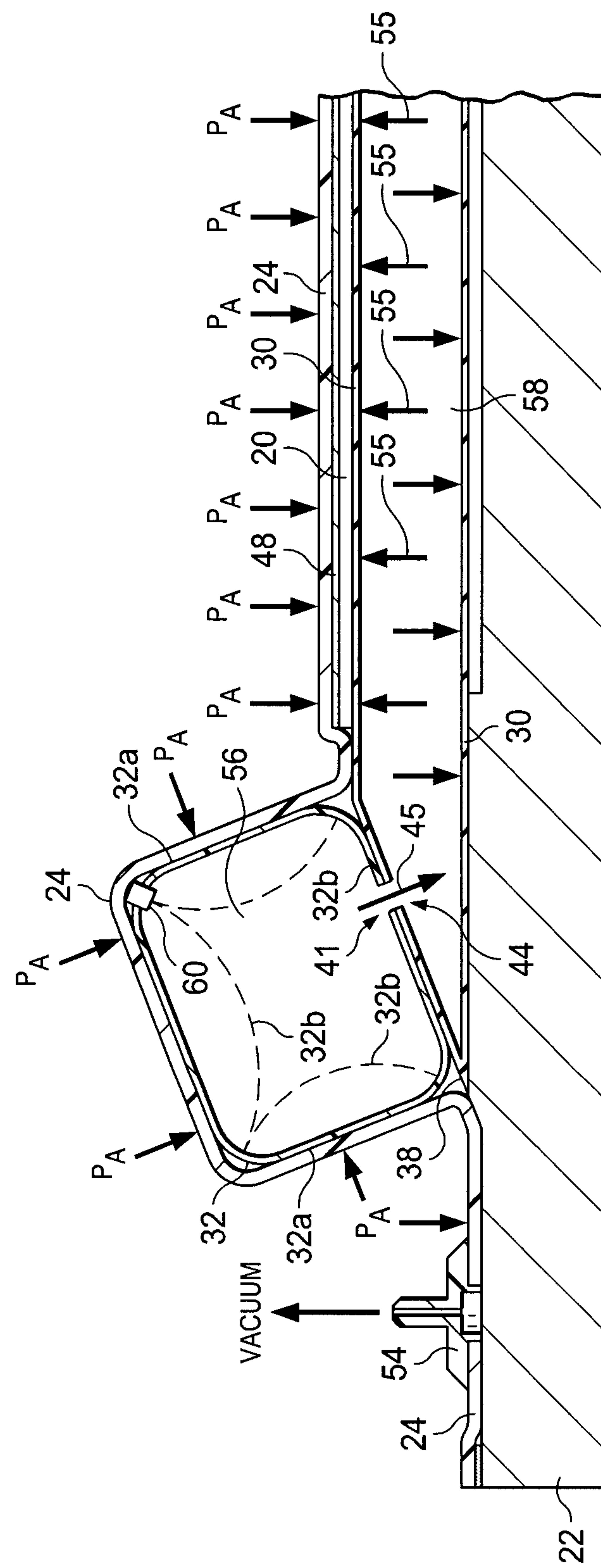
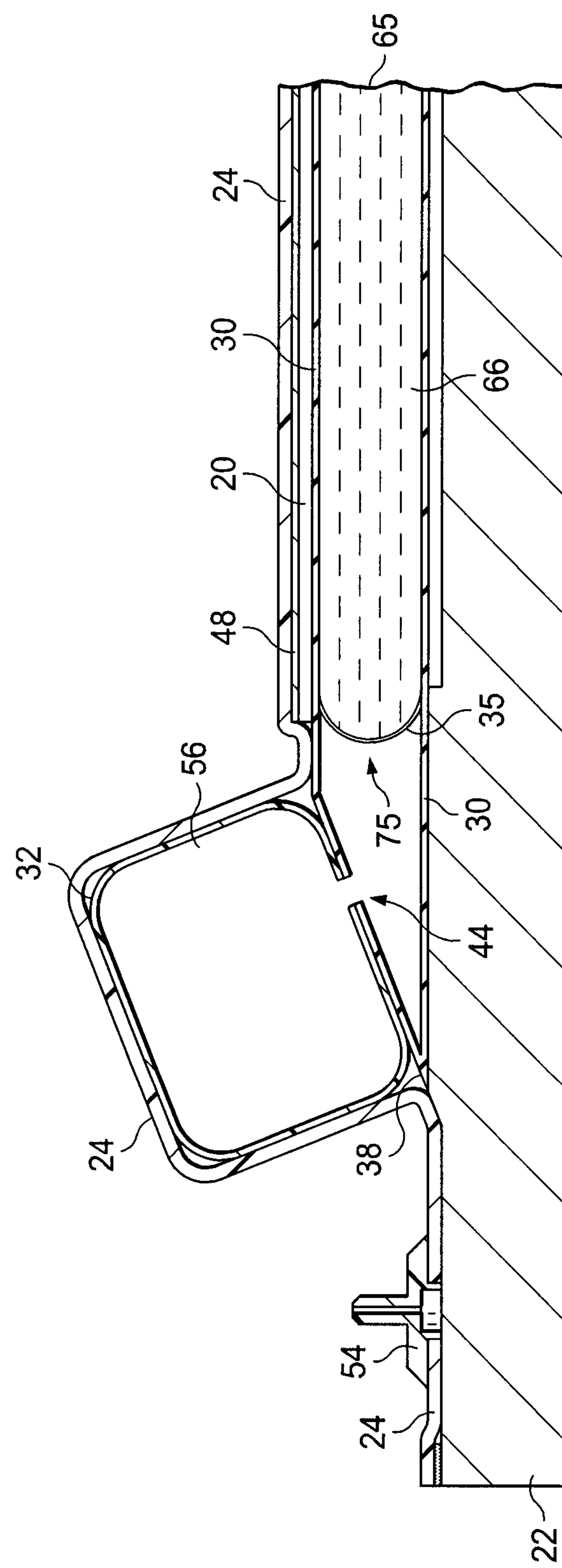


