US 20240085118A1

(19) United States
(12) Patent Application Publication
Margavio et al.
(10) Pub. No.: US 2024/0085118 A1
(43) Pub. Date: Mar. 14, 2024

(54) ADDITIVE MANUFACTURED OSCILLATING HEAT PIPE DEVICE WITH FLUSHABLE CHANNELS

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(21) Appl. No.: **18/463,593**

(22) Filed: **Sep. 8, 2023**

Related U.S. Application Data

(60) Provisional application No. 63/404,800, filed on Sep. 8, 2022.

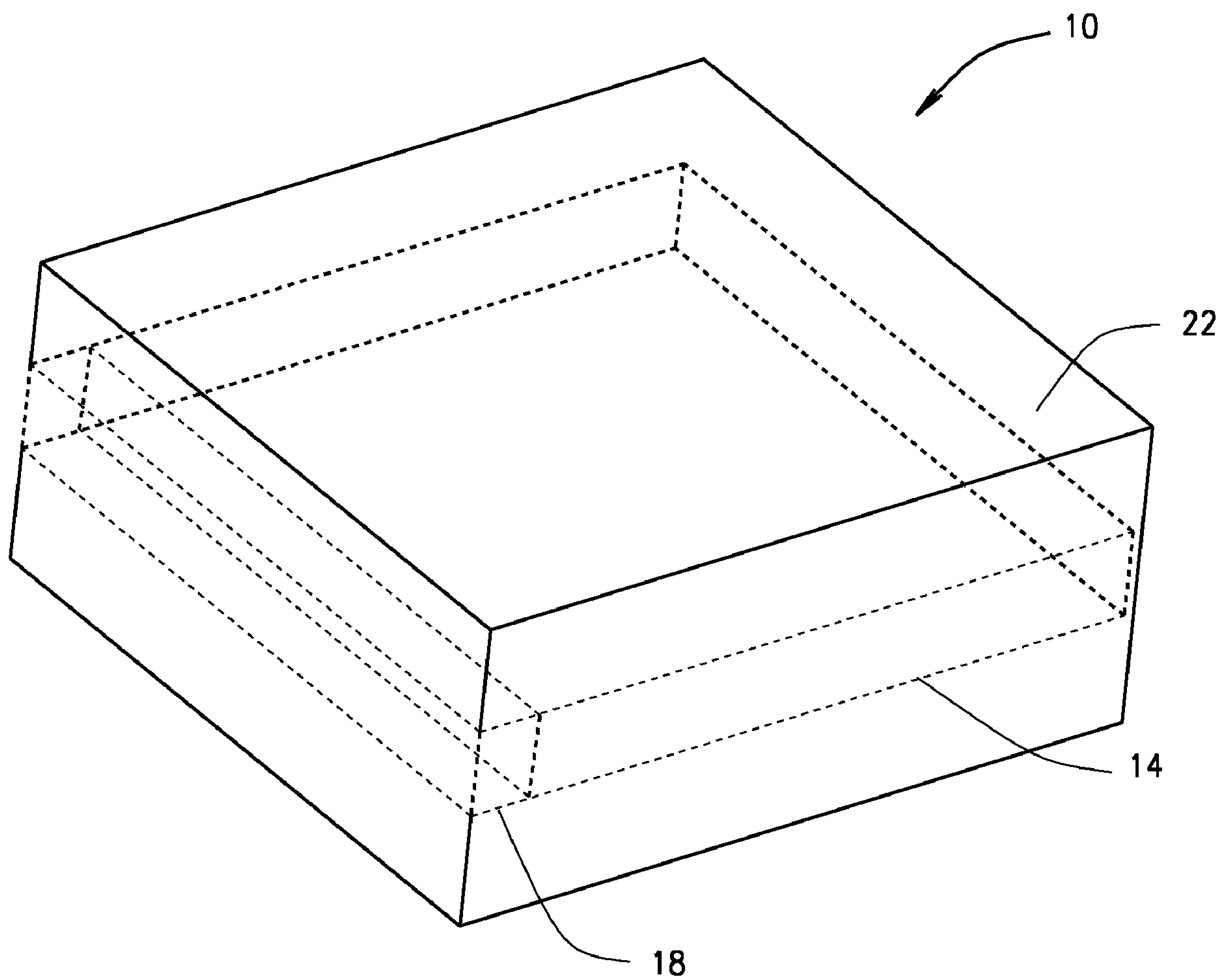
Publication Classification

(51) **Int. Cl.**
F28D 15/02 (2006.01)
F28F 9/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F28D 15/0275*** (2013.01); ***F28D 15/0283*** (2013.01); ***F28F 9/002*** (2013.01); *F28F 2265/22* (2013.01); *F28F 2275/06* (2013.01)

(57) **ABSTRACT**

An oscillating heat pipe (OHP) device that comprise a body having a top face, a bottom face and at least one side face, a plurality of hollow OHP channels formed internally within the body, and an oscillating heat pipe (OHP) flushing duct system. The flushing duct system is formed in at least one of a body top face, a bottom face and at least one side face of an OHP device. The flushing duct system fluidly connects one or more of a plurality of OHP channels formed internally within the OHP device to an ambient environment of the device. The flushing duct system comprising at least one welding receptacle.



