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(54) **APPARATUSES AND METHODS FOR PROVIDING A SOLAR THERMAL ENERGY ABSORBER TUBE FOR A SOLAR COLLECTOR SYSTEM**

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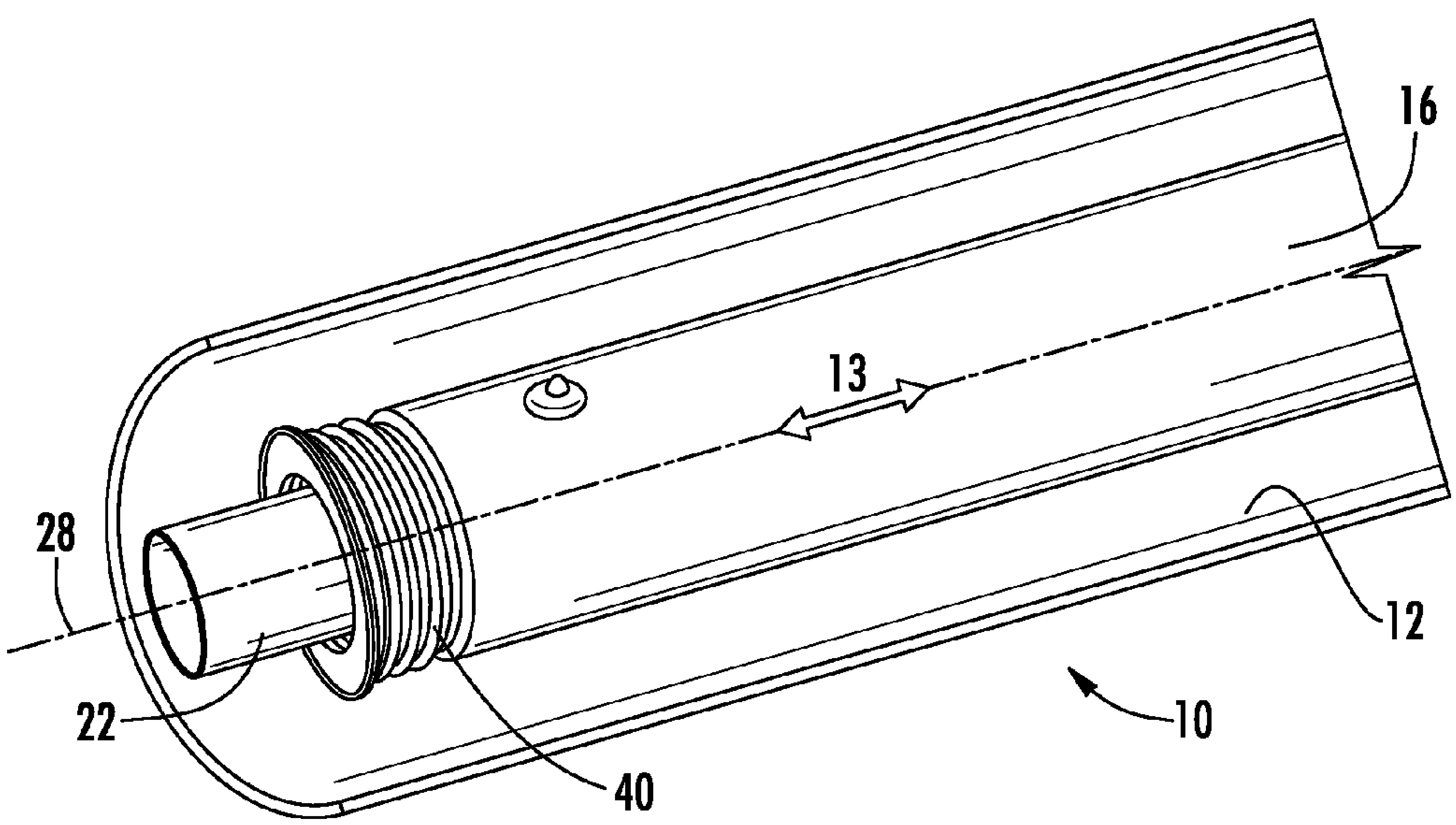
(57) **ABSTRACT**

Various embodiments provide an absorber tube that comprises an inner tube having an exterior surface, at least a portion of which contains a plurality of coating layers. The absorber tube also includes an outer tube spaced apart from the inner tube so as to define a cavity between the two. At least one of the coating layers may be configured to substantially impede migration of gaseous particles from the interior surface and into said cavity. At least one of the coating layers may be a reflective copper coating that is adhered to the exterior surface via an electrical charging process. An absorber tube comprising a connecting member between central and end portions of the tube is also provided. The central portion may be formed from carbon steel, while remaining portions are formed from stainless steel. Coating layers may be likewise adhered to only the central portion.



