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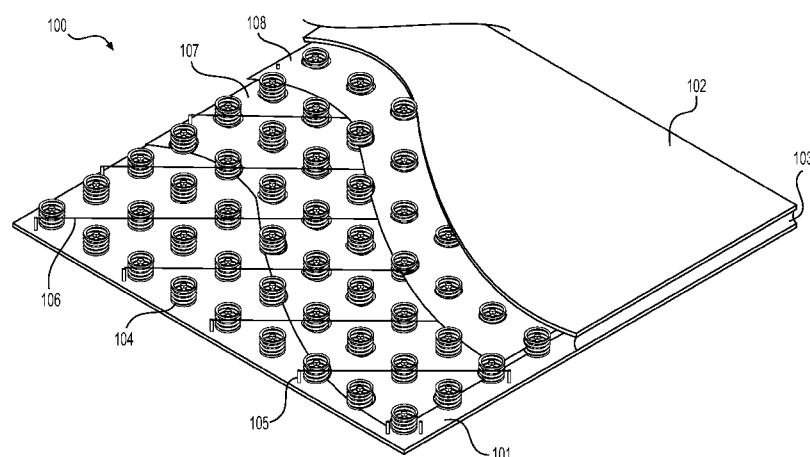


FIG. 1

(57) Abstract: A thermally insulative sealed hollow panel with significantly improved thermal resistance, comprising inner and outer plates spaced apart by helically coiled springs, and at least one layer of low thermal emissivity foil supported by crisscrossing wires anchored at points along the perimeter edge of the inner plate.



THERMALLY INSULATED PANEL

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This application is a PCT application and claims priority to currently pending United States patent application serial no. 14/181,605 filed February 14, 2014 entitled “Thermally Insulated Panel”, the contents of which are incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[002] The present invention relates to thermal insulation, more particularly to vacuum insulated panels.

BACKGROUND

[003] Thermal barriers are physical structures that are designed to greatly impede the flow of heat from the high temperature side to the low temperature side. There are three primary mechanisms that allow heat to migrate; conduction, convection, and radiation. Conduction, convection, and radiation occur simultaneously; i.e. they occur in parallel, allowing heat to transfer along three different routes at once. A good thermal barrier will inhibit all three of these mechanisms. The greater the inhibition, the higher the classification of the thermal barrier. This classification is known as the R-value, or resistance value. Under uniform conditions this is calculated as the ratio of the temperature difference across an insulator and the heat transfer per unit area per unit time. In the United States, the customary units for R-value are BTU / (h °F ft²).

[004] There are different materials known for their insulation properties. The construction industry prefers glass-fiber batting, loose fill, rigid foam, and foam-in-place. These are good

insulators and are relatively inexpensive, but generally do not have an R-value greater than 49. In addition, these higher R-value products require large thicknesses to achieve good insulation. For example, to achieve an R-value of 49 with fiberglass batting, it must be nearly 16 inches thick, which is too thick for general construction needs. Thus, there has been a long-standing need for a lightweight, thin, highly insulative panel with very large R-values. In view of the above, the below description provides examples of panels that address the deficiencies of the prior art as well as provide in some instances, R-values approaching 100 or more.

SUMMARY OF THE INVENTION

[005] The following presents a simplified summary in order to provide a basic understanding of some aspects of the claimed subject matter. This summary is not an extensive overview, and is not intended to identify key/critical elements or to delineate the scope of the claimed subject matter. Its purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

[006] In one aspect of various exemplary embodiments, a thermally insulative sealed hollow panel is provided, the panel comprising: a first plate disposed adjacent to a substantially parallel second plate; a plurality of helically coiled springs with axes of compression that are substantially perpendicular to the plates and disposed therebetween, said axes being substantially equidistant from each other; at least one layer of a low thermal emissivity film disposed between the plates and substantially parallel thereto, wherein the film engages the plurality of springs; and a flexible perimeter edge membrane joined to at least one perimeter edge of the first plate and at least one perimeter edge of the second plate, thereby forming a closed cavity with a pressure between 0 and 1 atm.

[007] In one aspect of various exemplary embodiments, a thermally insulative sealed hollow panel is provided, the panel comprising: a support structure comprising, a first frame disposed adjacent to a substantially parallel second frame, each frame having at least one perimeter member and a plurality of cross members, a plurality of helically coiled springs with axes of compression that are substantially perpendicular to the frames with the springs disposed therebetween, a plurality of guy wires, each guy wire having a first end and a second end, the first end being joined to the first plate and the second end being joined to the second plate, whereby the guy wires diagonally traverse a central region, and at least one layer of low thermal emissivity film disposed between the frames and substantially parallel thereto, wherein the film engages at least one of the plurality of springs; and an enclosure surrounding the support structure thereby creating a closed cavity with a pressure between 0 and 1 atm, wherein the enclosure is joined to the first frame and the second frame.