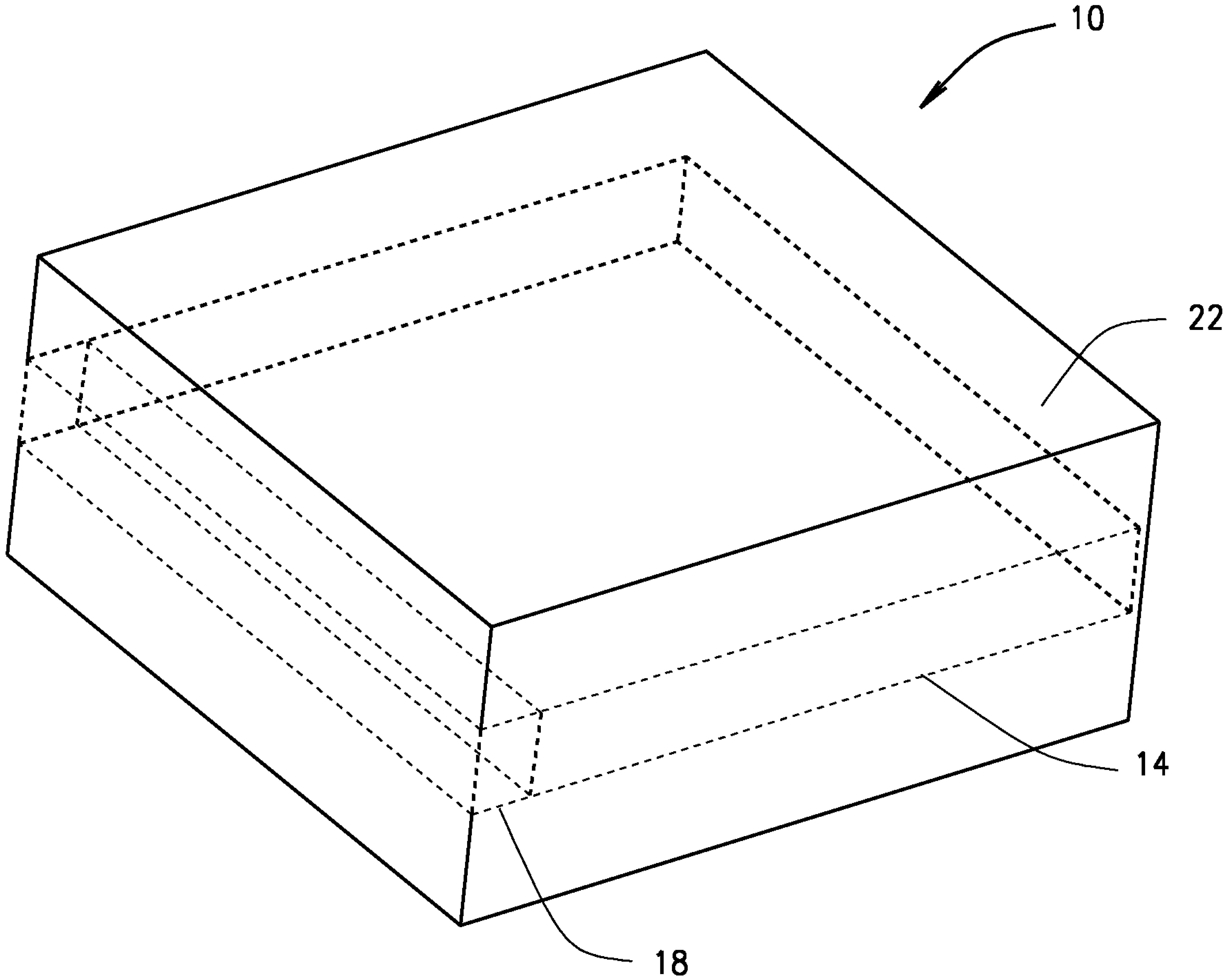


FIG. 1

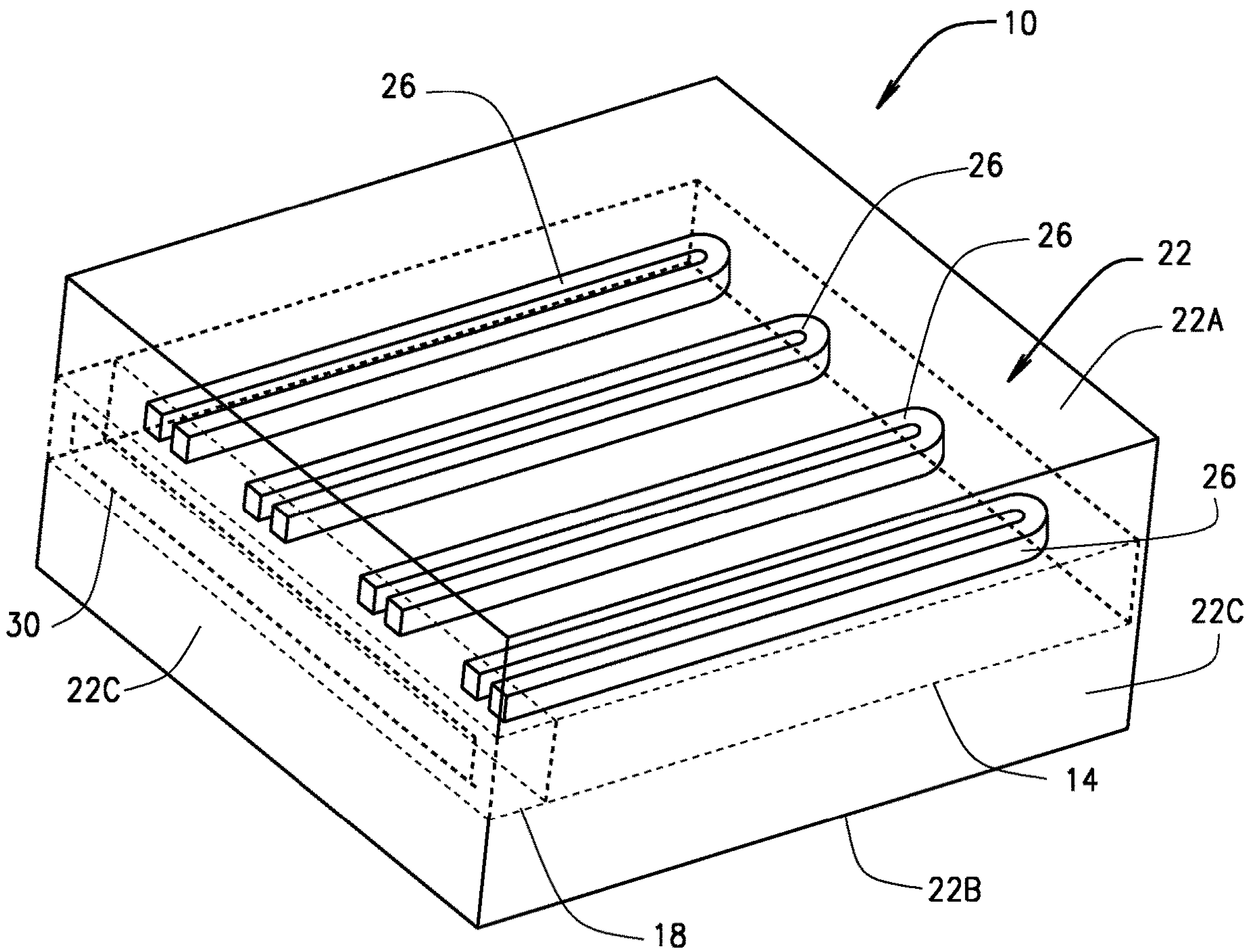


FIG. 2

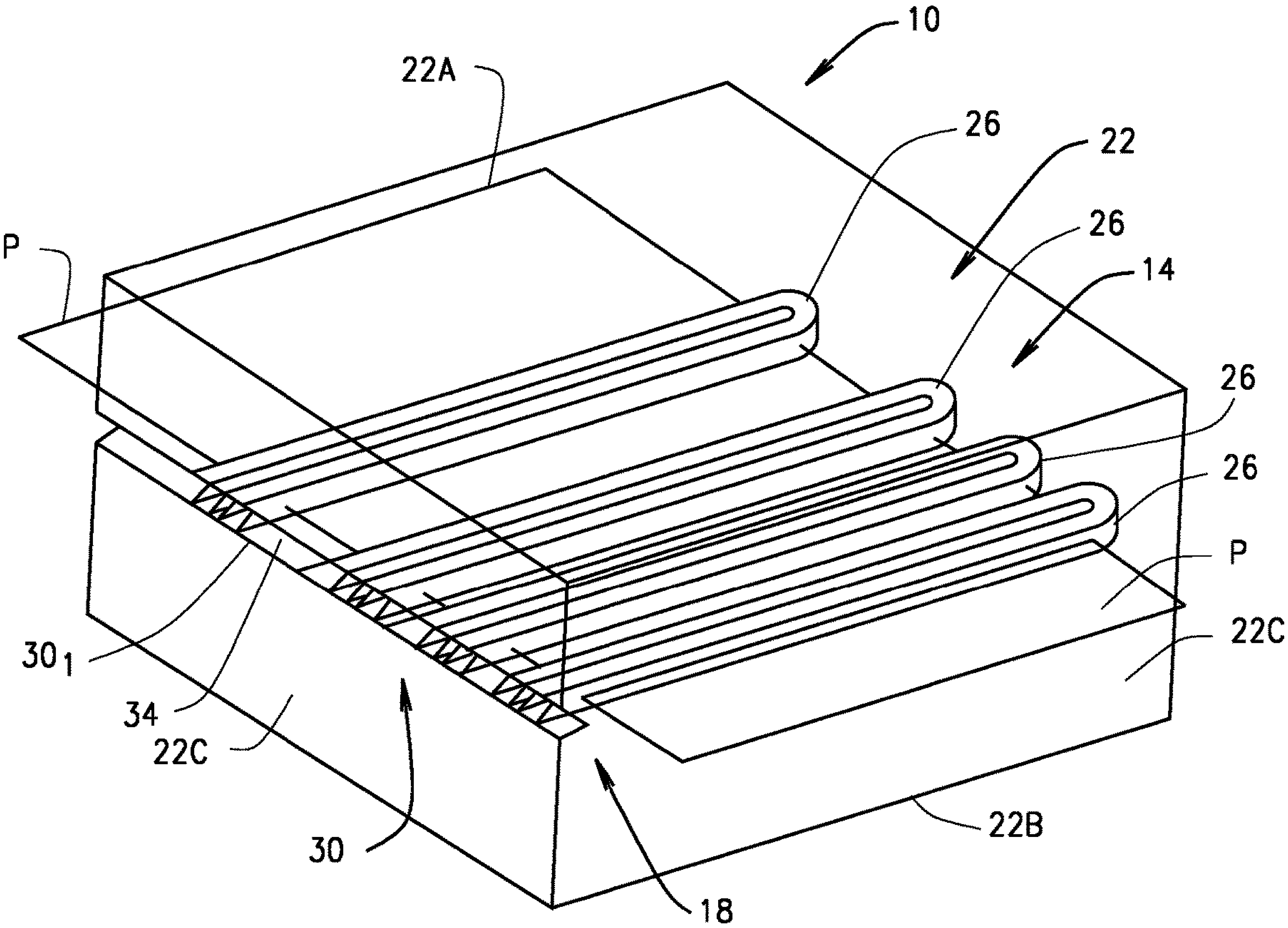

10
22A
26
22
26
14
P
26
26
P
22C
30₁
34
22C
30
18
22B

FIG. 3A

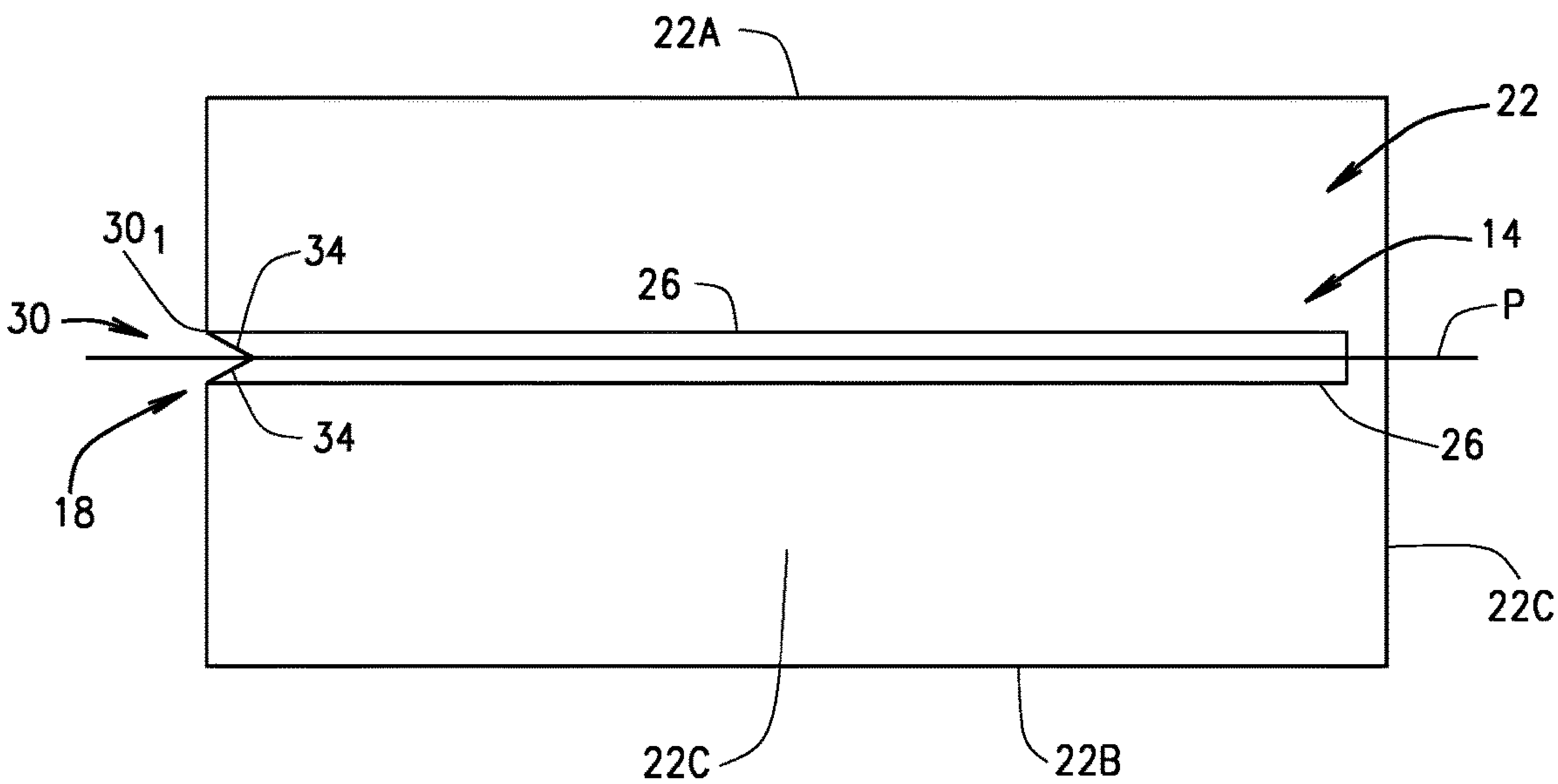

22A
22
30₁
34
14
26
P
30
34
26
18
22C
22C
22B

FIG. 3B

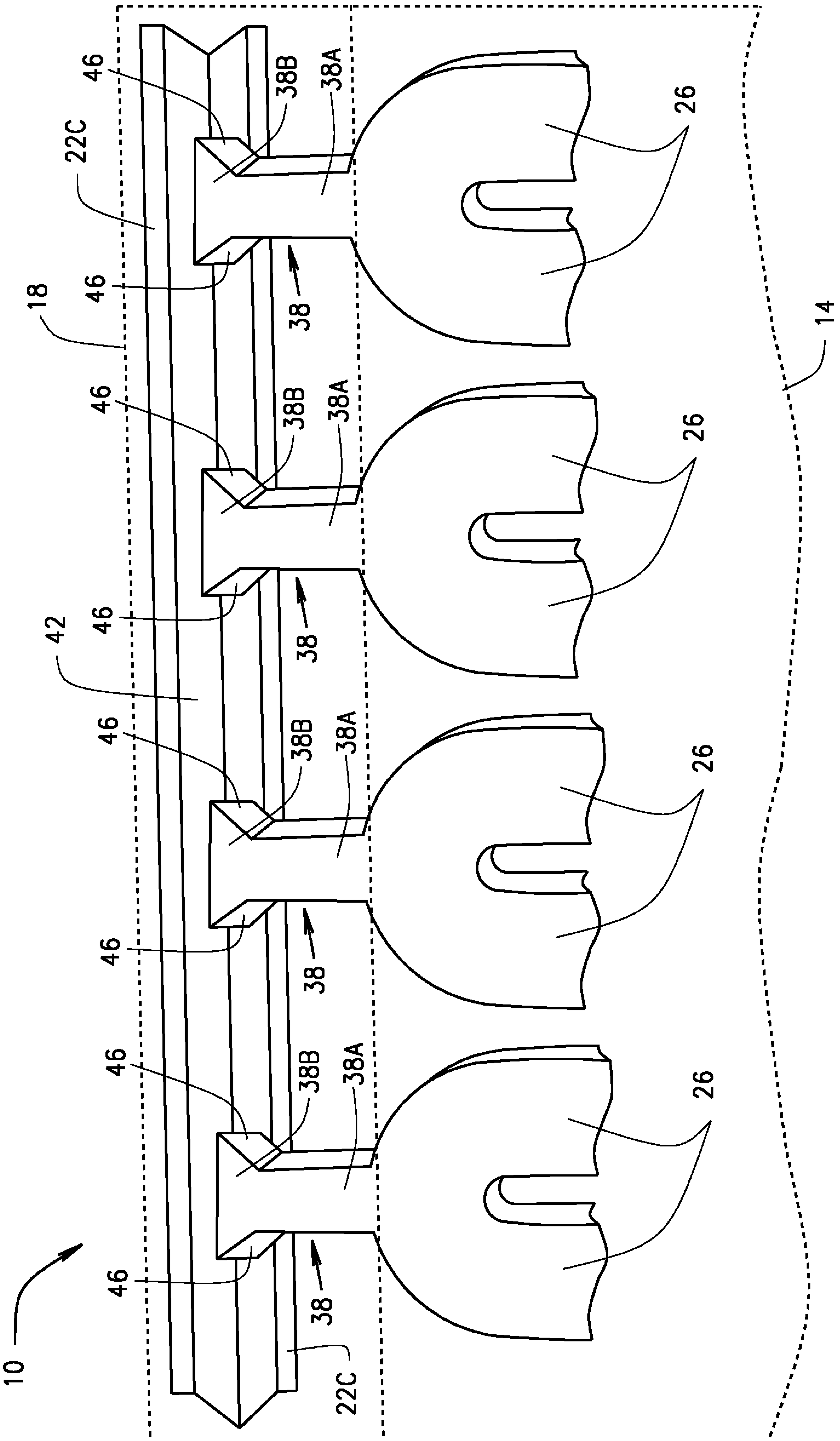


FIG. 4A

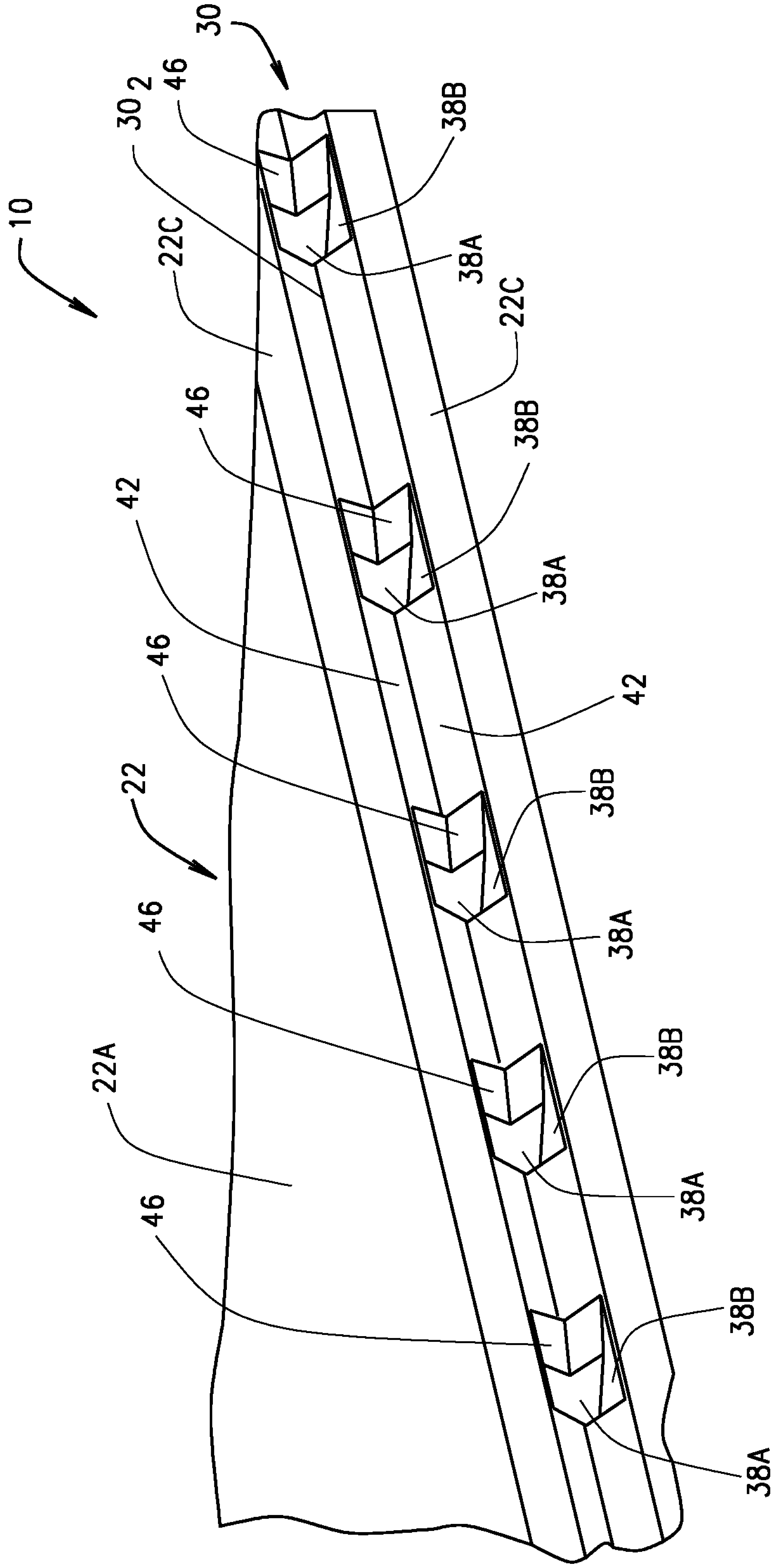

30
30_2
46
38B
10
22C
38A
22C
38B
46
42
38A
42
46
38B
22