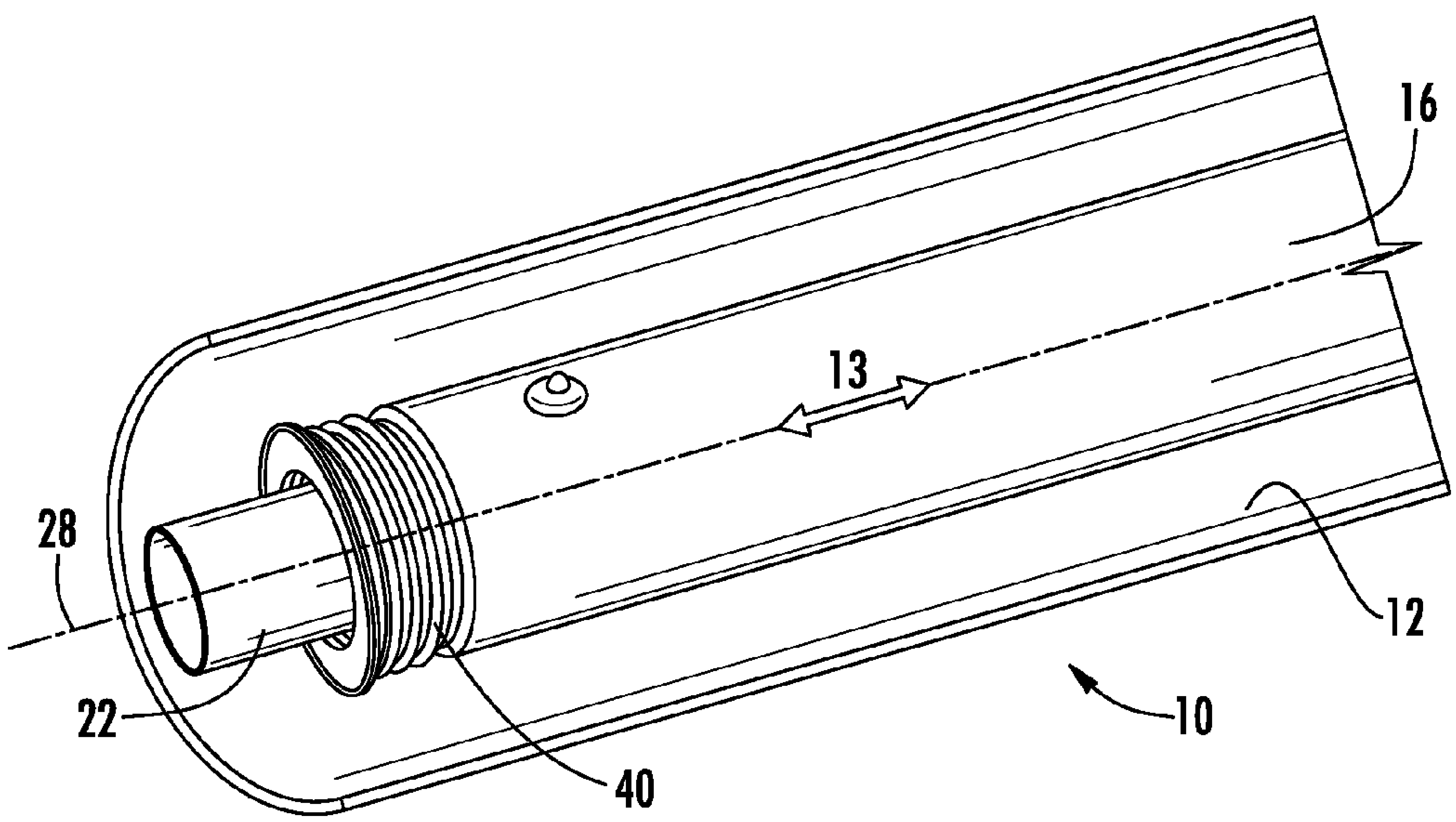


FIG. 1

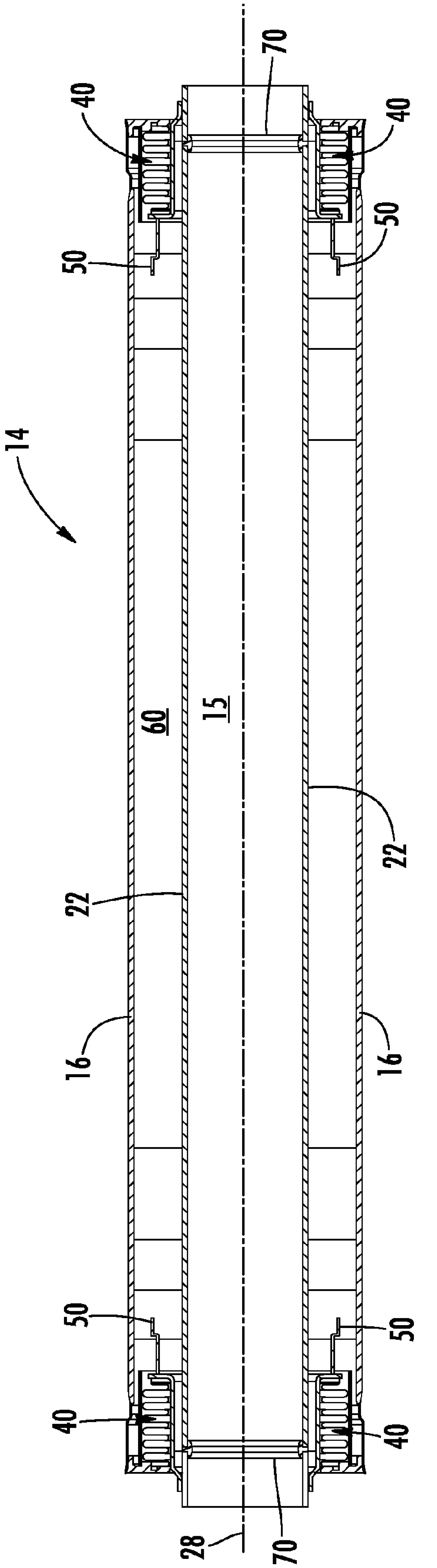


FIG. 2

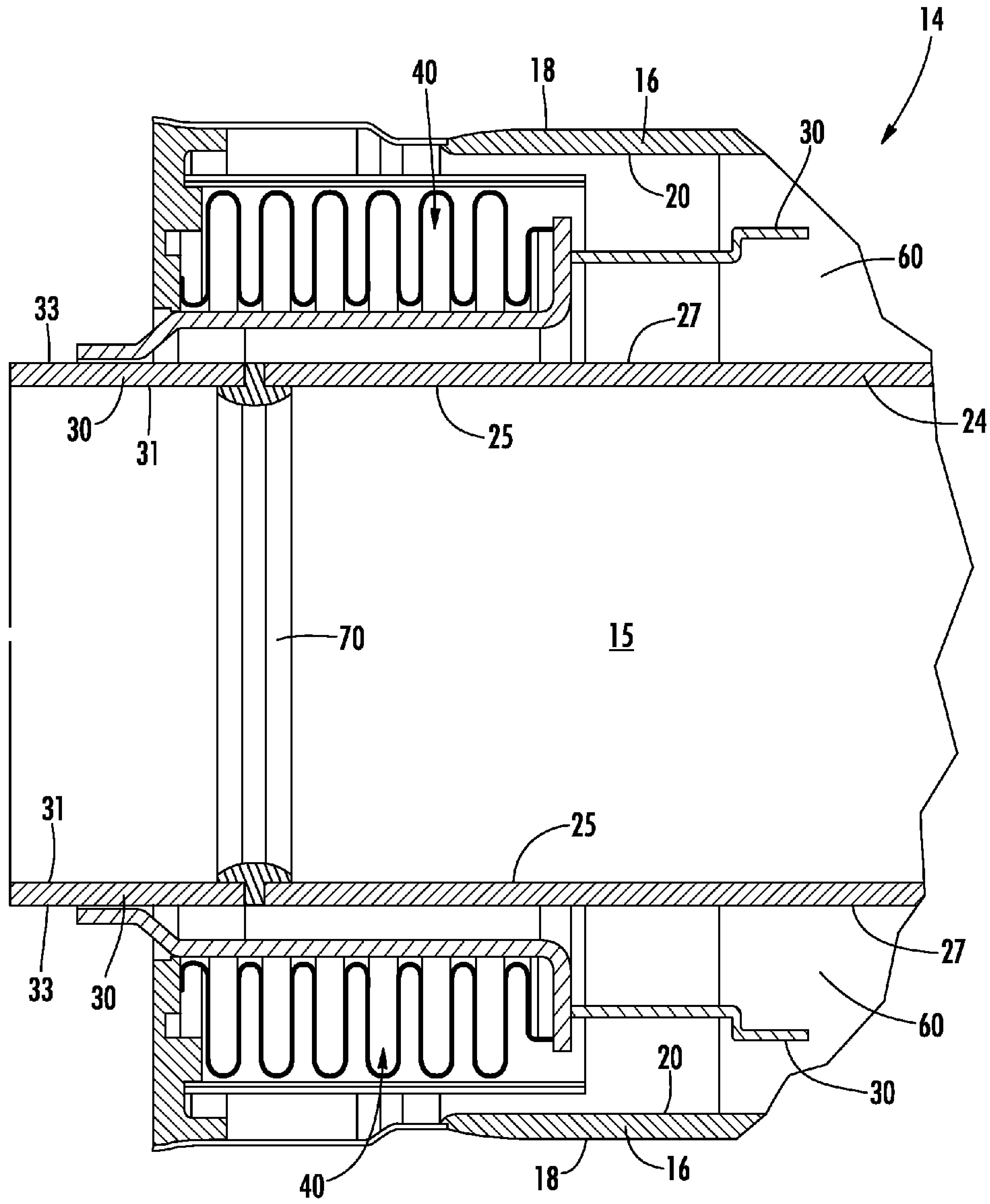

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FIG. 3

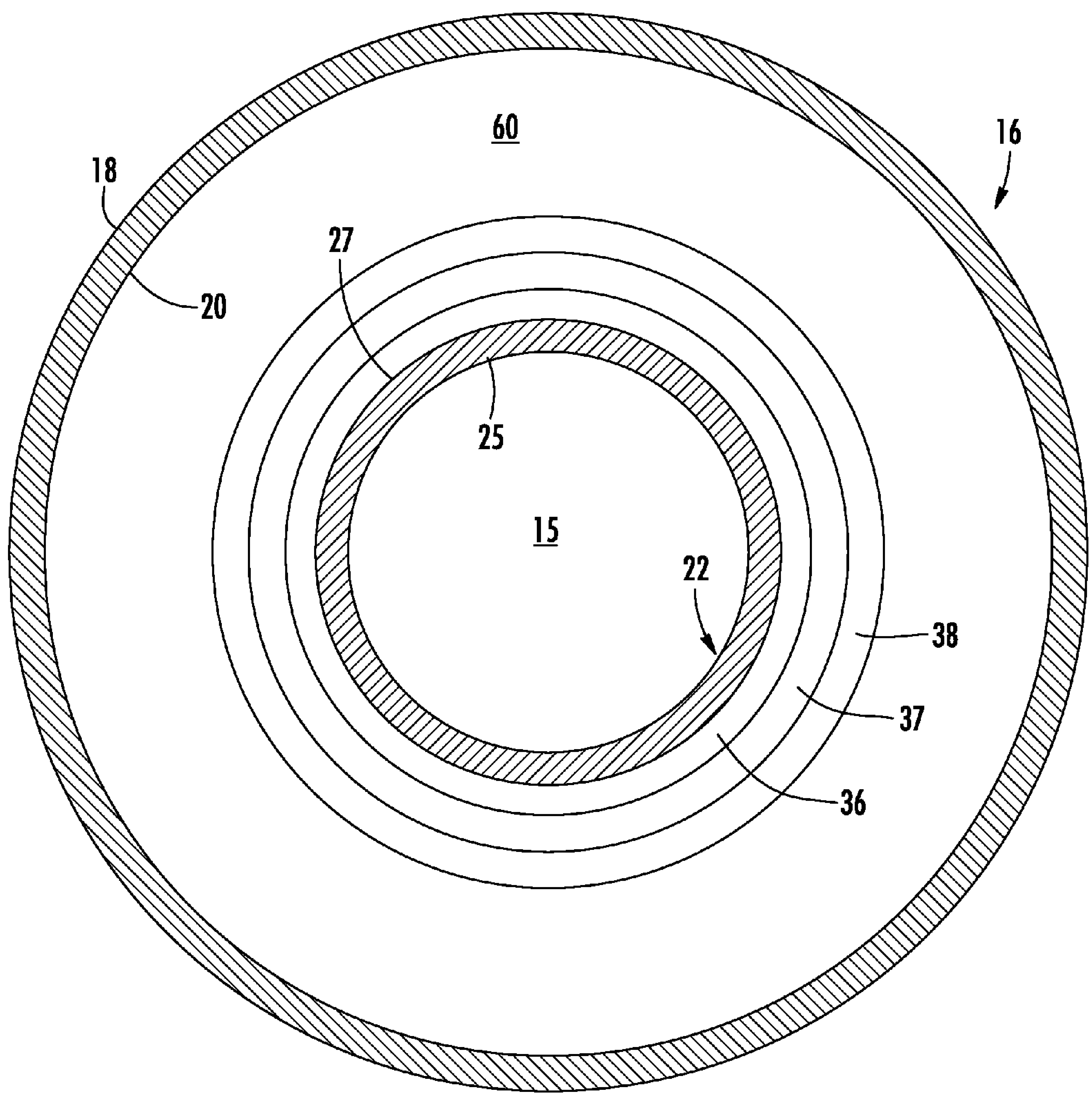

FIG. 4

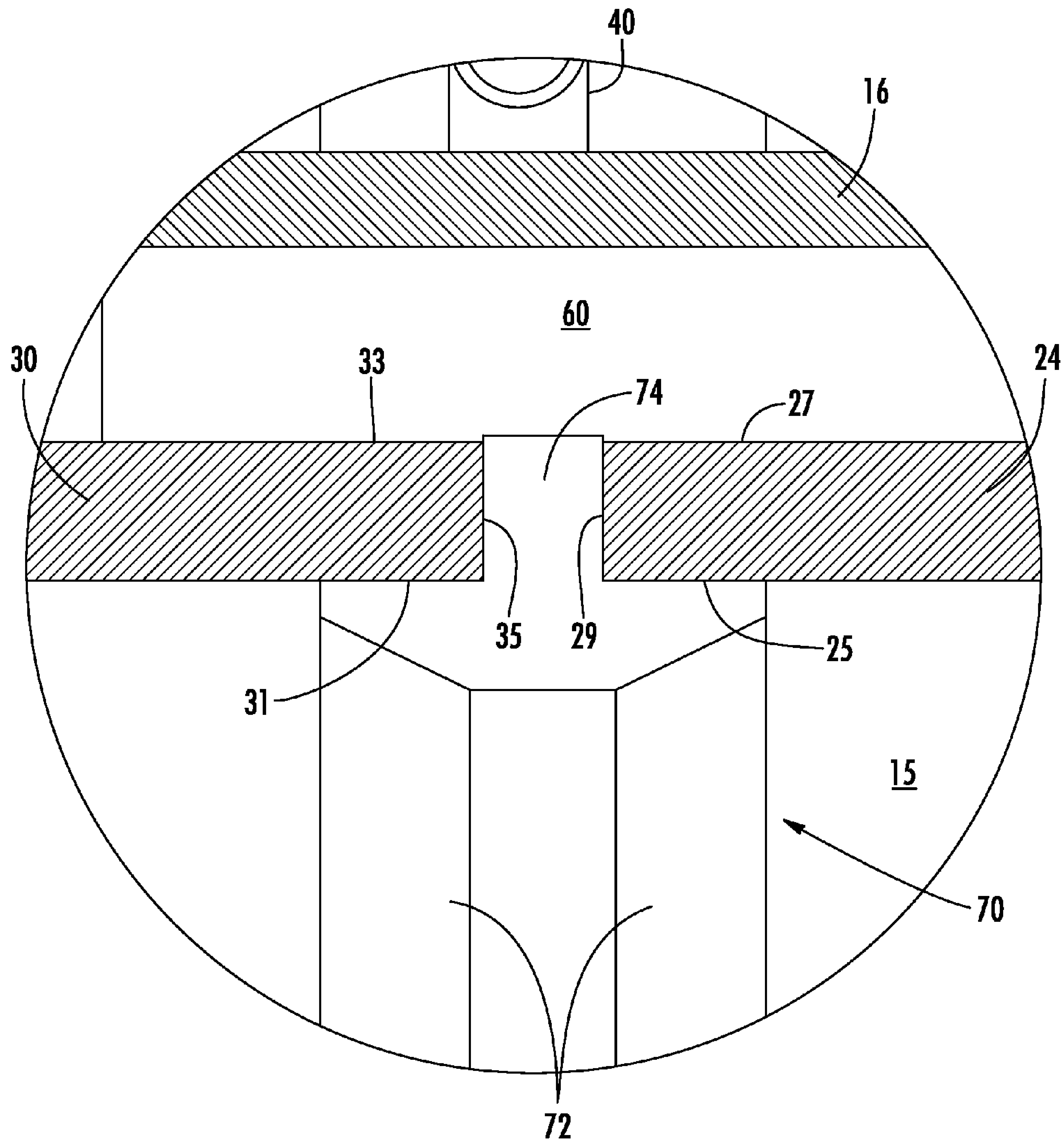

FIG. 5

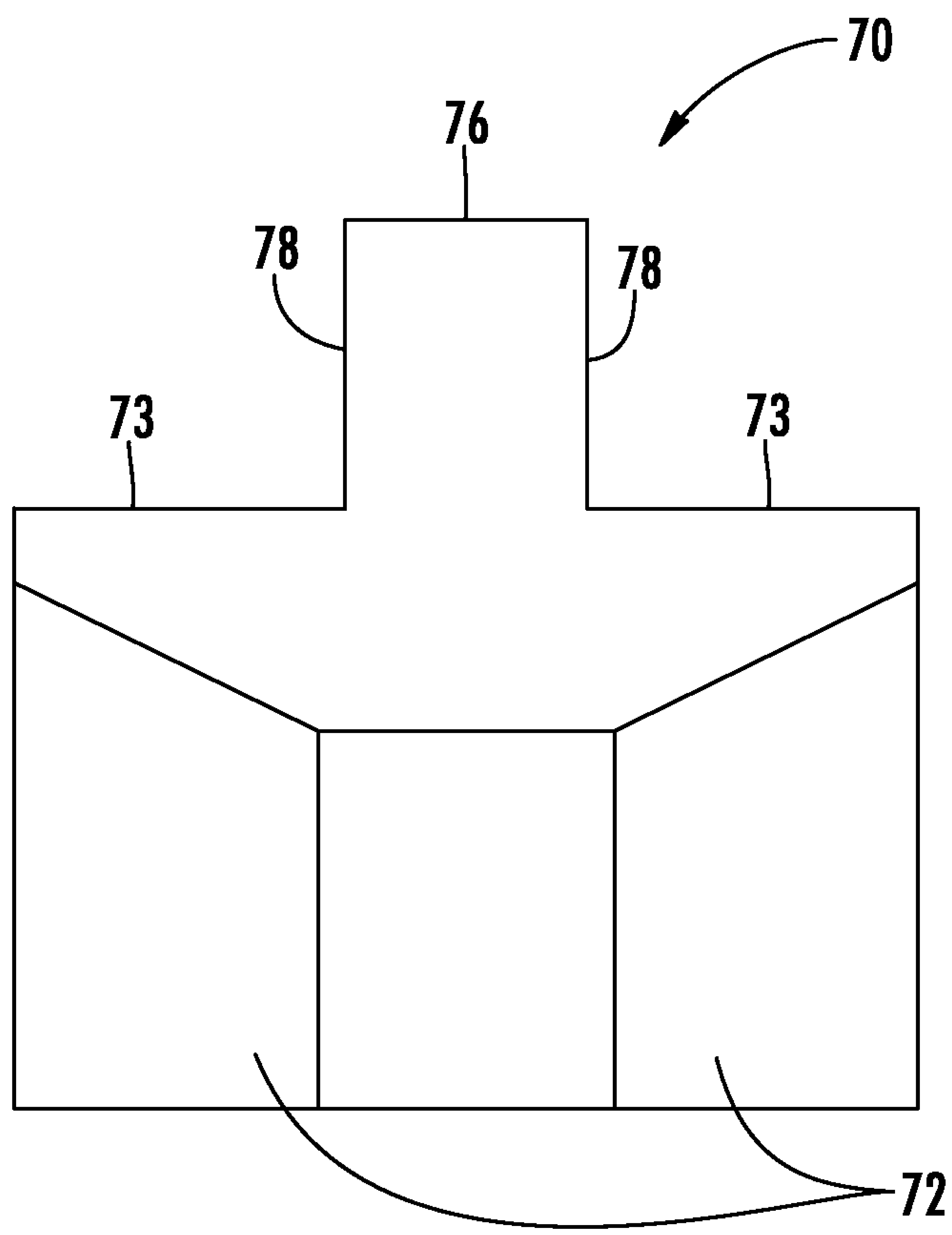

FIG. 6

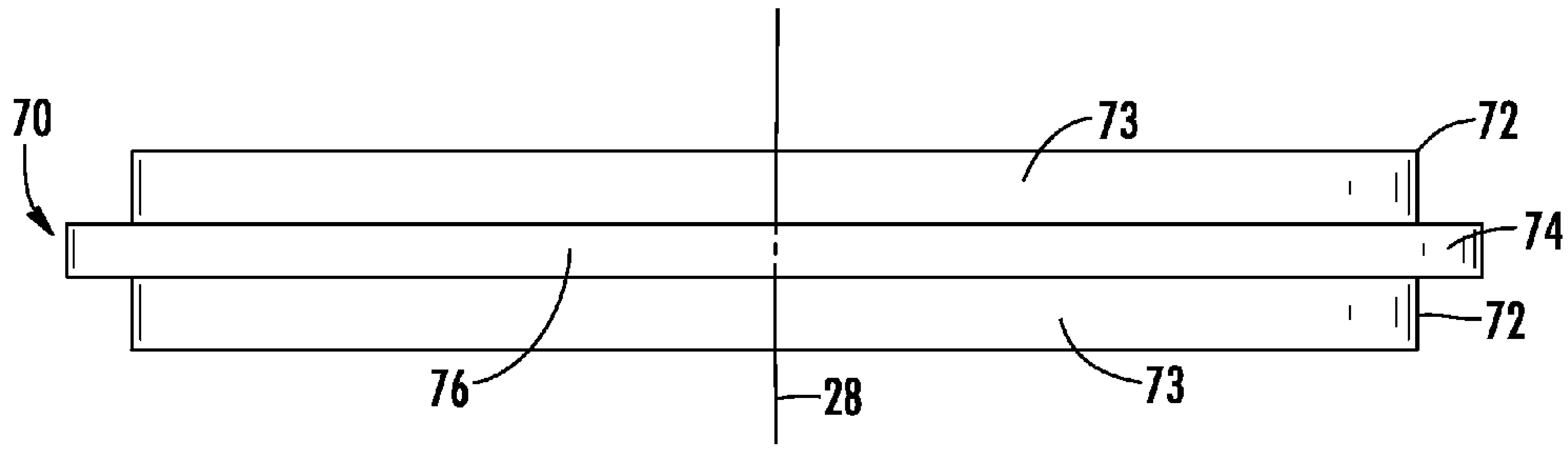

FIG. 7A

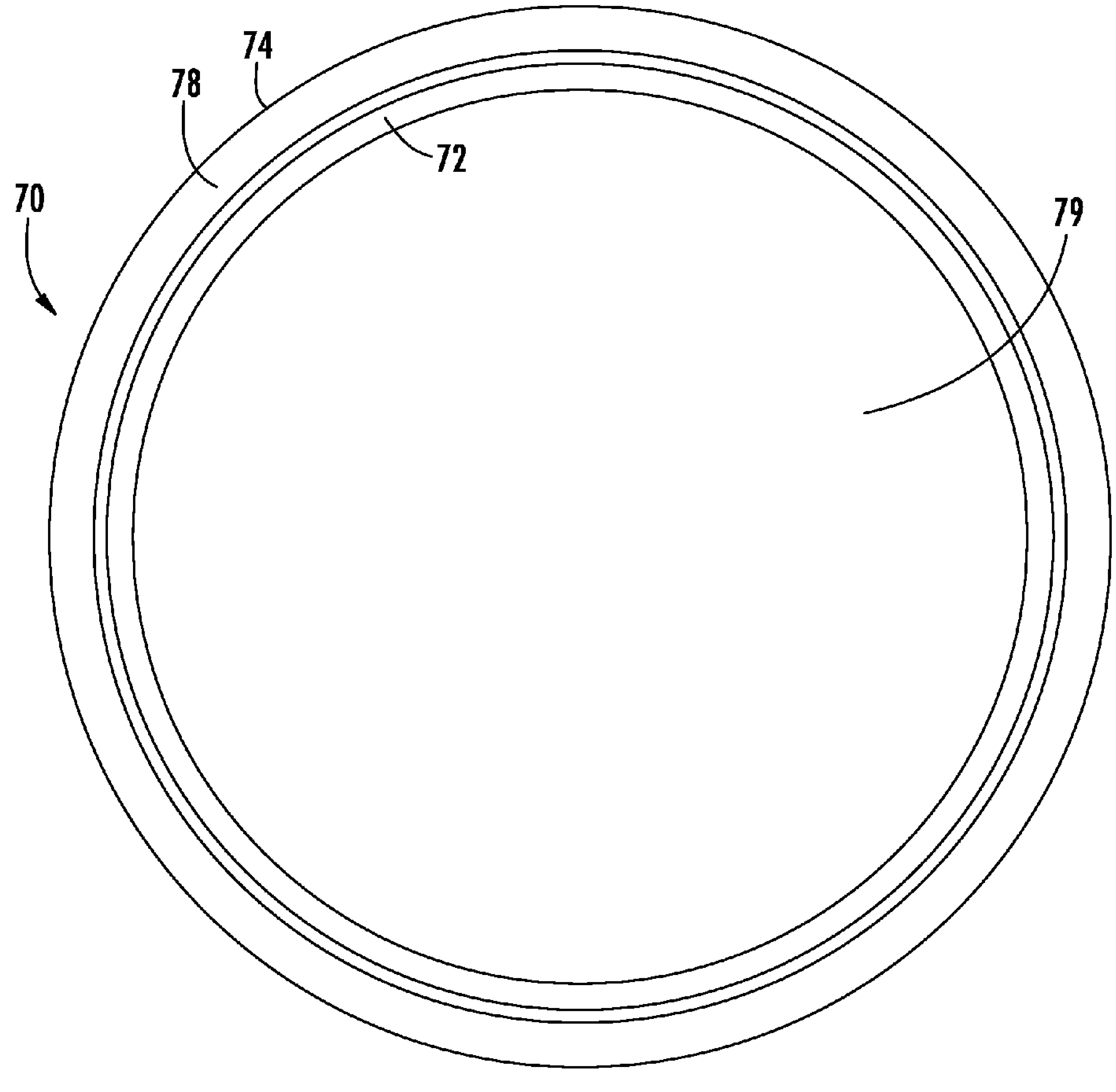

FIG. 7B

APPARATUSES AND METHODS FOR PROVIDING A SOLAR THERMAL ENERGY ABSORBER TUBE FOR A SOLAR COLLECTOR SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Application No. 61/585,868 entitled, "Apparatuses and Methods for Providing a Solar Thermal Energy Absorber Tube for a Solar Collector System" that was filed on Jan. 12, 2012, the entirety which is hereby incorporated by reference herein.

BACKGROUND

[0002] 1. Technical Field

[0003] Embodiments of the present invention relate generally to solar thermal energy absorber tubes used in the collection and use of solar thermal energy by solar concentrators and solar collector systems. More particularly, the various embodiments provide an inner tube of an absorber tube that comprises a metallic coating layer, which minimizes permeation of hydrogen from a fluid within the inner tube and into an evacuated cavity formed between the inner tube and