FIG. 10

10/14



11/14

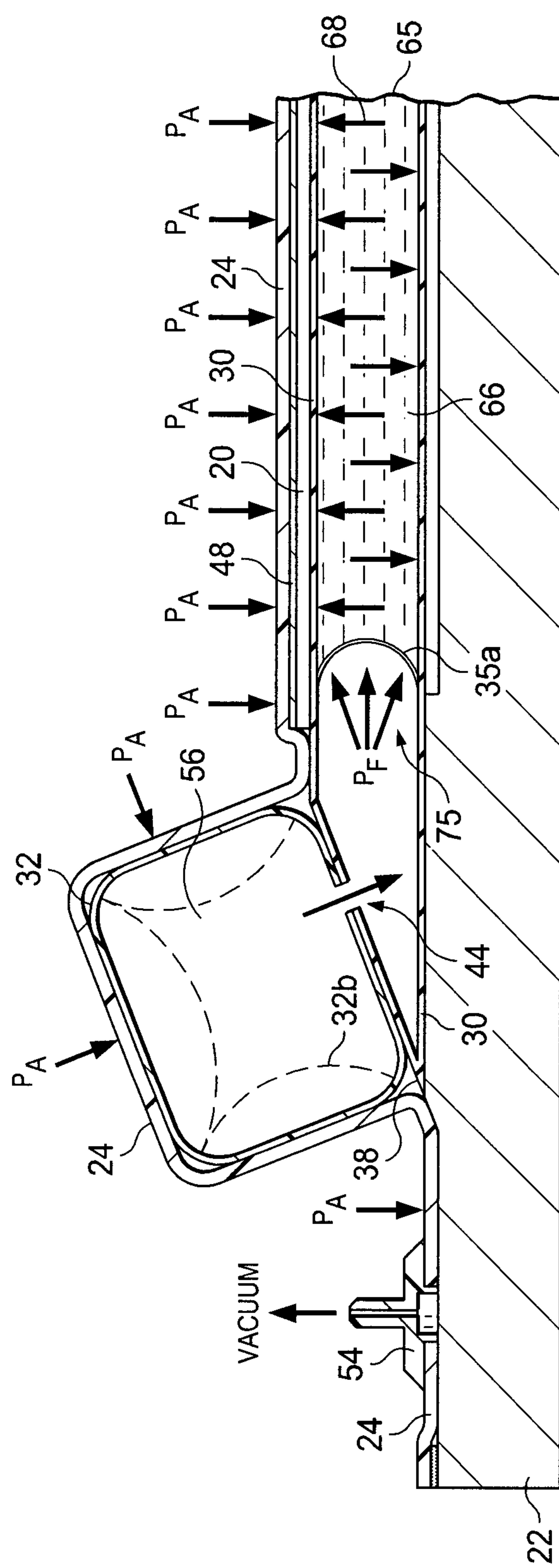