38A
46
38B
22A
38A
46
38B
38A

FIG. 4B

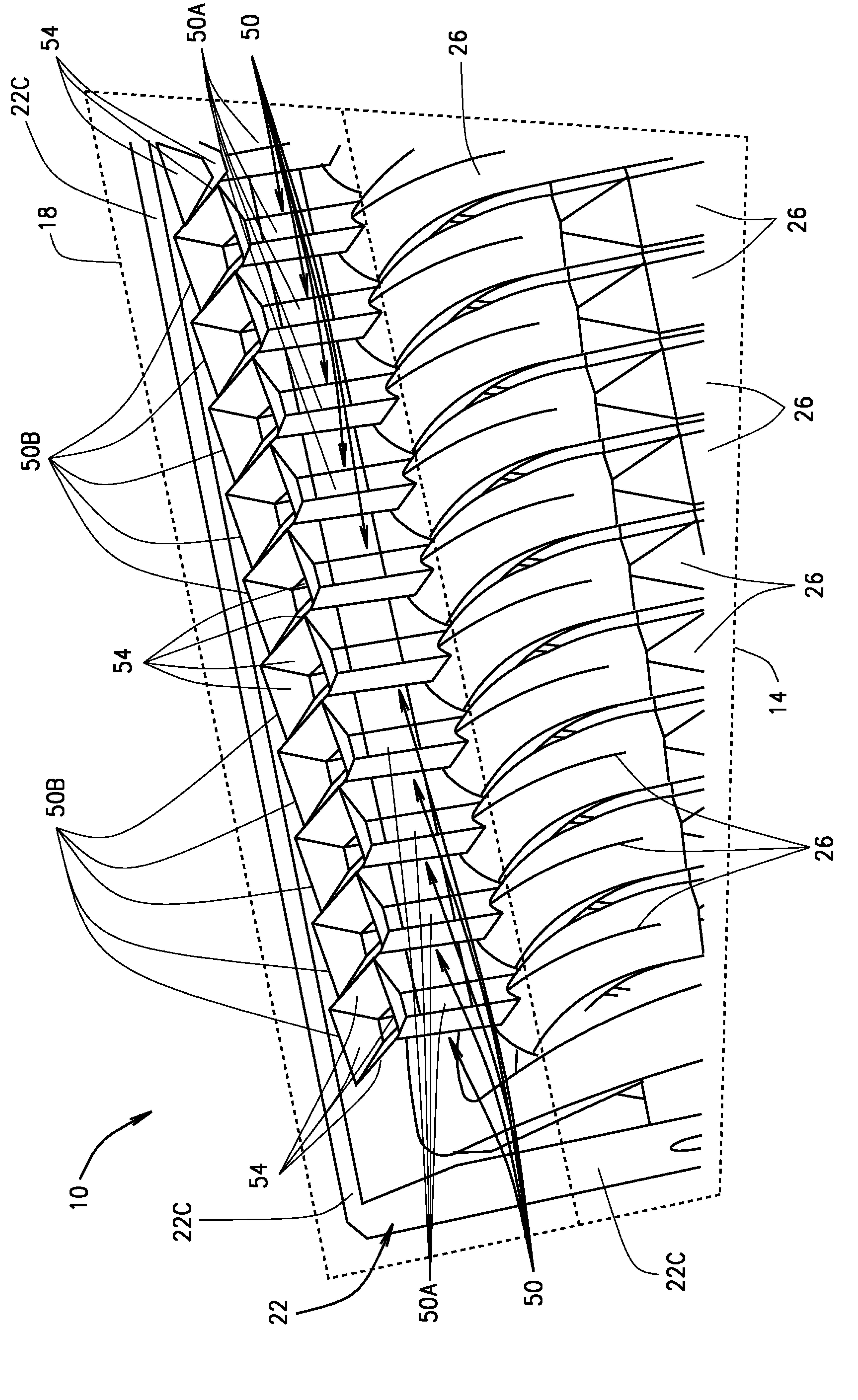


FIG. 5

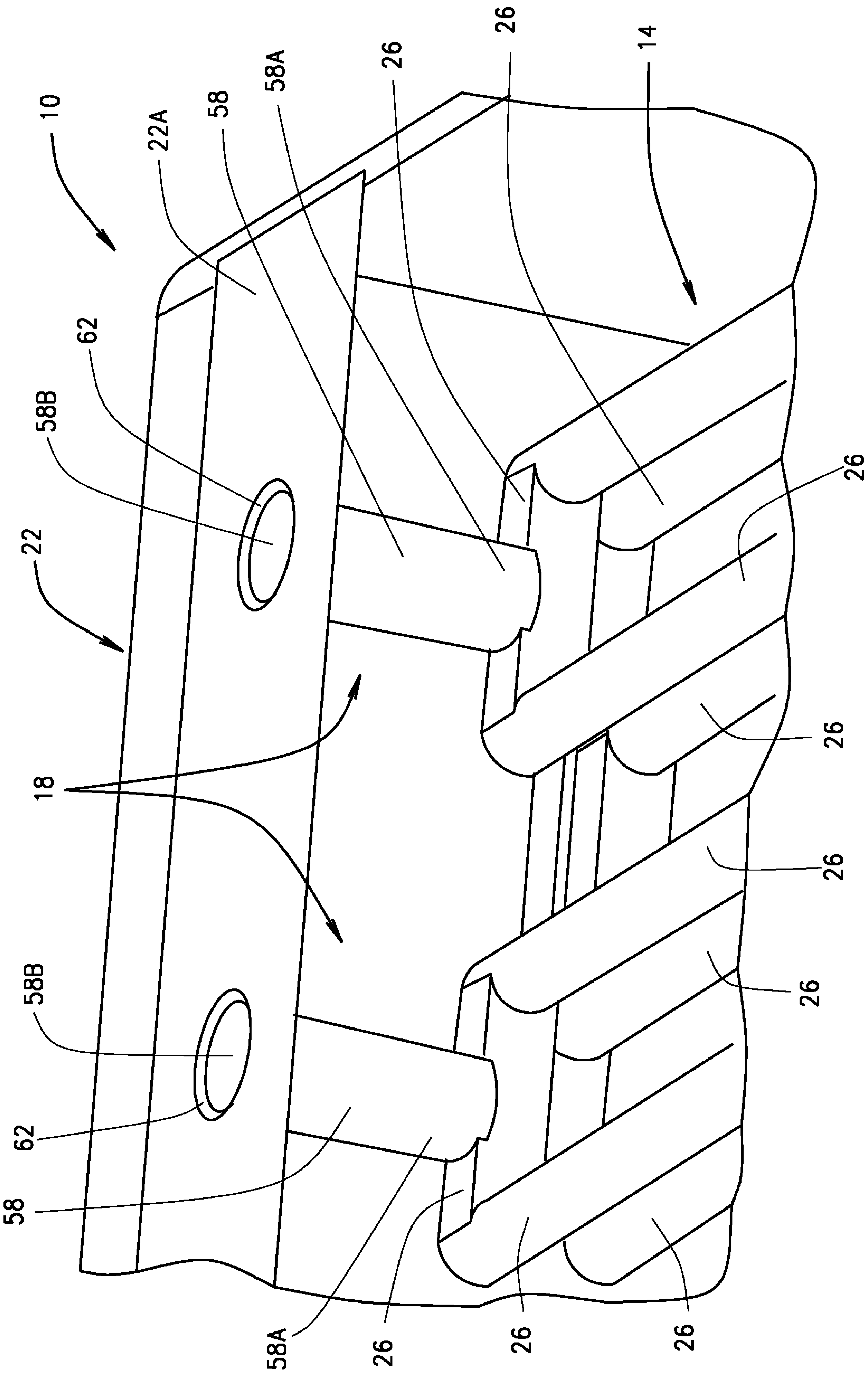


FIG. 6

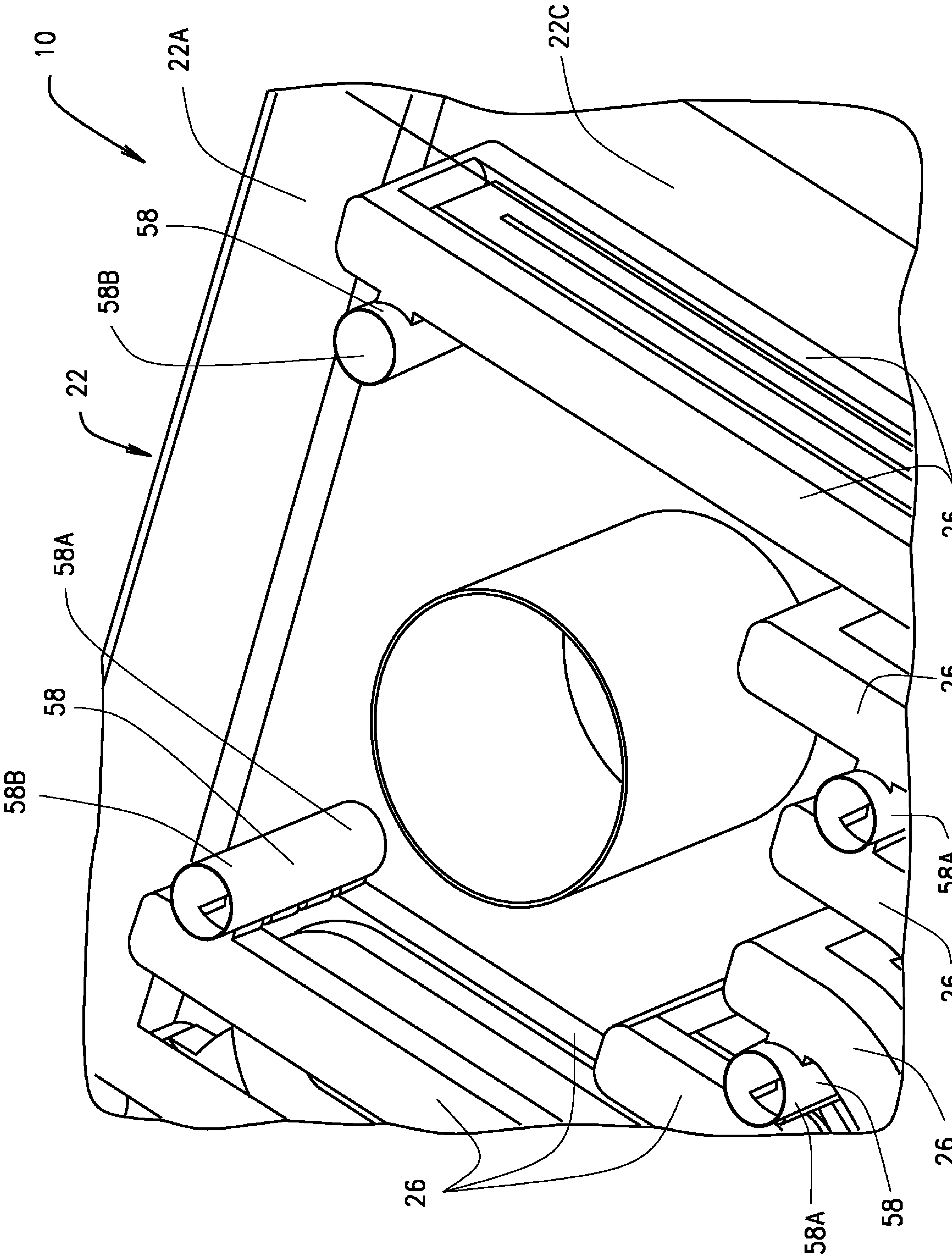


FIG. 7

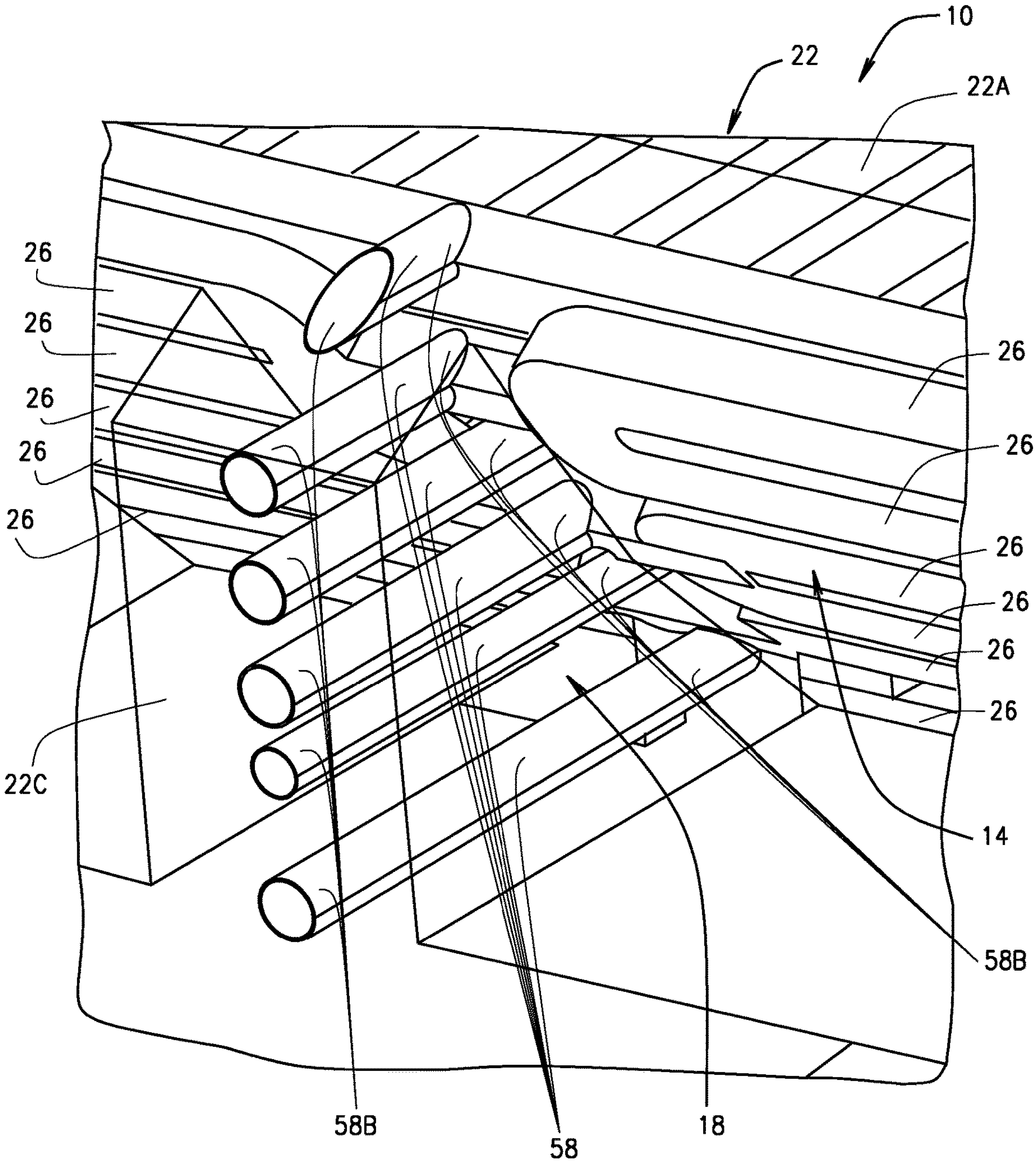


FIG. 8

DN XXXX

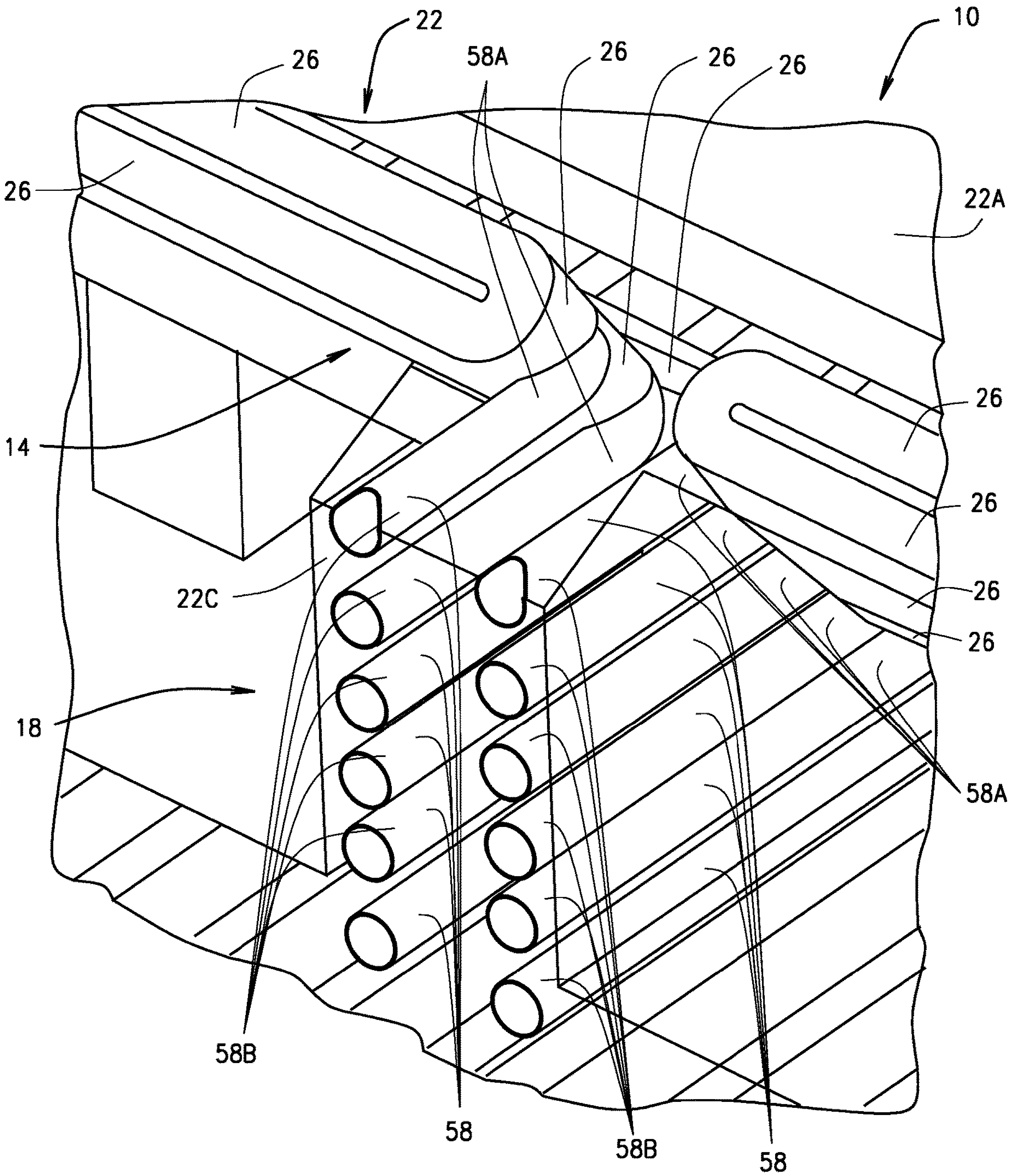


FIG. 9

ADDITIVE MANUFACTURED OSCILLATING HEAT PIPE DEVICE WITH FLUSHABLE CHANNELS

GOVERNMENT RIGHTS

[0001] This invention was developed in the course of work under National Aeronautics and Space Administration (NASA) Contract 80NSSC21C0339. The U.S. government may possess certain rights in the invention.

FIELD

[0002] The present teachings relate to oscillating heat pipe (OHP) devices, and more particularly to OHP devices manufactured using additive manufacturing and methods of manufacturing devices such that the OHP microchannels can be flush free of powder residue resulting from the additive manufacturing.