an outer surrounding tube. Various embodiments further provide an interface assembly, which permits the use of differing materials between an absorption portion and a mounting portion of the inner tube.

[0004] 2. Description of Related Art

[0005] Solar concentrators and solar collector systems work by collecting solar thermal energy (e.g., sunlight) from a large area and concentrating it into a smaller area. Various types of solar concentrators and solar collector systems exist and include at least parabolic solar concentrators. Parabolic solar concentrators use mirrored surfaces curved in a parabolic shape to focus sunlight onto the mathematical focal point of their inherent parabola. Trough-shaped parabolic solar concentrators (e.g., parabolic troughs), like various other types of solar collector systems, typically comprise elongated absorber tubes, or heat collection elements (HCE), which run the length of the trough. A longitudinal axis of the absorber tube generally corresponds to the focal region. In this manner, the parabolic trough focuses sunlight directly onto the absorber tube.

[0006] Parabolic trough solar concentrators are generally positioned in solar collector system fields, often containing hundreds, if not thousands, of adjacently positioned parabolic trough solar concentrators. Together, the multiple adjacently positioned parabolic trough solar concentrators may form a parabolic trough power plant. In such parabolic trough power plants, a fluid, typically oil, runs through each of the absorber tubes positioned in the focal region of each of the parabolic troughs. The focused sunlight upon each of the absorber tubes heats the fluid to high temperatures before the fluid passes through a heat exchanger, which generates steam. The steam may then be used to run a conventional power plant.

[0007] Many absorber tubes, as commonly known and understood in the art, comprise an inner tube formed from a single piece of material. Generally speaking, the inner tube is formed from a stainless steel material, as such provides the anti-corrosive properties necessary to withstand various external environmental conditions encountered during use. However, stainless steel material is relatively heavy, weak, and exhibits properties that result in a relatively slow heat transfer rate, all of which contribute to various degrees of inefficiencies within solar concentrators and solar collector systems. As such, a need exists for an inner tube configuration that provides improved characteristics relative to those generally viewed as lacking in stainless steel, while also not sacrificing those advantageous characteristics of stainless steel (e.g., weather resistance).