FIG. 12

12/14

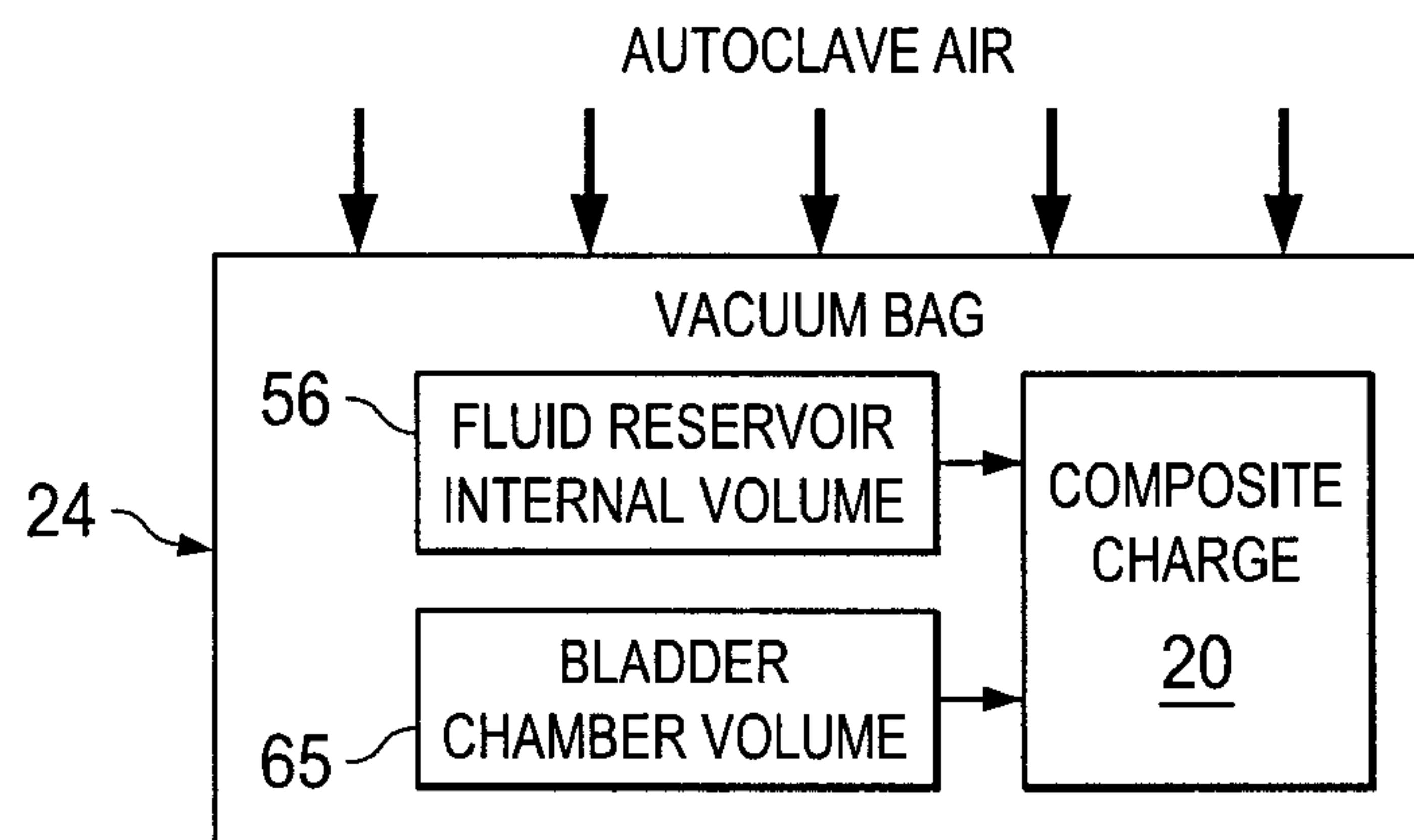