BACKGROUND

[0003] The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

[0004] Additive manufacturing (e.g., SLS (selective laser sintering), MBJ (metal binder jet), EBAM (electron beam AM), etc.) of oscillating heat pipe (OHP) devices has been attempted but has resulted in the OHP microchannels of the devices (e.g., microchannels between 0.005 inches and 0.100 inches in wall thickness, depth, and width) containing powder residue (e.g., powder left over from printing remains in channels). If this residual powder is not removed from the OHP microchannels, it can cause obstructions, blockages and increased viscous losses that will negatively affect the operation and functionality of the OHP device. For instance, the residual powder can trap or block the working fluid such that the working fluid will be prevented from flowing through a portion of the OHP channels, reduce or stop flow and/or increase the pressure gradient with the OHP channel, thereby reducing cooling efficiency and functionality or preventing operation of the OHP device.

SUMMARY

[0005] The present disclosure provides an OHP device that is fabricated using additive manufactures, and manufacturing methods thereof. Generally, the OHP device of the present disclosure comprises a plurality of OHP channels that are open on one end to allow for the channels to be flushed to clear out the channels. Another term for the removal of powder from these flush ports may be depowdering the channel field. Furthermore, in order to be able to seal the OHP channels after flushing, the channels are constructed to have a weldable geometry. For example, in various embodiments the OHP device of the present disclosure comprises a chamfer feature (with regard to a cross-sectional view) of the exit ports to enable welding thereof. The chamfer feature can be formed in the exterior wall of the open ends of the channels to allow for easy TIG or laser welding to create a final seal of the channels.

[0006] For example, in various embodiments the present disclosure provides an oscillating heat pipe (OHP) device that comprise a body having a top face, a bottom face and at least one side face, a plurality of hollow OHP channels formed internally within the body, and an oscillating heat pipe (OHP) flushing duct system. The flushing duct system is formed in at least one of a body top face, a bottom face and at least one side face of an OHP device. The flushing duct system fluidly connects one or more of a plurality of OHP channels formed internally within the OHP device to an ambient environment of the device. The flushing duct system comprising at least one welding receptacle.

[0007] This summary is provided merely for purposes of summarizing various example embodiments of the present disclosure so as to provide a basic understanding of various aspects of the teachings herein. Various embodiments, aspects, and advantages will become apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the described embodiments. Accordingly, it should be understood that the description and specific examples set forth herein are intended for purposes of illustration only and are not intended to limit the scope of the present teachings.

DRAWINGS

[0008] The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present teachings in any way

[0009] FIG. **1** is a block diagram generically illustrating an oscillating heat pipe (OHP) device comprising OHP channel system and an OHP channel flushing duct system in accordance with various embodiments of the present disclosure.

[0010] FIG. **2** is a block diagram generically illustrating the oscillating heat pipe (OHP) device shown in FIG. **1** wherein the OHP channel system includes a plurality of OHP channels and the OHP channel flushing duct system includes a welding receptacle in accordance with various embodiments of the present disclosure.

[0011] FIGS. **3**A and **3**B exemplarily illustrate the oscillating heat pipe (OHP) device shown in FIGS. **1** and **2** wherein the welding receptacle of OHP flushing duct system comprises an elongated linear welding trough in accordance with various embodiments of the present disclosure.

[0012] FIGS. **4**A and **4**B exemplarily illustrate the oscillating heat pipe (OHP) device shown in FIGS. **1** and **2** wherein the OHP flushing duct system comprises a flush port and an elongated linear welding trough in accordance with various embodiments of the present disclosure.

[0013] FIG. **5** exemplarily illustrates the oscillating heat pipe (OHP) device shown in FIGS. **1** and **2** wherein the OHP flushing duct system comprises a plurality of flush ports and wherein the welding receptacle of the OHP flushing duct system comprises the mouths of the plurality of flush ports in accordance with various embodiments of the present disclosure.

[0014] FIG. **6** exemplarily illustrates the oscillating heat pipe (OHP) device shown in FIGS. **1** and **2** wherein the OHP flushing duct system comprises a plurality of flushing conduits and wherein the welding receptacle of the OHP flushing duct system comprises distal end portions of the plurality of flushing conduits in accordance with various embodiments of the present disclosure.

[0015] FIG. **7** exemplarily illustrates the oscillating heat pipe (OHP) device shown in FIGS. **1** and **2** wherein the OHP flushing duct system comprises a plurality of flushing conduits and wherein the welding receptacle of the OHP flushing duct system comprises distal end portions of the plurality of flushing conduits in accordance with various other embodiments of the present disclosure.

[0016] FIG. **8** exemplarily illustrates the oscillating heat pipe (OHP) device shown in FIGS. **1** and **2** wherein the OHP flushing duct system comprises a plurality of flushing conduits and wherein the welding receptacle of the OHP flushing duct system comprises distal end portions of the plurality of flushing conduits in accordance with yet other embodiments of the present disclosure.

[0017] FIG. **9** exemplarily illustrates the oscillating heat pipe (OHP) device shown in FIGS. **1** and **2** wherein the OHP flushing duct system comprises a plurality of flushing conduits and wherein the welding receptacle of the OHP flushing duct system comprises distal end portions of the plurality of flushing conduits in accordance with still yet other embodiments of the present disclosure.

[0018] Corresponding reference numerals indicate corresponding parts throughout the several views of drawings.

DETAILED DESCRIPTION

[0019] The following description is merely exemplary in nature and is in no way intended to limit the present teachings, application, or uses. Throughout this specification, like reference numerals will be used to refer to like elements. Additionally, the embodiments disclosed below are not intended to be exhaustive or to limit the invention to the precise forms disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art can utilize their teachings. As well, it should be understood that the drawings are intended to illustrate and plainly disclose presently envisioned embodiments to one of skill in the art, but are not intended to be manufacturing level drawings or renditions of final products and may include simplified conceptual views to facilitate understanding or explanation. As well, the relative size and arrangement of the components may differ from that shown and still operate within the spirit of the invention.

[0020] As used herein, the word "exemplary" or "illustrative" means "serving as an example, instance, or illustration." Any implementation described herein as "exemplary" or "illustrative" is not necessarily to be construed as preferred or advantageous over other implementations. All of the implementations described below are exemplary implementations provided to enable persons skilled in the art to practice the disclosure and are not intended to limit the scope of the appended claims.

[0021] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a", "an", and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises", "comprising", "including", and "having" are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps can be employed.

[0022] When an element, object, device, apparatus, component, region or section, etc., is referred to as being "on", "engaged to or with", "connected to or with", or "coupled to or with" another element, object, device, apparatus, component, region or section, etc., it can be directly on, engaged, connected or coupled to or with the other element, object, device, apparatus, component, region or section, etc., or intervening elements, objects, devices, apparatuses, components, regions or sections, etc., can be present. In contrast, when an element, object, device, apparatus, component, region or section, etc., is referred to as being "directly on", "directly engaged to", "directly connected to", or "directly coupled to" another element, object, device, apparatus, component, region or section, etc., there may be no intervening elements, objects, devices, apparatuses, components, regions or sections, etc., present. Other words used to describe the relationship between elements, objects, devices, apparatuses, components, regions or sections, etc., should be interpreted in a like fashion (e.g., "between" versus "directly between", "adjacent" versus "directly adjacent", etc.).

[0023] As used herein the phrase "operably connected to" will be understood to mean two are more elements, objects, devices, apparatuses, components, etc., that are directly or indirectly connected to each other in an operational and/or cooperative manner such that operation or function of at least one of the elements, objects, devices, apparatuses, components, etc., imparts or causes operation or function of at least one other of the elements, objects, devices, apparatuses, components, etc. Such imparting or causing of operation or function can be unilateral or bilateral.

[0024] As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. For example, A and/or B includes A alone, or B alone, or both A and B.

[0025] Although the terms first, second, third, etc. can be used herein to describe various elements, objects, devices, apparatuses, components, regions or sections, etc., these elements, objects, devices, apparatuses, components, regions or sections, etc., should not be limited by these terms. These terms may be used only to distinguish one element, object, device, apparatus, component, region or section, etc., from another element, object, device, apparatus, component, region or section, etc., and do not necessarily imply a sequence or order unless clearly indicated by the context.

[0026] Moreover, it will be understood that various directions such as "upper", "lower", "bottom", "top", "left", "right", "first", "second" and so forth are made only with respect to explanation in conjunction with the drawings, and that components may be oriented differently, for instance, during transportation and manufacturing as well as operation. Because many varying and different embodiments may be made within the scope of the concept(s) taught herein, and because many modifications may be made in the embodiments described herein, it is to be understood that the details herein are to be interpreted as illustrative and non-limiting.

[0027] FIG. **1** is a block diagram generically illustrating an oscillating heat pipe (OHP) device **10** comprising an OHP channels system **14** integrally formed within a body **22** of the OHP device **10** and a flushing duct system **18** integrally formed within a body **22** of the OHP device **10**, in accordance with various embodiments of the present disclosure. The OHP device **10** can be fabricated using generally any desired manufacturing or fabrications process, however OHP device **10** will be exemplarily described and illustrated herein as being fabricated utilizing an additive manufacturing method wherein the OHP channel system **14** and the flushing duct system **18** are integrally formed within the body **22** of the OHP device **10** during the printing of the OHP device **10**. As described in detail further below, the flushing duct system **18** is structured and operable to fluidly connect the OHP channel system **14** to the ambient environment such that a flushing or depowdering process can be performed to flush out or depowder (i.e., remove) any debris and/or any residual fabrication dust, powder or particles disposed within the OHP channel system **14**. For example, in various embodiments, a flushing fluid can be flushed through the OHP channel system **14** to flush out any debris and/or any residual fabrication dust, powder or particles disposed within the OHP channel system **14**. As also described in detail further below, the flushing duct system **18** is further structured and operable to provide a means for hermetically sealing the flushing duct system **18**, and hence the OHP channel system **14** from the ambient environment after the OHP channel system **14** has been flushed.

[0028] As described above, in various embodiments the flushing process can comprise forcing a flushing fluid through the OHP channel system **14** to flush out and remove any debris and/or any residual fabrication dust or particles. In such instances, the flushing fluid can be any suitable flushing fluid such as acetone, isopropyl alcohol (IPA), or deionized water. Alternatively, it is envisioned that the OHP channel system **14** can be flushed, via the flushing duct system **18**, using any other suitable flushing method, for example, gas flushing with pressurized nitrogen dioxide (N2), feeding a wire or micro-size brush through OHP channel system **14**, using an acid etching process, using a thermal shock method, using a vibration method, etc. Furthermore, although the body **22** of OHP device **10** is exemplarily illustrated throughout the various figures to generally have a 3D rectangular cuboid shape, the OHP device body **22** can have any desired shape. More specifically, in various embodiments the OHP device **10** comprising the OHP channel system **14** and the flushing duct system **18** is exemplarily described and illustrated herein as being an OHP electronics device for use in applications where ventilation and/or ambient air cooling of the OHP device **10** are unavailable or restricted. For example, the OHP device **10** as described herein can be utilized for aircraft electronics, wherein the body **22** is a flat rectangular cuboid electronics substrate (e.g., a circuit board) having the OHP channel system **14** and the flushing duct system **18** integrally formed therein. However, it is envisioned that the OHP device **10** can be utilized in any complex geometry in which an OHP device **10** will well serve the respective thermal needs. For example, the OHP device **10** can have any shape and geometry needed to suit any configuration and application, such as electronics boards for aircraft battery banks that have curved edge regions (e.g., contour to the shape of each battery cell). Furthermore, the OHP device **10** can be something other than a substrate for electronics. Wherein the OHP device **10** can have a variety of complex geometries configured to suit a particular need. For example, it is envisioned that OHP device **10** can be a contoured panel configured as a leading edge of an aircraft wing.

[0029] Referring now to FIGS. **1** and **2**, the OHP device body **22** comprises a top face **22**A and bottom face **22**B and one or more side face **22**C. For example, in embodiments wherein the body **22** has a rectangular cuboid shape the body **22** will comprise four side faces **22**C, or in embodiments wherein the body **22** has a triangular prism shape the body **22** will comprise three side faces **22**C, or in embodiments wherein the body **22** has a cylindrical shape, the body **22** will comprise one side face **22**C, etc. The flushing duct system **18** is disposed in or formed in one or more of the top face **22**A, the bottom face **22**B and the side face(s) **22**C. The OHP channel system **14** comprises one or more meandering OHP channel **26** that fluidly connects with the flushing duct system **18** to thereby fluidly connect each OHP channel **26** to the ambient environment. Additionally, as described further below, the flushing duct system **18** comprises one or more welding receptacle **30** structured and operable to aid in hermetically sealing the OHP channels **26** from the ambient environment after the OHP channels have been flushed as described herein. Particularly, the welding receptacle(s) **30** is/are structured and operable to receive a sealant (e.g., a welding material for use with laser welding or tungsten inert gas (TIG) welding) to hermetically seal the OHP channels **26** from the ambient environment after the OHP channels **26** have been flushed.