[0008] Many absorber tubes, as commonly known and understood in the art, comprise an absorbing layer or coating that is configured to facilitate, or at best not impede, the transmittal of thermal energy (e.g., sunlight) through the inner tube of the absorber tube and thus into the fluid contained therein. Such inner tubes, however, generally remain susceptible to migration and/or permeation of hydrogen molecules (e.g., from the heated fluid) into a space between the inner and outer tubes of the absorber tube. Various techniques have been employed to minimize such migration and/or permeation, with at least some conventional absorber tubes incorporating a plurality of getters in the space configured to absorb the hydrogen molecules. However, getters may require additional maintenance, may block at least a portion of thermal energy transmission to the fluid, and/or may not fully prevent migration and/or permeation. As such, a need exists for an absorber tube configuration that provides an improved degree of migration and/or permeation prevention, while also minimizing the need for the plurality of getters, as previously described herein.

BRIEF SUMMARY OF VARIOUS EMBODIMENTS OF THE INVENTION

[0009] Various embodiments of the present invention provide an absorber tube that comprises an inner tube having an exterior surface, at least a portion of which contains a plurality of coating layers. Various embodiments of the present invention still further provide an inner tube having a connecting member located between central and end portions of the tube, wherein the central portion may be formed from carbon steel and/or coated with at least a reflective layer.

[0010] More specifically, according to various embodiments, an absorber tube configured for the collection of solar thermal energy in a solar concentrator system is provided. The absorber tube comprises an inner tube comprising an interior surface and an exterior surface, at least a portion of the exterior surface comprising a plurality of coating layers; and an outer tube substantially surrounding the inner tube and being spaced apart from and concentric with the inner tube so as to define a cavity between the inner tube and the outer tube, wherein at least one of the plurality of coating layers is configured to substantially impede migration of gaseous molecular particles from the interior surface of the inner tube and into the cavity.

[0011] In certain embodiments, the plurality of coating layers comprise a copper coating, the copper coating being operatively adhered to the exterior surface of the inner tube by generating an electrical charge between the copper coating and the exterior surface, the copper coating further being configured to deflect a substantial portion of the gaseous molecular particles toward an interior volume of the inner tube so as to substantially impede migration of gaseous molecular particles from the interior volume and into the cavity between the inner tube and the outer tube.

[0012] According to various embodiments, an absorber tube configured for the collection of solar thermal energy in a solar concentrator system is also provided. The absorber tube comprises an inner tube comprising: (A) a central portion; (B) at least one end portion, the at least one end portion being configured to facilitate mounting the absorber tube relative to the solar concentrator system; and (C) at least one connecting member, the at least one connecting member being located intermediate the central portion and the at least one end portion. The central portion of the inner tube is formed from a steel-based material having a structural composition substantially different from a material of the at least one end portion.

[0013] In certain embodiments, the connecting member comprises an annular ring portion and a protrusion portion. A diameter of the annular ring portion is substantially the same as a diameter of an interior surface of the inner tube, such that at least a portion of the annular ring portion is configured to form a seal between the interior surface of the inner tube and the connecting member; and a diameter of the protrusion portion is substantially the same as a diameter of an exterior surface of the inner tube, such that at least a portion of the protrusion portion is configured to form a seal between a passage through the inner tube and the connecting member.

[0014] In certain embodiments, the at least one end portion comprises a first end portion and a second end portion; the at least one connecting member comprises a first connecting member and a second connecting member, the first connecting member being located intermediate the central portion and the first end portion, the second connecting member being located intermediate the central portion and the second end portion; the first connecting member comprises a first annular ring portion and a first protrusion portion, a diameter of the first annular ring portion being substantially the same as a diameter of an interior surface of the inner tube, such that at least a portion of the first annular ring portion is configured to form a seal between the interior surface of the inner tube and the first connecting member, a diameter of the first protrusion portion being substantially the same as a diameter of an exterior surface of the inner tube, such that at least a portion of the first protrusion portion is configured to form a seal between a passage through the inner tube and the first connecting member; and the second connecting member comprises a second annular ring portion and a second protrusion portion, a diameter of the second annular ring portion being substantially the same as a diameter of an interior surface of the inner tube, such that at least a portion of the second annular ring portion is configured to form a seal between the interior surface of the inner tube and the second connecting member, a diameter of the second protrusion portion being substantially the same as a diameter of an exterior surface of the inner tube, such that at least a portion of the second protrusion portion is configured to form a seal between a passage through the inner tube and the second connecting member.

[0015] Still further, according to various embodiments, a method is provided for manufacturing an absorber tube configured for the collection of solar thermal energy in a solar concentrator system. The method comprises the steps of: (A) providing an absorber tube comprising: (1) an inner tube comprising an interior surface and an exterior surface; and (2) an outer tube substantially surrounding the inner tube and being spaced apart from and concentric with the inner tube so as to define a cavity between the inner tube and the outer tube; (B) inserting a reflective coating material into the cavity between the inner tube and the outer tube; and (C) creating an electrically charged vacuum within the cavity, such that the reflective coating material is electrically attracted to and thus adhered to the exterior surface of the inner tube.

[0016] In certain embodiments, the method further involves the reflective layer comprising a copper coating; the copper coating being negatively charged; and the vacuum being positively charged so as to cause the copper coating to be forced into contact with the exterior surface of the inner tube.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0017] The accompanying drawings incorporated herein and forming a part of the disclosure illustrate several aspects of the present invention and together with the detailed description serve to explain certain principles of the present invention. In the drawings, which are not necessarily drawn to scale:

[0018] FIG. **1** is a perspective view of a parabolic trough **10** in accordance with various embodiments;

[0019] FIG. **2** is a cross-sectional view of an absorber tube **14** in accordance with various embodiments;

[0020] FIG. **3** is a detailed cross-sectional view of the absorber tube **14** of FIG. **2**, further illustrating a connecting member **70** in accordance with various embodiments;

[0021] FIG. **4** is cross-sectional view of the absorber tube **14** of FIG. **2**, illustrating an outer tube **16**, an inner tube **22**, and various coating layers **34**, **36**, and **38** in accordance with various embodiments;

[0022] FIG. **5** is another detailed cross-sectional view of the connecting member **70**, as positioned in accordance with various embodiments relative to the outer tube **16** and the inner tube **22** of the absorber tube **14** of FIG. **3**;

[0023] FIG. **6** is another detailed cross-sectional view of the connection member **70** in accordance with various embodiments, with the outer tube **16** and the inner tube **22** of FIG. **5** removed;

[0024] FIG. **7**A is a top view of the connecting member **70** of FIGS. **5** and **6**; and

[0025] FIG. **7**B is a side view of the connecting member **70** of FIGS. **5** and **6**.

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS

[0026] Various embodiments of the present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, embodiments of the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly known and understood by one of ordinary skill in the art to which the invention relates. The term "or" is used herein in both the alternative and conjunctive sense, unless otherwise indicated. Like numbers refer to like elements throughout.

ELEMENT LIST

[0027] **10** parabolic trough

[0028] **12** mirror

[0029] **14** absorber tube

[0030] **15** oil

[0031] **16** outer tube
[0032] **18** outer wall
[0033] **20** inner wall
[0034] **48** end
[0035] **22** inner tube
[0036] **24** absorption portion
[0037] **25** inner wall
[0038] **27** outer wall
[0039] **29** end
[0040] **30** mounting portion
[0041] **31** inner wall
[0042] **33** outer wall
[0043] **35** end
[0044] **40** expansion element
[0045] **50** getter
[0046] **60** space
[0047] **70** connecting member
[0048] **72** annular ring
[0049] **73** end
[0050] **74** protrusion
[0051] **76** end
[0052] **78** side
[0053] **79** cavity

[0054] Turning now to FIGS. **1** and **2**, it may be understood that various embodiments of the present invention provide for an absorber tube **14** for use with a parabolic trough **10**. In certain embodiments, the absorber tube **14** may feature an inner tube **22**, an outer tube **16**, at least one expansion element **40**, and at least one getter **50**. The expansion element **40** may be configured to minimize stress imparted to the absorber tube **14** during thermal expansion. In certain embodiments, the expansion element **40** may be structured and configured substantially as disclosed in at least U.S. Patent Application Publication No. 2010/0126499 filed by Wei David Lu of Greer, S.C. and incorporated herein by reference in its entirety. In other embodiments, the expansion element **40** may be otherwise structured and configured as may be commonly known and used in the art for particular applications.

[0055] With specific reference to FIG. **2**, an exemplary embodiment of the absorber tube **14**. It should be understood that the absorber tube **14** may be incorporated into any of a variety of solar collector systems, as commonly known and understood in the art, and that the illustration of use within the parabolic trough **10** (see FIG. **1**) is intended as non-limiting. In those embodiments involving the parabolic trough **10**, the trough may include a parabolic mirror **12** configured to focus sunlight imparted thereon onto the absorber tube **14**. In various embodiments, the parabolic trough **10** and the absorber tube **14** may extend any length in the longitudinal direction **13**. In certain embodiments, the longitudinal direction **13** is substantially parallel to a common axis **28** of the inner tube **22** and the outer tube **16** of the absorber tube **14**, as also illustrated in FIG. **2**.