FIG. 13

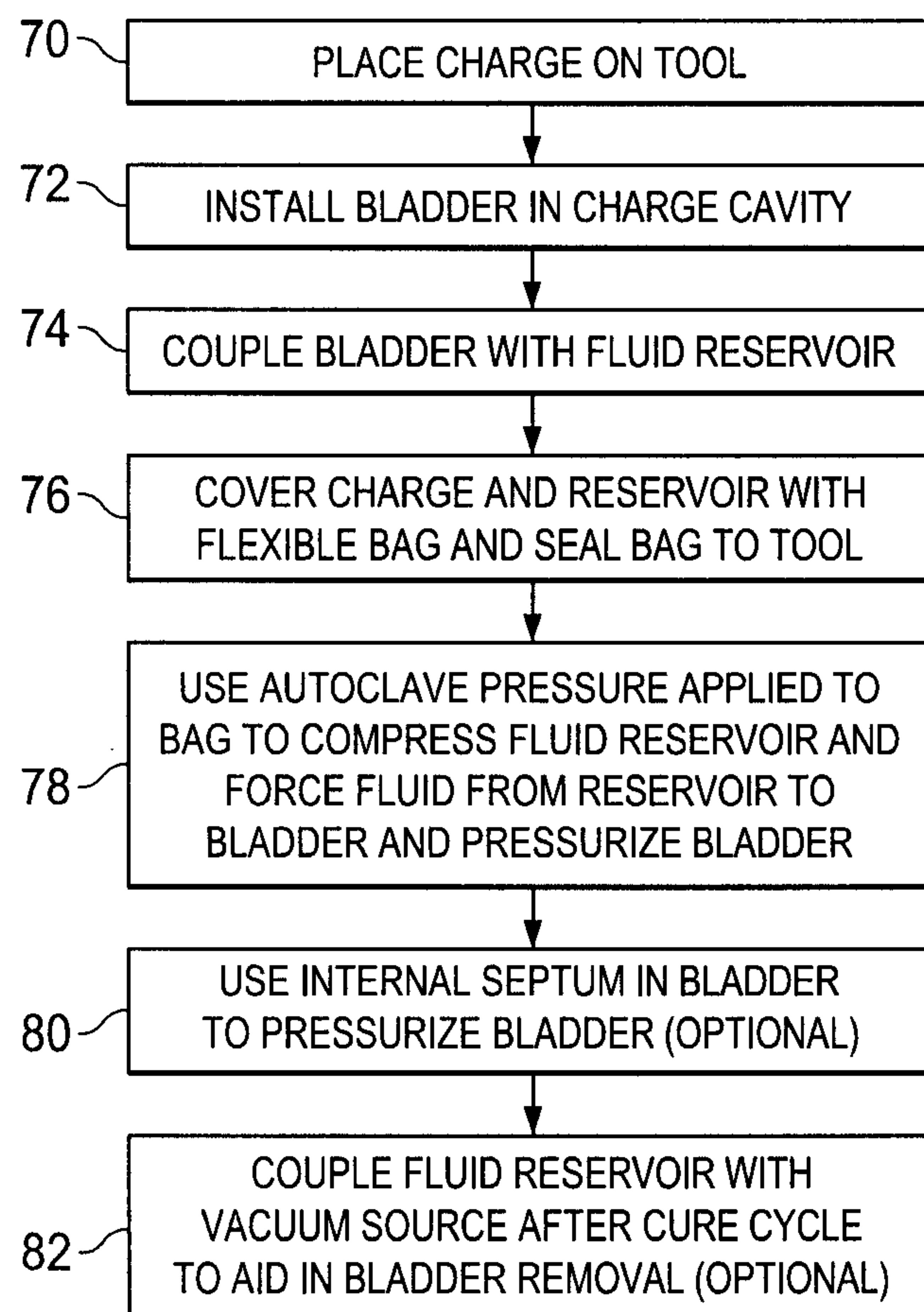


FIG. 14