[0030] The OHP channels **26** can comprise one or more closed loop OHP channel **26** and/or one or more open loop OHP channel **26**. Additionally, in various embodiments, the body **22** OHP device **10** can comprise one or more two-dimensional (2D) planar layer of OHP channels **25**, wherein each OHP channel **26** lies within a respective 2D planar layer. That is, each OHP channel **26** lies within a respective two-coordinate plane (i.e., within a respective X and Y coordinate plane). Alternatively, in various embodiments, the body **22** OHP device **10** can comprise one or more three-dimensional (3D) OHP channel **26** that is formed within the body **22** to lie within a three-coordinate space (i.e., within an X, Y and Z coordinate space). In all embodiments, each OHP channel **26** is fluidly connected to a respective one of the flushing duct system **18**. In various embodiments, the OHP channels **26** are micro-sized channels (i.e., micro-channels) having maximum cross-sectional height and width between 0.001 inch and 1.0 inch (e.g., between 0.005 inch and 0.100 inch). Additionally, the OHP channels can have any cross-sectional shape. For example, the cross-sectional shape of the OHP channels **26** square, rectangular, triangular, teardrop, trapezoidal, pentagonal, hexagonal, polygonal, chamfered roof shape or any other desired cross-sectional shape and remain within the scope of the present disclosure. In addition to the flushing duct system **18** fluidly connecting each OHP channel **26** to the ambient environment so that each OHP channel **26** can be flushed to remove all debris and/or sintering powder residue the flushing duct system **18** is structured and operable to provide a means for each OHP channel **26** to be hermetically sealed after flushing.

[0031] Generally, the OHP device **10** is a passive heat transfer device that transports heat using a saturated two-phase working fluid hermetically sealed within the capillary-sized OHP channels **26** (e.g., micro-channels). The hydraulic diameter of the OHP channels **26** is small enough and the surface tension of the working fluid is great enough such that the OHP channels **26** have a capillary effect on the working fluid causing the working fluid to disperse itself throughout the interior area of the OHP channels **26** in discrete liquid "plugs" and vapor "bubbles". As described above, the OHP channels **26** have a meandering path traveling between areas of the body **22** in thermal contact with one or more heat source (e.g., as an electronic device such as an integrated circuit semiconductor device, or other heat generating device that is provided, disposed, integrally formed with, or fabricated on the body **22**) and areas of the body **22** in thermal contact with one or more heat sink or cooling zone. When heat from a heat source is absorbed by the working fluid, the resulting working fluid evaporation and condensation process, as described below, creates pressure imbalances within the OHP channels **26** that, coupled with the random distribution of liquid plugs and vapor bubbles, generates motion of the two-phase mixture within the OHP channels.

[0032] More specifically, the OHP channels **26** are integrally formed within the body **22** and pass near and/or adjacent and in close proximity (e.g., within approximately one to hundreds of microns) to one or more heat source and the capillary dimensions of the OHP channels **26** (e.g., from hundreds of nanometers to tens of thousands of microns, and in some instances up to approximately 1.0 ince) force the working fluid into a train of liquid plugs and vapor bubbles. As heat is absorbed from the heat source(s) by the working fluid within the OHP channels **26**, evaporation and condensation of the working fluid occurs that cause a pressure imbalance from heat absorption region(s) (also known as evaporator region(s)) of the OHP channels **26** to heat rejection region(s) (also known as condenser region(s)) of the OHP channels **26**. The heat absorption regions/evaporator regions of the OHP channels **26** are areas OHP channels **26** where the OHP channels **26** pass within the body **22** near and/or adjacent and close proximity to one or more heat source regions of the body **22**. The heat source regions of the body **22** are regions of the body **22** having one or more heat generating device disposed on or integrally formed with the body **22** (e.g., one or more electronic device such as an integrated circuit semiconductor device, or other heat generating device that is provided, disposed, integrally formed with, or fabricated on the body **22**). The heat rejection region(s)/condenser region(s) of the OHP channels **26** are the regions of the OHP channels **26** that pass within the body **22** near and/or adjacent a cooling zone of the body **22**. The cooling zone of the body **22** is a region of the body **22** not occupied by a heat generating device and/or near and/or adjacent and/or in close proximity to and in thermally conductive contact with one or more heat sink. For example, the cooling zone(s) of the body **22** is/are region(s) of the body **22** where the OHP channels **26** pass within the body **22** near and/or adjacent a region of top face **22**A, the bottom face **22**B, or a side face **22**C that is not occupied by a heat generating device and is/are exposed to ambient air, and/or is/are in thermally conductive contact with one or more heat sink.

[0033] This pressure imbalance forces the working fluid to move within the OHP channels **26**, transferring heat (e.g., both latent and sensible heat) from the heat absorption region(s)/evaporation regions(s) of the OHP channels **26** to the heat rejection region(s) **22**/condenser regions(s) of the OHP channels **26**, thereby removing heat from, and cooling, the respective heat generating devices, and the overall body **26**. More specifically, when heat is absorbed at the heat absorption region(s) of the OHP channels **26**, bubbles are formed by partial vaporization of the working fluid within the channels in the heat source region(s). The bubbles' expansion is limited radially by the fixed diameter of the OHP channels **26** and thus, the bubbles expand axially (i.e., along the length of the OHP channels **26**). The axial-wise expansion dislodges neighboring plugs/bubbles in the OHP channels **26** and forces them away from the heat source region(s) of the body **22**. The dislodged vapor phase working fluid moves through the OHP channels **26** to the heat rejection region(s) adjacent the cooling zones of the body **22** where the heat of the vapor phase working fluid is rejected into the ambient air and/or heat sink such that the vapor phase working fluid converts back to liquid phase, which then moves back to the heat absorption region(s) of the OHP channels **26** to repeat the vaporization-condensation cycle to continuously remove heat from, and cool, the respective heat generating devices, and the OHP device **10** overall.

[0034] As described above, the pattern of OHP channels **26** can form a closed-loop (e.g., circulating), or they can be sealed at each end to form an open-loop (e.g. serpentine or linear). Furthermore, the pattern of OHP channels **26** can travel in two dimensions (i.e., in x-y plane or in a r-θ plane) or in all three physical dimensions (i.e., x-y-z and/or r-θ-h). The cross-sectional geometry of the OHP channels **26** can have generally any desired shapes and OHP channel lengths can vary (e.g., from less than 1 cm to greater than 10 m) so long as the OHP channels **26** maintain the capillary effect where the working fluid inside the channel volume is dispersed in discrete liquid "plugs" and vapor "bubbles". The working fluid can be any desired working fluid selected based on its thermophysical properties (e.g., vapor pressures, latent heats, specific heats, densities, surface tensions, critical temperatures, pour points, viscosities, etc.) and compatible with the material(s) used to form the body and channels.

[0035] As also described above, the OHP device **10**, can be made from a wide range of material and/or fluid combinations and in generally any shape and size desired in order to meet the specifications of a given application's heat source(s) and heat sink(s) or rejection regions(s) (e.g. the respective sizes, heat loads, heat fluxes, locations, temperatures, gravitational fields, coefficients of thermal expansion requirements, etc., of the OHP device **10**). More particularly, the OHP device **10** can be formed using any desired manufacturing or fabrication process. As exemplarily described herein, in various embodiments the OHP device **10** comprising the OHP channel system **14** and the flushing duct system **18** disclosed herein is ideally suited for fabrication utilizing additive manufacturing techniques to inherently form the OHP channels **26** within the body **22** such as SLS (selective laser sintering), SLM (selective laser melting), DMLM (direct metal laser melting), PBF (powder bed fusion), MBJ (metal binder jet), Cold Spray, Electrochemical additive manufacturing (ECAM), EBAM (electron beam additive manufacturing), or any other powder based directed energy deposition technique.

[0036] Generally, any suitable material can be used with such additive manufacturing techniques such as steels, cobalt chromes, precious metals such as gold, silver platinum, etc., or other suitable materials including but not limited to AlSi10Mg, Al6061, and other aluminum alloys; aluminum metal matrix composites; 316SS, 17-4PH, 316L, and other Fe-based printed alloys; Inconel 625, Inconel 718, Hastelloy X, and other Ni super alloys; C103, Niobium alloys, Tungsten alloys, Molybdenum alloys, specifically high Rhenium alloys, Ti6Al4V and other Titanium alloys;

99%+Cu, GRCop-84, GRCop-42, Cu110, and other copper alloys; ceramic printed with binder jet, or alternatively various not-metals such as polymers, composites, glass, etc. When the OHP device **10** is fabricated using such additive manufacturing techniques, the OHP channel system **14** and the flushing duct system **18** can be directly printed in place, or alternatively the flushing duct system **18** can be cut into the OHP device **10** with a ball endmill or other milling operation.

[0037] Although the OHP device **10** comprising the flushing duct system **18** disclosed herein is ideally suited for devices fabricated using additive manufacturing techniques, it is envisioned that alternatively, in various other embodiments, the OHP device **10** can be fabricated or manufactured using other fabricating or manufacturing methods or processes, for example the OHP channel system **14** (comprising the OHP channels **26**) and the flushing duct system **18** can be formed using bulk micromachining, surface micromachining, deep reactive ion etching, LIGA (lithography, electroplating, and molding), hot embossing, micro-EDM (electrical discharge machining), XeF2 Dry Phase Etching, focused ion beam micromachining, CVD (chemical vapor deposition), and/or PVD (physical vapor deposition) and then sealing the OHP channels **26** with a lid or cover; welding, laminating brazing or diffusion bonding multiple layers together, or any other suitable known or unknown manufacturing or fabricating process.

[0038] Referring now to FIGS. **3**A and **3**B, as described above the OHP system **14** comprises a plurality of OHP channels **26** that can be disposed within the body **22** in a closed-loop or open-loop configuration and in a 2D or 3D configuration. FIGS. **3**A and **3**B exemplarily illustrate the OHP channels **26** in a 2D open-loop configuration where all the OHP channels lie within a common plane P. Additionally, in various embodiments, the welding receptacle(s) **30** of flushing duct system **14** comprises one or more elongated linear welding trough **301** disposed within one or more of the top, bottom and/or side faces **22**A, **22**B and/or **22**C. Additionally, the elongated linear welding trough(s) **301** is/are disposed within the plane P of the OHP channels **26**, that is, the elongated linear welding trough(s) **301** is/are disposed 'in-plane' with OHP channels **26**. Each of the OHP channels **26** are fluidly connected to a respective one of the elongated linear welding trough(s) **301**. Each of the one of the elongated linear welding trough(s) **301** extends linearly across at least a portion of the respective top, bottom and/or side face **22**A, **22**B and/or **22**C. For example, as exemplarily illustrated in FIGS. **3**A and **3**B, in various embodiments, the elongated linear welding trough(s) **301** comprises a single linear welding trough **301** that extends entirely across one of a plurality of side faces **22**C of the OHP device body **22**. Moreover, in various embodiments, the elongated linear welding trough(s) **301** comprise(s) one or more tapered, beveled, chamfered, or angled sidewall **34**. For example, as exemplarily illustrated in FIGS. **3**A and **3**B, in various embodiments, the elongated linear welding trough **301** comprises two tapered/beveled/chamfered/angled sidewalls **34** that form a V-shaped linear trough.