[0056] Still further, as commonly known and understood in the art, additional parabolic trough **10** and absorber tubes **14** may be physically positioned adjacent one another so as to provide for additional solar energy collection capabilities. In various embodiments, the parabolic mirrors **12** and/or absorber tubes **14** may also be made mobile such that their orientation may be adjusted in accordance with movement of the sun so as to achieve maximum solar collection. Such and still other possible configurations, as commonly known and understood in the art, are described in further detail in at least U.S. Patent Application Publication No. 2010/0126499 filed by Wei David Lu of Greer, S.C. and incorporated herein by reference in its entirety.

[0057] As may be understood with reference to FIG. **2**, the at least one getter **50** according to various embodiments may be located between the outer tube **16** and the inner tube **22** of the absorber tube **14**. In certain embodiments, the at least one getter **50** may be configured to capture hydrogen molecules that permeate from a fluid **15** contained within the inner tube **22** and into a space **60** between the outer tube **16** and the inner tube, all as will be described in further detail below. In this manner, the capture of hydrogen molecules minimizes the occurrence of inefficiencies caused by the loss of heat in the fluid **15** and the undue heating and possible fracture or compromise of the outer tube **16**. In these and other embodiments, the at least one getter **50** may be constructed, structured and configured substantially as disclosed in at least U.S. Patent Application Publication No. 2010/0126499 filed by Wei David Lu of Greer, S.C. and incorporated herein by reference in its entirety. In other embodiments, the at least one getter **50** may be otherwise constructed, structured and configured as may be commonly known and used in the art for particular applications.

[0058] Remaining with FIG. **2**, the absorber tube **14** according to various embodiments may be configured such that a space **60** is formed between the inner tube **22** and the outer tube **16**. The space **60** in certain embodiments may be evacuated so that a vacuum is formed therein, so as to increase insulation properties of the absorber tube **14**, as is commonly known and understood in the art. As such, the inner tube **22** in these and other embodiments may be hot while the outer tube **16** remains cool to the touch. The vacuum of space **60** thus increases the efficiency of the absorber tube **14** as a whole. Additional advantages and configurations of the space **60** are described in at least U.S. Patent Application Publication No. 2010/0126499 filed by Wei David Lu of Greer, S.C. and incorporated herein by reference in its entirety. In other embodiments, the space **60** within the absorber tube **14** may be otherwise constructed, structured and configured as may also be commonly known and used in the art for particular applications.

[0059] Turning now to FIG. **3**, it should be understood that the outer tube **16** of the absorber tube **14** according to various embodiments may comprise an outer wall **18** and an inner wall **20**, as will be described in further detail below. In certain embodiments, the outer tube **16** may be formed from glass capable of permitting light energy to pass there-through with little or no resistance or reflection. In at least one embodiment, the outer tube **16** may be formed from borosilicate glass. In still other embodiments, the outer tube **16** may be formed from any of a variety of transparent materials, as commonly known and used in the art to substantially permit unhindered passage of sunlight there-through.

[0060] Remaining with FIG. **3**, the inner tube **22** according to various embodiments may similarly comprise an absorption portion **24** and at least one mounting portion **30**, each separated relative to one another by a connecting member **70**, as will be described in further detail later. Generally speaking, the absorption portion **24** of the inner tube **22** corresponds generally to an interior or central portion of the absorber tube **14** relative to the full length of the absorber tube, while each of the mounting portions **30** correspond to outer portions relative to the same. In this manner, in certain embodiments, the absorption portion **24** may be configured to be that portion of the inner tube **22** that captures solar energy in the form of, for example, sunlight. In these and other embodiments, the mounting portion **30** may be configured to position the at least one expansion element **40**, the at least one getter **50**, and/or the outer tube **16** relative to the inner tube, thereby minimizing any possible obstruction of solar energy in reaching the absorption portion **24**. Mounting techniques relative to the mounting portion **30**, as described herein, are further described in at least U.S. Patent Application Publication No. 2010/0126499 filed by Wei David Lu of Greer, S.C. and incorporated herein by reference in its entirety.

[0061] According to various embodiments, at least a portion of the inner tube **22** may be formed from a material substantially different from that of the remainder of the inner tube **22** and/or the outer tube **16**. In certain embodiments, at least the absorption portion **24** of the inner tube **22** is formed from carbon steel material, while the mounting portion **30** and the outer tube **16** are formed from a commonly known stainless steel material (e.g., the non-limiting examples of a Series 300—304, 310, or 316—rated stainless steel). In this manner, the absorption portion **24** of the inner tube **22** provides in various embodiments improved performance characteristics relative to commonly known inner tubes **22** fully formed from stainless steel.

[0062] As non-limiting examples, the formation of at least the absorption portion **24** from a carbon steel material results in an overall lighter weight of the absorber tube **14**, a harder and stronger surface to withstand operational conditions, and/or a heightened rate of heat transfer of thermal energy to the fluid **15** within the absorber tube. Still further, in certain embodiments, the formation of at least the absorption portion **24** from a carbon steel material results in an expansion of the absorption portion **24** (e.g., along its longitudinal length) of approximately one inch (1"), for absorber tubes **14** having a total length of approximately four meters (4 m). Such is in comparison to an expansion (along the same longitudinal length) of approximately six inches (6") for absorber tubes **14** formed entirely from stainless rather than carbon steel. As such, in these and still other embodiments, an additional non-limiting advantage exists in that less complex and smaller expansion elements **40** may be incorporated within the absorber **14**, thereby reducing costs and inefficiencies otherwise oftentimes encountered.

[0063] According to various embodiments, the inner tube **22** of the absorber tube **14** may contain a fluid **15** that is generally heated as a result of the passage of thermal energy (e.g., sunlight) into the inner tube, as has been previously described herein. In certain embodiments, the fluid **15** may comprise a hydrocarbon (CxHy), such as the non-limiting example of crude oil. As commonly known and understood in the art, and as has been described in at least U.S. Patent Application Publication No. 2010/0126499 filed by Wei David Lu of Greer, S.C. and incorporated herein by reference in its entirety, gas molecules (e.g., hydrogen in oils) separate when heated, causing them to oftentimes permeate from within the inner tube **22** and into the space **60** adjacent the outer tube **16**, thus creating concerns and inefficiencies as previously described herein. Various types of permeating gas molecules, also commonly known and understood in the art, include the non-limiting examples of air, carbon dioxide, carbon monoxide, nitrogen, oxygen, and/or water.

[0064] Various configurations of absorber tubes **14** have sought to mitigate problems associated with gas permeation by incorporating a plurality of getters **50** (see FIGS. **2** and **3**), which absorb the gas (e.g., hydrogen) molecules that enter the space **60**. However, various embodiments of the present invention, as illustrated in at least FIG. **4** seek not only address the above-referenced problems, but also to minimize the number of getters necessary, as such require maintenance during operation. To minimize the need for such maintenance, amongst other concerns, various embodiments incorporate a plurality of coating layers **36**, **37**, and **38** onto the inner tube **22** of the absorber tube **14**. In certain embodiments, only a portion of the inner tube **22** contains the plurality of coating layers **36**, **37**, and **38**, while in other embodiments, the entirety of the tube is coated. In at least the illustrated embodiment, only the absorption portion **24** of the inner tube **22** contains the coating layers **36**, **37**, and **38**.

[0065] Remaining with FIG. **4**, according to various embodiments, the absorption portion **24** of the inner tube **22** (and in some instances the entirety of the inner but **22**, as will be described in further detail below) may comprise a plurality of coating layers **36**, **37**, and **38** adhered to the outer wall **27** of the absorption portion (see also FIG. **3**). In these and other embodiments, the plurality of coating layers comprises an innermost copper layer **36**, an intermediary bonding layer **37**, and an outermost absorbing layer **38**. In certain embodiments, the innermost copper layer **36** is adhered to the outer wall **27** of the inner tube **22**. In at least one embodiment, the copper layer **36** is adhered to the outer wall **27** by electrically charging the outer wall **27** so as to attract the copper layer **36** upon formation of the vacuum within the space **60**, as previously described herein. In other embodiments, the copper layer **36** may be adhered to the outer wall **27** in any of a variety of ways, provided such does not adversely impact the physical characteristics of the copper material itself.

[0066] As a non-limiting example, the copper layer **36** may be adhered to at least a portion of the inner tube **22** by electrically charging the copper layer upon it being placed within the space **60** between the inner tube and the outer tube **16**. In certain embodiments, a vacuum created within the space **60** may be initially positively charged. Upon insertion, the copper layer **36** may be negatively charged, thus causing the copper layer to be forced into contact (e.g., via electromagnetic forces) with the outer wall **24** of the inner tube **22**. It should be understood that, in other embodiments, the copper layer **36** may be adhered to at least a portion of the inner tube **22** in any of a variety of commonly known and understood methods, as may be desirable or perhaps advantageous for a particular application.