13/14

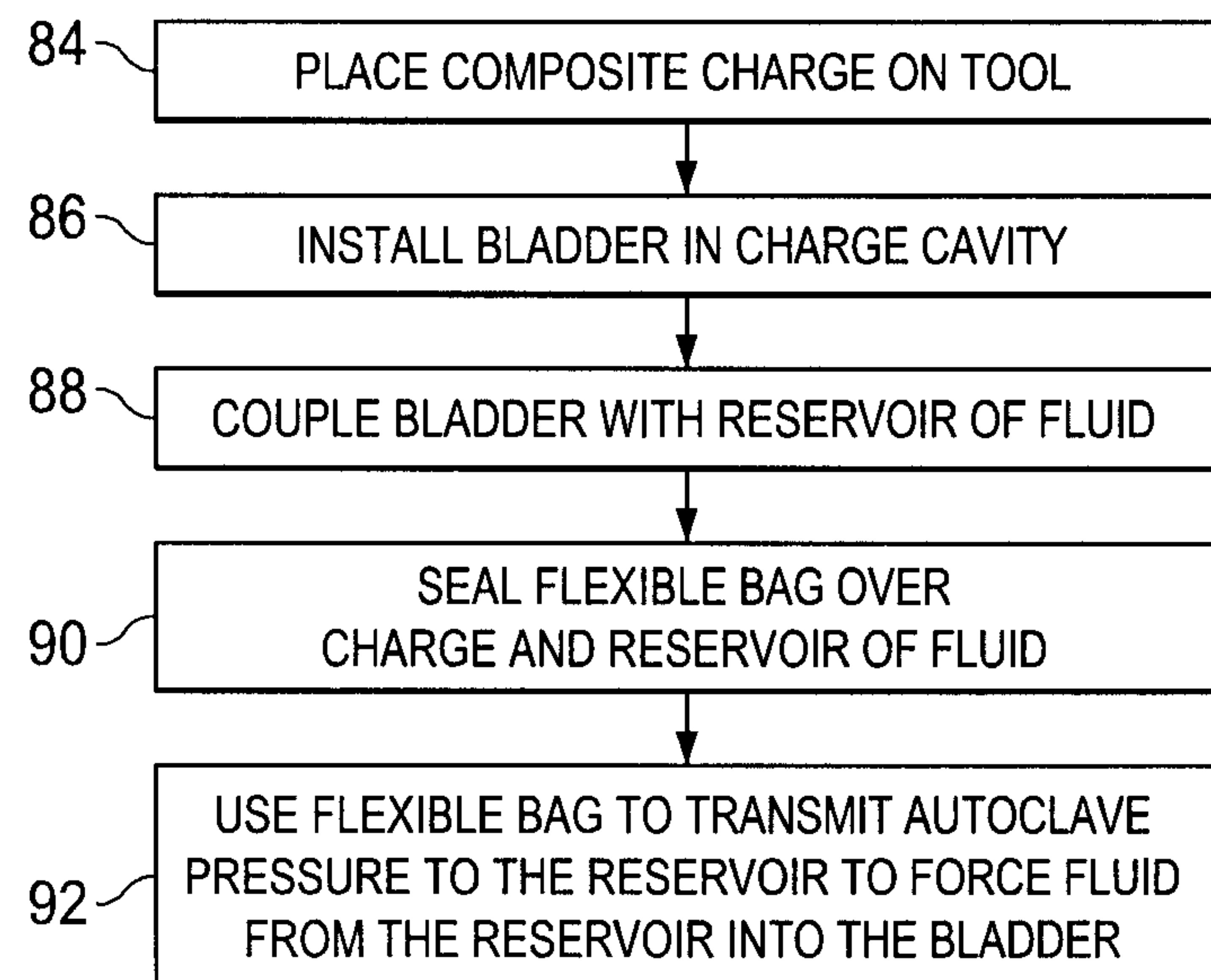


FIG. 15