[0039] The angle of the tapered/beveled/chamfered/angled linear welding trough sidewall(s) **34** relative to the outer surface of the one or more top, bottom and/or side face **22**A, **22**B and/or **22**C can be any desired angle, e.g., 25°, 30°, 35°, 40°, 45°, 50°, etc. The tapered/beveled/chamfered/angled sidewall(s) **34** 'open up' or widen the elongated linear welding trough(s) **301** at the outer surface of the one or more top, bottom and/or side face **22**A, **22**B and/or **22**C to aid in the efficacy of hermetically sealing the OHP channels **26**. Particularly, the tapered/beveled/chamfered/angled sidewall(s) **34** provide increased surface area for the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy) to contact and adhere to the sidewall(s) **34** (e.g., provides better mechanical bond with the sidewall(s) **34** and avoids voids in the weld and provides a hermetic seal). Additionally, the widened elongated linear welding trough(s) **301** provide(s) a larger target zone in which to apply the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy). Additionally, in various embodiments wherein the sealant is a laser welding alloy and the OHP channels **26** is/are hermetically sealed using a laser welding process, the widened elongated linear welding trough(s) **301** provide(s) a broader field of view for the welding laser.

[0040] Referring now to FIGS. **4**A and **4**B, FIG. **4**A is an exemplary isometric view of a portion of the OHP device **10** wherein a portion of the body **22** has been removed to illustrate the OHP channel system **14** and the flushing duct system **18** integrally formed internally within the body **22** in accordance with various embodiments of the present disclosure. FIG. **4**B is an isometric view of the OHP device **10** shown in FIG. **4**A having the body **22** shown. As described above the OHP system **14** comprises a plurality of OHP channels **26** that can be disposed internally within the body **22** in a closed-loop or open-loop configuration and in a 2D or 3D configuration. FIGS. **4**A and **4**B exemplarily illustrate the OHP channels **26** in a 2D configuration wherein the OHP channels **26** can be interpreted to be in an open-loop or closed-loop configuration and wherein all the OHP channels **26** lie within a common plane P. The common plane P is not shown in FIGS. **4**A and **4**B but is easily and readily understood by one skilled in the art with reference to FIG. **3**A.

[0041] In various embodiments, the flushing duct system **18** comprises at least one flush port **38** and the one or more welding receptacle **30**. In various instances the welding receptacle(s) **30** comprises one or more elongated linear welding trough **302** disposed within one or more of the top, bottom and/or side faces **22**A, **22**B and/or **22**C. Each flush port **38** is fluidly connected to a corresponding one of the plurality of OHP channels **26** and the linear welding trough **302** fluidly connects with the plurality of OHP channels **26** via the flush port(s) **38**. Each of the elongated linear welding trough(s) **302** extend(s) linearly across at least a portion of the respective top, bottom and/or side face **22**A, **22**B and/or **22**C. For example, as exemplarily illustrated in FIGS. **4**A and **4**B, in various embodiments, the one or more elongated linear welding trough **302** comprises a single linear welding trough **302** that extends entirely across one of a plurality of side faces **22**C of the OHP device body **22**. Each flush port **38** comprises a tubular neck **38**A fluidly connected to a respective one of the plurality OHP channels **26** and mouth **38**B integrally formed with the neck **38**A and fluidly connected to linear welding trough(s) **302** and the ambient environment, thereby fluidly connecting each OHP channel to the ambient environment.

[0042] In various embodiments, the flush port(s) **38** and the elongated linear welding trough(s) **302** is/are disposed within the plane P of the OHP channels **26**. That is, as exemplarily illustrated in FIGS. **4**A and **4**B, in various embodiments the flush port(s) **38** extend from the OHP channels **26** 'in-plane' with OHP channels **26**, whereby the elongated linear welding trough(s) **302** is/are also disposed 'in-plane' with OHP channels **26**. Alternatively, in various embodiments, the flush port(s) **38** can extend from the OHP channels **26** 'out-of-plane' with OHP channels **26**, whereby the elongated linear welding trough(s) **302** is/are also disposed within the one or more top, bottom and/or side faces **22**A, **22**B and/or **22**C 'out-of-plane' with OHP channels **26**, For example, the flush port(s) **38** can extend from the OHP channels **26** at any desired angle (e.g., 20°, 30°, 40°, 50°, 60°, 70°, 70°, 90°, etc.), whereby the elongated linear welding trough(s) **302** will be disposed within the one or more top, bottom and/or side faces **22**A, **22**B and/or **22**C 'out-of-plane' with OHP channels **26**.

[0043] In various embodiments, the elongated linear welding trough(s) **302** comprise(s) one or more tapered, beveled, chamfered, or angled sidewall **42**. For example, as exemplarily illustrated in FIGS. **4**A and B, in various embodiments, the elongated linear welding trough **302** comprises two tapered/beveled/chamfered/angled sidewalls **42** that form a V-shaped linear trough. The angle of the tapered/beveled/chamfered/angled linear welding trough sidewall(s) **42** relative to the outer surface of the one or more top, bottom and/or side face **22**A, **22**B and/or **22**C can be any desired angle, e.g., 25°, 30°, 35°, 40°, 45°, 50°, etc. The tapered/beveled/chamfered/angled sidewall(s) **42** 'open up' or widen the elongated linear welding trough(s) **302** at the outer surface of the one or more top, bottom and/or side face **22**A, **22**B and/or **22**C to aid in the efficacy of hermetically sealing the OHP channels **26**. Particularly, the tapered/beveled/chamfered/angled sidewall(s) **42** provide increased surface area for the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy) to contact and adhere to the sidewall(s) **42** (e.g., provides better mechanical bond with the sidewall(s) **42** and avoids voids in the weld and provides a hermetic seal). Additionally, the widened elongated linear welding trough(s) **302** provide(s) a larger target zone in which to apply the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy). Additionally, in various embodiments wherein the sealant is a laser welding alloy and the OHP channels **26** is/are hermetically sealed using a laser welding process, the widened elongated linear welding trough(s) **302** provide(s) a broader field of view for the welding laser.

[0044] Additionally, in various embodiments, the mouth **38**B of each flush port **38** comprises one or more tapered, beveled, chamfered, or angled sidewall **46**. For example, as exemplarily illustrated in FIGS. **4**A and B, in various embodiments, each flush port mouth **38**B comprises two opposing tapered/beveled/chamfered/angled sidewalls **46**. The angle of the tapered/beveled/chamfered/angled flush port mouth sidewalls **46** relative to the outer surface of the one or more top, bottom and/or side face **22**A, **22**B and/or **22**C in which the elongated linear welding trough **302** is formed can be any desired angle, e.g., 25°, 30°, 35°, 40°, 45°, 50°, etc. The tapered/beveled/chamfered/angled sidewall(s) **46** 'open up' or widen the respective flush port mouth **38**B to aid in the efficacy of hermetically sealing the OHP channels **26**. Particularly, the tapered/beveled/chamfered/angled sidewall(s) **46** provide increased surface area for the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy) to contact and adhere to the sidewall(s) **46** (e.g., provides better mechanical bond with the sidewall(s) **42** and avoids voids in the weld and provides a hermetic seal). Additionally, the widened flush port mouth (s) **38**B provide(s) a larger target zone in which to apply the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy). Additionally, in various embodiments wherein the sealant is a laser welding alloy and the OHP channels **26** is/are hermetically sealed using a laser welding process, the widened flush port mouth(s) **38**B provide(s) a broader field of view for the welding laser.

[0045] Referring now to FIG. **5**, FIG. **5** is an exemplary isometric view of a portion of the OHP device **10** wherein a portion of the body **22** has been removed to illustrate the OHP channel system **14** and the flushing duct system **18** integrally formed internally within the body **22** in accordance with various embodiments of the present disclosure. As described above the OHP system **14** comprises a plurality of OHP channels **26** that can be disposed internally within the body **22** in a closed-loop or open-loop configuration and in a 2D or 3D configuration. FIG. **5** exemplarily illustrates the OHP channels **26** in a 3D configuration wherein the OHP channels **26** can be interpreted to be in an open-loop or closed-loop configuration and wherein all the OHP channels **26** do not lie within a common plane P. In various embodiments, the OHP flushing duct system **18** comprises a plurality of flush ports **50** having a tubular neck **50**A fluidly connected to the respective one of the plurality of OHP channels **26** and mouth **50**B integrally formed with the neck **50**A and terminating at and extending inward from the respective top, bottom and/or side face **22**A, **22**B and/or **22**C such that each neck **50**A and each respective OHP channel **26** is fluidly connected to the ambient environment. In such embodiments, the welding receptacle **30** of the OHP flushing duct system **18** comprises the plurality of flushing port mouths **50**B. It is envisioned that the flush port(s) **50** can extend from the OHP channels **26** at any desired angle (e.g., 20°, 30°, 40°, 50°, 60°, 70°, 70°, 90°, etc.),

[0046] In various embodiments, the welding receptacles/flush port mouths **30**/**50**B comprise one or more tapered, beveled, chamfered, or angled sidewall **54**. For example, as exemplarily illustrated in FIG. **5**, in various embodiments, each welding receptacle/flush port mouth **30**/**50**B comprises four tapered/beveled/chamfered/angled sidewalls **54**. The angle of the tapered/beveled/chamfered/angled welding receptacle/flush port mouth sidewalls **54** relative to the outer surface of the one or more top, bottom and/or side face **22**A, **22**B and/or **22**C in which welding receptacles/flush port mouths **30**/**50**B are formed can be any desired angle, e.g., 25°, 30°, 35°, 40°, 45°, 50°, etc. The tapered/beveled/chamfered/angled sidewall(s) **54** 'open up' or widen the respective welding receptacle/flush port mouth **30**/**50**B to aid in the efficacy of hermetically sealing the OHP channels **26**. Particularly, the tapered/beveled/chamfered/angled sidewall(s) **54** provide increased surface area for the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy) to contact and adhere to the sidewall (s) **54** (e.g., provides better mechanical bond with the sidewall(s) **54** and avoids voids in the weld and provides a hermetic seal). Additionally, the widened welding receptacles/flush port mouths **30**/**50**B provide a larger target zone in which to apply the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy). Additionally, in various embodiments wherein the sealant is a laser welding alloy and the OHP channels **26** is/are hermetically sealed using a laser welding process, the widened welding receptacles/flush port mouths **30**/**50**B provide a broader field of view for the welding laser.

[0047] Furthermore, it is envisioned that in various embodiments the dimensions of the OHP channels **26** (e.g., the depth and/or width of the OHP channels **26**) can be larger than the dimensions of the flush port neck (e.g., flush port neck **38**B and/or **50**B). In such instances, it is envisioned that each OHP channel **26** can be formed to have a tapered geometry in the area where the flush port neck **38**B/**50**B extends from the OHP channel **26**, as exemplarily illustrated in FIG. **5**. Such a geometry will prevent or substantially reduce the amount of debris and/or sintering powder residue from lodging at the junction of the flush port neck **38**B/**50**B and the OHP channel **26** and failing to flushed out as described herein.

[0048] Referring now to FIGS. **6**, **7**, **8** and **9**, FIGS. **6**, **7**, **8** and **9** each exemplary illustrate an isometric view of a portion of the OHP device **10** wherein a portion of the body **22** has been removed to illustrate the OHP channel system **14** and the flushing duct system **18** integrally formed internally within the body **22** in accordance with various different embodiments of the present disclosure. As described above the OHP system **14** comprises a plurality of OHP channels **26** that can be disposed internally within the body **22** in a closed-loop or open-loop configuration and in a 2D or 3D configuration. FIGS. **6**, **7**, **8** and **9** exemplarily illustrate the OHP channels **26** in a 3D configuration wherein the OHP channels **26** can be interpreted to be in an open-loop or closed-loop configuration and wherein all the OHP channels **26** do not lie within a common plane P.