[0067] It should be understood that the physical characteristics of copper provide a unique combination of heat loss and reflectivity. In particular, according to various embodiments wherein gas molecules are subject to permeation from within the inner tube **22** and out into the space **60** adjacent the outer tube **16**, the copper layer **36** provides a reflective surface that not only impedes the gas molecules (e.g., hydrogen) from escaping the inner tube **22**, but also reflects such back into the fluid **15** contained therein, thereby improving the overall efficiency of a solar concentrator or solar collection system upon which the absorber tube **14** according to various embodiments is installed. It should be understood that in certain embodiments, provision of the copper layer **36** impedes migration and/or permeation of gas molecules, while in other embodiments, the copper layer **36** may be configured so as to substantially prevent the same. In still other embodiments, the copper layer **36** may be configured so as to impede migration and/or permeation of gas molecules to a particular degree sufficient to reduce by ¼ the number of getters **50** required within the space **60**, while in further envisioned embodiments, the copper layer **36** may enable a greater degree of reduction in the number of getters **50**, as may be desirable for a particular application.

[0068] Returning now to FIG. **4**, it should be understood that various embodiments of the inner tube **22** may be coated not only with the copper layer **36**, as previously described herein, but also with at least a thermal energy absorber layer **38**. In certain embodiments, the absorber layer **38** comprises a nitride material configured to facilitate absorption of thermal energy through the inner tube **22** and into the fluid **15** contained therein. In at least one embodiment, the absorber layer **38** comprises an aluminum nitride (ALN) coating, while in other embodiments, the absorber coating may comprise a titanium nitride (TIN) coating.

[0069] In various embodiments, the absorber layer **38** and the copper layer **36** are adhered relative to one another via a bonding layer **37**. In certain embodiments, the bonding layer is an aluminum nitride—stainless steel coating that provides adhesive characteristics between the absorber and copper layers **36**, **38**. In other embodiments, the bonding layer may be any of a variety of commonly known and used adhesive materials sufficient to bond two respective coating layers relative to one another. It should be understood, however, that in these and still other embodiments, the bonding layer **37**, like the absorber layer **38** must likewise be configured so as to not substantially impede the absorption of thermal energy into the inner tube **22** and the fluid **15** contained therein.

[0070] Remaining with FIG. **4**, but with combined reference with FIG. **3**, various embodiments may be configured such that an entirety of the inner tube **22** is at least partially coated with a desirable combination of the absorber layer **38**, the copper layer **36**, and/or the bonding layer **37**, as may be desirable for particular applications. In certain embodiments, the layers **36**-**38** may substantially coat the entirety of the inner tube **22**. In other embodiments, however, it should be understood that only the absorption portion **24** (see FIG. **3** in particular) may contain the layers **36**-**38**, while the mounting portion **30** of the inner tube **22** may remain substantially free from such layers. In at least the illustrated embodiments, the absorption portion **24** is substantially coated with the respective layers **36**-**38**, although in still other embodiments, only a portion of the absorption portion **24** may be coated, as may be desirable for a particular application.

[0071] Refocusing again on FIG. **3**, the absorber tube **14** according to various embodiments may further comprise a connecting member **70**. In certain embodiments, the connecting member **70** is configured to provide an interface between the absorption portion **24** and the mounting portion **30** of the inner tube **22**. In at least the illustrated embodiment, the connecting member **70** is formed from a stainless steel material substantially the same as that form which the mounting portion **30** is formed, as previously described herein. In this manner, the connecting member **70** according to certain embodiments is configured to withstand external environmental conditions (e.g., corrosion, weather, etc.) in a manner substantially the same as previously described herein with reference to the mounting portion **30** of the inner tube **22**. However, it should be understood that the connecting member **70** may be formed from any of a variety of materials, as commonly known and understood in the art, provided such exhibit a sufficient degree of environmentally-resistive characteristics, as may be desirable for a particular application.

[0072] Turning now to FIGS. **5**-**7**, it may be seen that the connecting member **70** according to various embodiments may be generally disc shaped and include an annular ring portion **72**, an outwardly extending protrusion portion **74**, and a cavity **79** formed there within. In certain embodiments, a diameter of the cavity **79** may define an inner diameter of the annular ring portion **72**, which in turn may correlate substantially with an inner diameter of the inner tube **22** of the absorber tube **14**. In at least one embodiment, the diameter of the cavity **79** is roughly 65 millimeters while the diameter of the inner tube is roughly 70 millimeters. In other embodiments, the difference in diameters may be greater than or less than the 5 millimeter difference noted previously; however, it should be understood that the difference should be such that the connecting member **70** provides sufficient structure while not impeding flow of the fluid **15** contained within the inner tube **22**, to an extent that may be desirable for a particular application.

[0073] With particular reference to FIGS. **7**A-B, in various embodiments, the annular ring portion **72** may include at least two outer edge portions **73**. In certain embodiments, at least one of the at least two outer edge portions **73** is configured to be positioned substantially adjacent an inner wall **25** of the absorption portion **24** of the inner tube **22** (see also FIG. **5**). In these and still other embodiments, the remaining one of the at least two outer edge portions **73** is similarly configured to be positioned substantially adjacent an inner wall **31** of the mounting portion **30** of the inner tube **22** (see again FIG. **5**). In this manner, according to various embodiments, the at least two outer edge portions **73** define an outer diameter of the annular ring portion **72**, which is substantially the same as the inner diameter of the inner tube **22**, as previously described herein. In at least the illustrated embodiment, the outer diameter of the annular ring portion **72** and the inner diameter of the inner tube **22** are substantially **70** millimeters, while in other embodiments it should be understood that the two diameters may be less than or greater than 70 millimeters, as may be desirable for a particular application. In these and still other embodiments, however, the outer diameter of the annular ring portion **72** and the inner diameter of the inner tube **22** are generally configured to create a press or interference type fit between the two, thereby at least partially retaining the connecting member **70** at a particular location within the inner tube **22**.

[0074] As also illustrated by FIGS. **6**-**7**B, the protrusion portion **74** of the connecting member **70** according to various embodiments may similarly comprise an outer edge portion **76** and at least two side portions **78**. In certain embodiments, with reference as well to FIG. **5**, a first of the at least two side portions **78** may be configured so as to substantially engage an end **29** of the absorption portion **24** of the inner tube **22**. In these and still other embodiments, the remaining one of the at least two side portions **78** is similarly configured so as to substantially engage an end **35** of the mounting portion **30** of the inner tube **22** (see again FIG. **5**). In this manner, according to various embodiments, the at least two side portions **78** are interposed between the ends **29**, **35**, thereby containing the absorption portion **24** internal to the absorber tube **14** and thus protected from external environmental elements, as previously described herein.

[0075] Focusing in particular on FIGS. **5**-**6**, according to various embodiments, the outer edge portion **76** of the protrusion portion **74** is configured such that it defines an outer diameter of the connecting member **70**, greater than that defined by the edge portions **73** of the annular ring portion **72**. In certain embodiments, the outer edge portion **76** defines a diameter substantially the same as that defined by the outer wall **27** of the absorption portion **24** and the outer wall **33** of the mounting portion **30** of the inner tube **22**. In this manner, the outer edge portion **76**, together with the edge portions **73** effectively seal the connecting member **70** adjacent the portions **24**, **30** of the inner tube **22**, thereby substantially preventing any leakage of the fluid **15** contained therein. At the same time, in these and still other embodiments, the connecting member **70** provides a degree of flexibility (e.g., expansion) in response to thermal energy, as previously described herein.

[0076] It should be understood that although the connecting member **70** as illustrated in FIGS. **5**-**7**B and described herein has been described as generally disc-shaped and/or having an annular ring and/or protrusion portion, it should be understood that the connecting member may take on any of a variety of shapes, configurations, and/or sizes, as may be desirable for a particular application. In these and still other embodiments, the shapes, configurations and/or sizes of the connecting member **70** may be determined, at least in part from the shapes, configurations, and/or sizes of the associated absorber tube **14**, so as to maintain substantially the same relationship there-between. As a non-limiting example, although the absorber tube **14** portions and the connecting member **70** have been described and illustrated herein as generally circular or disc-shaped, alternative embodiments may be rectangular, square, or even triangularly-shaped, as may be desirable for a particular application, and such would remain within the spirit and scope of the various embodiments of the present invention.

[0077] Indeed, many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

That which is claimed:

1. An absorber tube configured for the collection of solar thermal energy in a solar concentrator system, said absorber tube comprising:

an inner tube comprising an interior surface and an exterior surface, at least a portion of said exterior surface comprising a plurality of coating layers; and

an outer tube substantially surrounding said inner tube and being spaced apart from and concentric with said inner tube so as to define a cavity between said inner tube and said outer tube,

wherein at least one of said plurality of coating layers is configured to substantially impede migration of gaseous molecular particles from said interior surface of said inner tube and into said cavity.

2. The absorber tube of claim **1**, wherein said plurality of coating layers comprise a reflective layer and an absorptive layer, said reflective layer being substantially intermediate said absorptive layer and said exterior surface of said inner tube.

3. The absorber tube of claim **2**, wherein said reflective layer is configured to deflect a substantial portion of said gaseous molecular particles toward said interior surface of said inner tube.