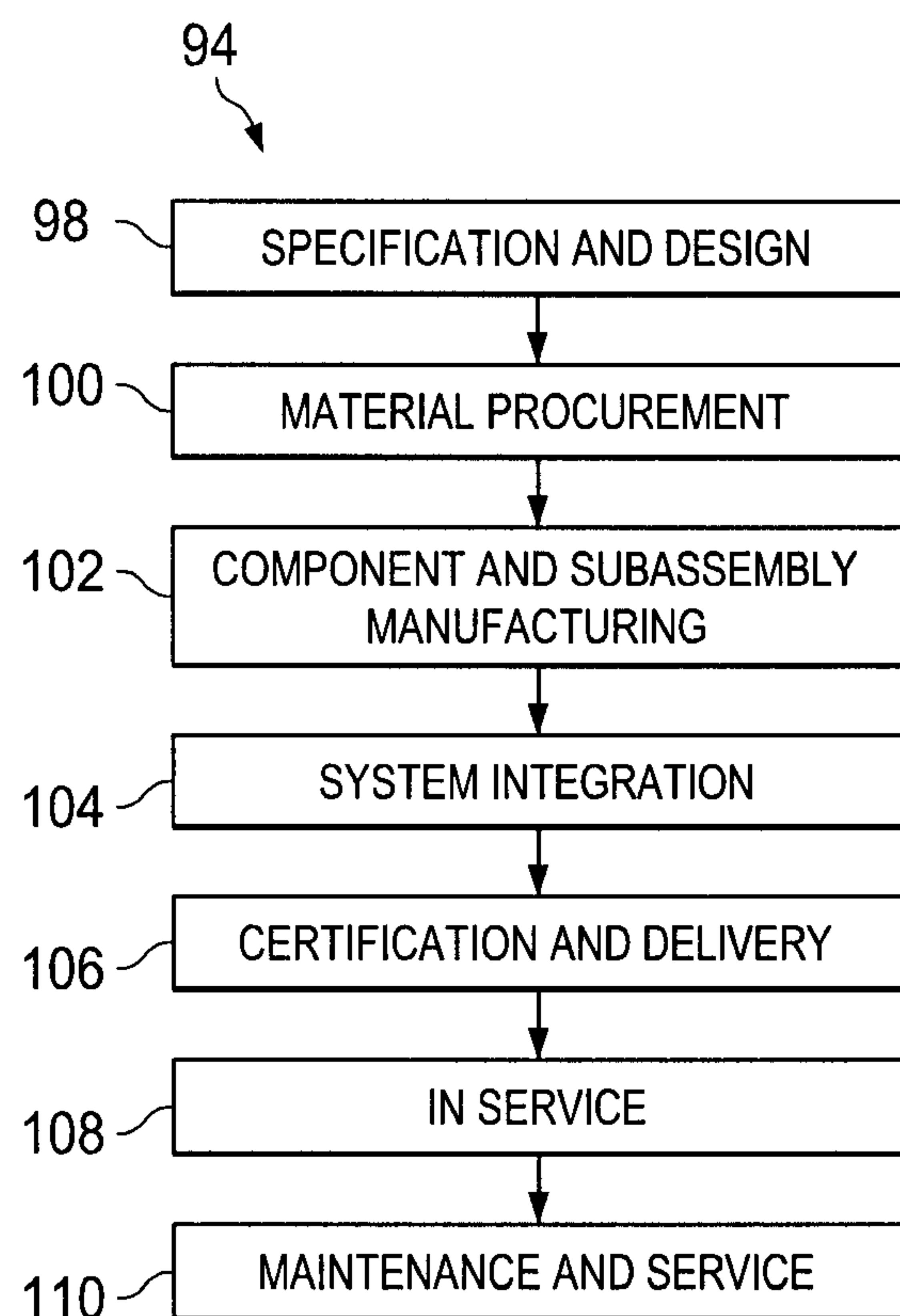


FIG. 16

14/14

FIG. 17