[0049] In various embodiments, the OHP flushing duct system **18** comprises a plurality of flushing conduits **58** that are fluidly connected to one or more OHP conduit **26** out-of-plane with OHP channels **26**. That is, the flushing conduits **58** are integrally formed with, fluidly connected to and extend from the OHP channels **26** at any desired angle. For example, the flushing conduits **58** are integrally formed with, fluidly connected to and extend from the OHP channels **26** at a 20°, 30°, 40°, 50°, 60°, 70°, 70°, 90°, etc. angle. The flushing conduits **58** comprise a proximal end **58**A and a distal end **58**B. In various embodiments, as exemplarily illustrated in FIGS. **6**, **8** and **9**, the proximal end **58**A of each flushing conduit **58** is integrally formed with and fluidly connected to a respective OHP channel **26**, and the distal end **58**B terminates flush with and extends inward from the respective top, bottom and/or side face **22**A, **22**B and/or **22**C such that each flushing conduit **58** and respective OHP channel **26** is fluidly connected to the ambient environment. In various other embodiments, as exemplarily illustrated in FIG. **7**, the proximal end **58**A of each flushing conduit **58** is integrally formed with and fluidly connected to a first OHP channel **26**, and the distal end **58**B is integrally formed with and fluidly connected to a second OHP channel **26** and terminates flush with and extends inward from the respective top, bottom and/or side face **22**A, **22**B and/or **22**C such that each flushing conduit **58** and the respective first and second OHP channels **26** are fluidly connected to the ambient environment. Moreover, in various embodiments, as exemplarily illustrated in FIGS. **6**, **7**, **8** and **9**, the welding receptacle **30** of the flushing duct system **18** comprises the flushing conduits **58**.

[0050] In various embodiments, as exemplarily illustrated in FIG. **6**, the distal end **58**B of the welding receptacles/flushing conduits **30**/**58** can comprise a tapered, beveled, chamfered, or angled edge or rim **62**. The angle of the tapered/beveled/chamfered/angled edges or rims **62** relative to the outer surface of the one or more top, bottom and/or side face **22**A, **22**B and/or **22**C in which welding receptacles/flushing conduits **30**/**58** are fluidly connected can be any desired angle, e.g., 25°, 30°, 35°, 40°, 45°, 50°, etc. The tapered/beveled/chamfered/angled edges or rims **62** ‘open up’ or widen the respective welding receptacle/flushing conduits **30**/**58** to aid in the efficacy of hermetically sealing the OHP channels **26**. Particularly, the tapered/beveled/chamfered/angled edges or rims **62** provide increased surface area for the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy) to contact and adhere to the edges or rims **62** (e.g., provides better mechanical bond with the edges or rims **62** and avoids voids in the weld and provides a hermetic seal). Additionally, the widened welding receptacles/flushing conduits **30**/**58** provide a larger target zone in which to apply the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy). Additionally, in various embodiments wherein the sealant is a laser welding alloy and the OHP channels **26** is/are hermetically sealed using a laser welding process, the widened welding receptacles/flushing conduits **30**/**58** provide a broader field of view for the welding laser. Additionally, it is envisioned that in various embodiments, the process of hermetically sealing the OHP channels **26**, via the respective welding receptacle/flushing conduit **30**/**58** comprises inserting a welding filler alloy wire having approximately the same diameter as the respective the respective welding receptacle/flushing conduit **30**/**58** then melting the wire within the respective welding receptacle/flushing conduit **30**/**58** to hermetically seal the OHP channels **26**. Alternatively, it is envisioned that the OHP device **10** can be fabricated such that the welding receptacle/flushing conduits **30**/**58** have a diameter that is approximately the same as a known welding filler alloy wire such that the welding filler alloy wire can be inserted into the welding receptacle/flushing conduits **30**/**58** then melted within the respective welding receptacle/flushing conduit **30**/**58** to hermetically seal the OHP channels **26**.

[0051] The method or process of fabricating, flushing and hermetically sealing the OHP device **10** is generally as follows. Initially, the OHP device **10** is fabricated utilizing any desired fabrication method (e.g., SLS (selective laser sintering), MBJ (metal binder jet), EBAM (electron beam AM), etc.) having the OHP channel system **14** (comprising the OHP channels **26**) and the flushing duct system **18** (comprising the welding receptacle(s) **30**) integrally formed within the body **22** as in the various embodiments described above. Subsequently, the OHP channels are flushed out or depowdered and cleaned to remove any debris and/or any residual fabrication dust, powder or particles disposed within the OHP channels **26** by forcing a flushing fluid through the respective OHP channel system **14**, via the flushing duct system **18**. The flushing fluid can be any suitable flushing fluid such as acetone, isopropyl alcohol (IPA), or deionized water. Alternatively, it is envisioned that the OHP channel system **14** can be flushed, via the flushing duct system **18**, using any other suitable flushing method, for example, gas flushing with pressurized nitrogen dioxide (N2), feeding a wire or micro-size brush through OHP channel system **14**, using an acid etching process, using a thermal shock method, using a vibration method, etc. Once the OHP channels **26** have been flushed, the OHP channels can be hermetically sealed utilizing the welding receptacle (s) **30**. Particularly, the welding receptacle(s) **30** is/are structured and operable to receive a sealant (e.g., a welding material for use with laser welding or tungsten inert gas (TIG) welding) to hermetically seal the OHP channels **26** from the ambient environment after the OHP channels **26** have been flushed. Thereafter, the OHP channels are at least partially filled with a saturated two-phase working utilizing a filler port (not shown) as is generally known in the art. It is envisioned that in various embodiment one or more of the flush ports **38**/**50** can be utilized as a filler port.

[0052] Although various embodiments of the welding receptacle **30** have been described herein to comprise one or more tapered, beveled, chamfered, or angled sidewall, edge or rim, it is envisioned that in various embodiments the welding receptacle **30** can be milled into the respective top, bottom and/or side faces **22**A, **22**B and/or **22**C using a ball end mill. In such embodiments, the respective welding receptacle **30** sidewall, edge or rim will have an arcuate, filleted or radiused surface, as opposed to the flat tapered, beveled, chamfered, or angled surface described above. However, the The arcuate/filleted/radiused sidewalls, edges or rims will provide substantially the same benefits and advantages. Particularly, the arcuate/filleted/radiused sidewalls, edges or rims will. 'open up' or widen the respective welding receptacle(s) **30** to aid in the efficacy of hermetically sealing the OHP channels **26**. More particularly, the arcuate/filleted/radiused sidewalls, edges or rims provide increased surface area for the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy) to contact and adhere to the arcuate/filleted/radiused sidewalls, edges or rims (e.g., provides better mechanical bond with the arcuate/filleted/radiused sidewalls, edges or rims and avoids voids in the weld and provides a hermetic seal). Additionally, the widened welding receptacle(s) **30** provide a larger target zone in which to apply the sealant (e.g., laser welding material or TIG welding material or other weld filler alloy). Additionally, in various embodiments wherein the sealant is a laser welding alloy and the OHP channels **26** is/are hermetically sealed using a laser welding process, the widened welding receptacle(s) **30** provide a broader field of view for the welding laser.

[0053] It should be noted that the diameter of the flush port necks described above (e.g., flush port necks **38**B and **50**B) and the flushing conduits described above (e.g., flushing conduits **58**) can be based on the diameter of the residual powder resulting from the respective additive manufacturing process and material. However, empirical testing has shown that flush port necks described above (e.g., flush port necks **38**B and **50**B) and the flushing conduits described above (e.g., flushing conduits **58**) having a diameter of 0.040 inches or greater, and/or a hydraulic diameter of between 0.020 and 0.250 inches is generally suitable to thoroughly flush, depowder, and clean the OHP channels **26** of the OHP devices **10** described herein utilizing the flushing features and functions describe herein.

[0054] The description herein is merely exemplary in nature and, thus, variations that do not depart from the gist of that which is described are intended to be within the scope of the teachings. Moreover, although the foregoing descriptions and the associated drawings describe example embodiments in the context of certain example combinations of elements and/or functions, it should be appreciated that different combinations of elements and/or functions can be provided by alternative embodiments without departing from the scope of the disclosure. Such variations and alternative combinations of elements and/or functions are not to be regarded as a departure from the spirit and scope of the teachings.

1. An oscillating heat pipe (OHP) flushing duct system, said system formed in at least one of a body top face, a bottom face and at least one side face of an OHP device, the flushing duct system fluidly connecting one or more of a plurality of OHP channels formed internally within the OHP device to an ambient environment of the device, the flushing duct system comprising at least one welding receptacle.

2. The system of claim **1**, wherein the flushing duct system is in-plane with the one or more OHP channels to which it is fluidly connected

3. The system of claim **1**, wherein the flushing duct system out-of-plan with the one or more OHP channels to which it is fluidly connected.

4. The system of claim **1**, wherein each of the at least one welding receptacle comprises at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall.

5. The system of claim **4**, wherein the at least one welding receptacle comprises a linear welding trough formed in one of the top face, the bottom face and the at least one side face of the OHP device such that the linear welding trough fluidly connects with at least one of the plurality of OHP channels and wherein the linear welding trough comprises the at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall.

6. The system of claim **4**, wherein the flushing duct system further comprises:

at least one flush port wherein each of the at least one flush port is fluidly connected to a corresponding one of the plurality of OHP channels; and

the at least one welding receptacle comprises a linear welding trough formed in one of the top face, the bottom face and the at least one side face of the OHP device such that the linear welding trough fluidly connects with the plurality of OHP channels via the at least one flush port and wherein the linear welding trough comprises the at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall.

7. The system of claim **6**, wherein each of the at least one flush port comprises:

a neck fluidly connected to the corresponding one of the plurality of OHP channels; and

a mouth fluidly connecting the neck to the linear welding trough.

8. The system of claim **7**, wherein the mouth of each of the at least one flush port comprises at least one of a mouth chamfered or arcuate edge and at least one mouth chamfered or arcuate sidewall.

9. The system of claim **4**, wherein the flushing duct system further comprises at least one flush port wherein each of the at least one flush port is fluidly connected to a corresponding one of the plurality of OHP channels, wherein each of the at least one flushing port comprises:

a neck fluidly connected to the corresponding one of the plurality of OHP channels; and

a mouth fluidly connecting the neck to the ambient environment of the device, wherein the mouth defines the at least one welding receptacle having the at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall.

10. The system of claim **1**, wherein the flushing duct system comprises a flushing conduit fluidly connecting at least one of the plurality of OHP channels to the ambient environment, wherein the flushing conduit defines the at least one welding receptacle

11. An oscillating heat pipe (OHP) device, said device comprising:

a body having a top face, a bottom face and at least one side face;

a plurality of hollow OHP channels formed internally within the body; and

a flushing duct system formed in at least one of the body top face, bottom face and at least one side face, the flushing duct system fluidly connecting one or more of the plurality of OHP channels to an ambient environment of the device, the flushing duct system comprising at least one welding receptacle.

12. The device of claim **11**, wherein the flushing duct system is in-plane with the one or more OHP channels to which it is fluidly connected

13. The device of claim **11**, wherein the flushing duct system out-of-plan with the one or more OHP channels to which it is connected.

14. The device of claim **11**, wherein each of the at least one welding receptacle comprises at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall.

15. The device of claim **14**, wherein the at least one welding receptacle comprises a linear welding trough formed in one of the top face, the bottom face and the at least one side face such that the linear welding trough fluidly connects with at least one of the plurality of OHP channels and wherein the linear welding trough comprises the at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall.

16. The device of claim **14**, wherein the flushing duct system further comprises:

at least one flush port wherein each of the at least one flush port is fluidly connected to a corresponding one of the plurality of OHP channels; and

the at least one welding receptacle comprises a linear welding trough formed in one of the top face, the bottom face and the at least one side face such that the linear welding trough fluidly connects with the plurality of OHP channels via the at least one flush port and wherein the linear welding trough comprises the at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall.

17. The device of claim **16**, wherein each of the at least one flush port comprises:

a neck fluidly connected to the corresponding one of the plurality of OHP channels; and

a mouth fluidly connecting the neck to the linear welding trough.

18. The device of claim **17**, wherein the mouth of each of the at least one flush port comprises at least one of a mouth chamfered or arcuate edge and at least one mouth chamfered or arcuate sidewall.

19. The device of claim **14**, wherein the flushing duct system further comprises at least one flush port wherein each of the at least one flush port is fluidly connected to a corresponding one of the plurality of OHP channels, wherein each of the at least one flushing port comprises:

a neck fluidly connected to the corresponding one of the plurality of OHP channels; and

a mouth fluidly connecting the neck to the ambient environment of the device, wherein the mouth defines the at least one welding receptacle having the at least one of a welding receptacle chamfered or arcuate edge and at least one welding receptacle chamfered or arcuate sidewall

20. The device of claim **11**, wherein the flushing duct system comprises a flushing conduit fluidly connecting at least one of the plurality of OHP channels to the ambient environment, wherein the flushing conduit defines the at least one welding receptacle

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