4. The absorber tube of claim **2**, wherein said reflective layer comprises a copper coating, said copper coating being configured to deflect a substantial portion of said gaseous molecular particles toward said interior surface of said inner tube.

5. The absorber tube of claim **2**, wherein said reflective layer is operatively adhered to said exterior surface of said inner tube.

6. The absorber tube of claim **5**, wherein said reflective layer comprises a copper coating that is operatively adhered to said exterior surface of said inner tube by generating an electrical charge between said copper coating and said exterior surface.

7. The absorber tube of claim **2**, wherein said absorptive layer comprises a nitride material configured to absorb a substantial portion of the solar thermal energy captured in said solar concentrator system.

8. The absorber tube of claim **1**, wherein said plurality of coating layers comprise a reflective layer, a bonding layer, and an absorptive layer, said reflective layer being substantially intermediate said bonding layer and said exterior surface of said inner tube, said bonding layer being substantially intermediate said reflective layer and said absorptive layer.

9. The absorber tube of claim **1**, wherein said plurality of coating layers comprise a copper coating, said copper coating being operatively adhered to said exterior surface of said inner tube by generating an electrical charge between said copper coating and said exterior surface, said copper coating further being configured to deflect a substantial portion of said gaseous molecular particles toward an interior volume of said inner tube so as to substantially impede migration of gaseous molecular particles from said interior volume and into said cavity between said inner tube and said outer tube.

10. The absorber tube of claim **1**, wherein:

said inner tube comprises a first end portion, a first connecting member, a second end portion, a second connecting member, and a central portion, said central portion being located intermediate said first and said second connecting portions, said first connecting member being further located intermediate said first end portion and said central portion, said second connecting member being further located intermediate said second end portion and said central portion; and

said at least a portion of said exterior surface of said inner tube comprising said plurality of coating layers consists of said central portion.

11. The absorber tube of claim **10**, wherein:

said central portion is formed from a carbon steel material;

said first and second connecting members are formed from a stainless steel material; and

said first and second end portions are formed from a stainless steel material.

12. The absorber tube of claim **10**, wherein:

said connecting member is substantially disc-shaped and comprises an annular ring portion and a protrusion portion;

a diameter of said annular ring portion is substantially the same as a diameter of said interior surface of said inner tube, such that at least a portion of said annular ring portion is configured to form a seal between said interior surface of said inner tube and said connecting member; and

a diameter of said protrusion portion is substantially the same as a diameter of said exterior surface of said inner tube, such that at least a portion of said protrusion portion is configured to form a seal between a passage through said inner tube and said connecting member.

13. The absorber tube of claim **10**, wherein said plurality of coating layers comprise at least a copper coating, said copper coating being operatively adhered to said central portion of said inner tube by generating an electrical charge between said copper coating and said central portion, said copper coating further being configured to deflect a substantial portion of said gaseous molecular particles toward an interior volume of said inner tube so as to substantially impede migration of gaseous molecular particles from said interior volume and into said cavity between said inner tube and said outer tube.

14. An absorber tube configured for the collection of solar thermal energy in a solar concentrator system, said absorber tube comprising:

an inner tube comprising:

(A) a central portion;

(B) at least one end portion, said at least one end portion being configured to facilitate mounting the absorber tube relative to said solar concentrator system; and

(C) at least one connecting member, said at least one connecting member being located intermediate said central portion and said at least one end portion; and

said central portion of said inner tube being formed from a steel-based material having a structural composition substantially different from a material of said at least one end portion.

15. The absorber tube of claim **14**, wherein said steel-based material of said central portion comprises carbon steel and said material of said at least one end portion comprises stainless steel.

16. The absorber tube of claim **15**, wherein said at least one connecting member is formed from a stainless steel material.

17. The absorber tube of claim **14**, wherein said steel-based material of said central portion is at least one of substantially lighter than, substantially harder than, and substantially stronger than said material of said at least one end portion.

18. The absorber tube of claim **14**, wherein, during use, the steel-based material of said central portion expands along a longitudinal axis of said inner tube at an expansion rate approximately ⅙ of an expansion rate for said material of said at least one end portion.

19. The absorber tube of claim **14**, wherein said connecting member is substantially disc-shaped.

20. The absorber tube of claim **14**, wherein said connecting member comprises an annular ring portion and a protrusion portion.

21. The absorber tube of claim **20**, wherein:

a diameter of said annular ring portion is substantially the same as a diameter of an interior surface of said inner tube, such that at least a portion of said annular ring portion is configured to form a seal between said interior surface of said inner tube and said connecting member; and

a diameter of said protrusion portion is substantially the same as a diameter of an exterior surface of said inner tube, such that at least a portion of said protrusion portion is configured to form a seal between a passage through said inner tube and said connecting member.

22. The absorber tube of claim **21**, wherein:

said annular ring portion comprises a first seat portion, said first seat portion being configured to form a seal between an interior surface of said at least one end portion and said connecting member;

said annular ring portion comprises a second seat portion, said second seat portion being configured to form a seal between an interior surface of said central portion and said connecting member; and

said protrusion portion is substantially intermediate said first seat portion and said second seat portion.

23. The absorber tube of claim **22**, wherein said first seat portion, said second seat portion, and at least a portion of said protrusion portion are configured to substantially mate with said central portion and said at least one end portion so as to form a press fit there-between.

24. The absorber tube of claim **14**, wherein:

said at least one end portion comprises a first end portion and a second end portion;

said at least one connecting member comprises a first connecting member and a second connecting member, said first connecting member being located intermediate said central portion and said first end portion, said second connecting member being located intermediate said central portion and said second end portion;

said first connecting member comprises a first annular ring portion and a first protrusion portion, a diameter of said first annular ring portion being substantially the same as a diameter of an interior surface of said inner tube, such that at least a portion of said first annular ring portion is configured to form a seal between said interior surface of said inner tube and said first connecting member, a diameter of said first protrusion portion being substantially the same as a diameter of an exterior surface of said inner tube, such that at least a portion of said first protrusion portion is configured to form a seal between a passage through said inner tube and said first connecting member; and

said second connecting member comprises a second annular ring portion and a second protrusion portion, a diameter of said second annular ring portion being substantially the same as a diameter of an interior surface of said inner tube, such that at least a portion of said second annular ring portion is configured to form a seal between said interior surface of said inner tube and said second connecting member, a diameter of said second protrusion portion being substantially the same as a diameter of an exterior surface of said inner tube, such that at least a portion of said second protrusion portion is configured to form a seal between a passage through said inner tube and said second connecting member.

25. The absorber tube of claim **24**, wherein:

said central portion is formed from a carbon steel material;

said first and second connecting members are formed from a stainless steel material; and

said first and second end portions are formed from a stainless steel material.

26. The absorber tube of claim **14**, wherein:

said absorber tube further comprises an outer tube substantially surrounding said inner tube and being spaced apart from and concentric with said inner tube so as to define a cavity between said inner tube and said outer tube;

said central portion of said inner tube comprises an interior surface and an exterior surface, at least a portion of said exterior surface of said central portion comprising a plurality of coating layers; and

at least one of said plurality of coating layers is configured to substantially impede migration of gaseous molecular particles from said interior surface of said central portion of said inner tube and into said cavity.

27. The absorber tube of claim **26**, wherein said plurality of coating layers comprise a copper coating, said copper coating being operatively adhered to said exterior surface of said central portion of said inner tube by generating an electrical charge between said copper coating and said exterior surface, said copper coating further being configured to deflect a substantial portion of said gaseous molecular particles toward an interior volume of said central portion of said inner tube so as to substantially impede migration of gaseous molecular particles from said interior volume and into said cavity between said central portion of said inner tube and said outer tube.

28. The absorber tube of claim **26**, wherein:

said plurality of coating layers comprise a reflective layer, a bonding layer, and an absorptive layer, said reflective layer being substantially intermediate said bonding layer and said exterior surface of said inner tube, said bonding layer being substantially intermediate said reflective layer and said absorptive layer;

said reflective layer is configured to deflect a substantial portion of said gaseous molecular particles toward said interior surface of said central portion of said inner tube; and

said absorptive layer is configured to absorb a substantial portion of the solar thermal energy captured in said solar concentrator system .

29. A method for manufacturing an absorber tube configured for the collection of solar thermal energy in a solar concentrator system, said method comprising the steps of:

(A) providing an absorber tube comprising:

(1) an inner tube comprising an interior surface and an exterior surface; and

(2) an outer tube substantially surrounding said inner tube and being spaced apart from and concentric with said inner tube so as to define a cavity between said inner tube and said outer tube;

(B) inserting a reflective coating material into said cavity between said inner tube and said outer tube; and

(C) creating an electrically charged vacuum within said cavity, such that said reflective coating material is electrically attracted to and thus adhered to said exterior surface of said inner tube.

30. The method of claim **29**, wherein:

said reflective layer comprises a copper coating;

said copper coating is negatively charged; and

said vacuum is positively charged so as to cause the copper coating to be forced into contact with said exterior surface of said inner tube.

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