[008] In one aspect of various exemplary embodiments, a thermally insulative sealed hollow panel is provided, the panel comprising: means for enclosing a vacuum sealable cavity, wherein the enclosing means comprise at least two substantially parallel sides and at least one flexible edge membrane; means for spacing the two sides; means for reducing radiative heat transfer between the two sides; means for supporting the radiative heat transfer reducing means; and means for anchoring the supporting means to the enclosing means, the anchoring means joined to at least one side of the enclosing means.

BRIEF DESCRIPTION OF THE DRAWINGS

[009] FIG. 1 is a perspective view with layered cross-section of an embodiment vacuum insulated panel.

[0010] FIG. 2 is a zoomed in view of a section of the panel shown in FIG. 1.

[0011] FIG. 3 is a top view of another embodiment vacuum insulated panel, showing an internal frame.

[0012] FIG. 4 is a zoomed in view of a section of the panel shown in FIG. 3.

[0013] FIG. 5 is a cross-section of another embodiment vacuum insulated panel.

[0014] FIG. 6 is a cross-section of still another embodiment vacuum insulated panel.

[0015] FIG. 7 is a top view of another embodiment vacuum insulated panel without the enclosure.

[0016] FIG. 8 is a sectioned, side view of the panel shown in FIG. 7.

[0017] FIG. 9 is a perspective view of an embodiment safety clasp.

DETAILED DESCRIPTION

[0018] In the following detailed descriptions of various exemplary embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown, by way of illustration, specific embodiments that may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present disclosure.

[0019] Another type of thermal barrier is a vacuum insulated panel (VIP). Generally, these panels are metal or plastic enclosures with sealed edges in order to evacuate most of the gaseous molecules from the interior of the enclosure. The reason for vacuum sealing an enclosure is because it greatly minimizes convective heat transfer between the high temperature side and the low temperature side. A perfect vacuum eliminates the convective transfer altogether. VIPs must have at least three sides (a cylinder); an internal side, an external side, and an edge side.

The most practical configuration for use in construction and on most structures would have six sides (a flat rectangular box) wherein the interior side adjoins the structure. The internal side may be the high temperature side or the low temperature side, depending on the application. For instance, the VIP may be the insulator for a freezer or for a furnace.

[0020] There are three primary applications of this technology that will affect a significant improvement in the reduction of energy consumption. The first is a small, self-contained unit like a refrigerator or freezer. The second is heat storage applications as related to intermittent alternate energy storage in the form of a very hot medium. Excess energy produced during high peak periods can be stored in high temperature fluids and released through heat pumps during low energy generation. Resisting heat loss would add to the overall efficiency of such a system. The third, and perhaps for the more energy conservationist application, is to apply this technology to the construction of hyper-insulated buildings. The skeletal I-beam construction of buildings could be greatly improved, from an energy consumption perspective, by utilizing an external “skin” composed of a connected series of hyper-insulative panels created in the manner described herein. Such a structure would be very similar to current construction methods and yet, the heating ventilation and air-conditioning (HVAC) requirements would be reduced by at least two-thirds.

[0021] One drawback that has heretofore plagued VIPs is the spacers used for keeping the plates separated. Pressure inside the enclosure is reduced as air is evacuated from inside the enclosure and the sides collapse toward each other because atmospheric pressure, or external pressure, becomes greater than the internal pressure. If left unsupported, then the plates would fully collapse and thermally conduct thereby losing insulative ability. VIPs may counteract the compressive force of air through the use of a rigid, highly-porous material, such as foam, to

support the enclosure. To improve the insulative value of a VIP, multiple layers of plastics or foam provide radiative baffles, but these layers still conduct heat. Cylindrical pins may be used as spacers to prevent plate compression and minimize conductive heat transfer, but any of these structural elements allow heat to freely conduct from one side of the panel to the other. In fact, quite substantially so. By way of example, a four-foot by eight-foot VIP with high stress stainless steel sides and enough 1mm diameter pins of the same material to prevent the panel from collapsing under vacuum will yield an R-value of approximately 2.5. R-values of 50 per inch thickness, measured at the center of the panel, have been achieved with a rigid core VIP.

[0022] Engineering a VIP involves making numerous design trade-off decisions. For example, vacuum sealing greatly increases the R-value, but the sides must be supported to prevent collapse. In another example, 6AL-4V Titanium (Ti) has a very low thermal conductivity ($6.70 \text{ W/m}\cdot\text{K}$), but it is expensive, almost prohibitively so. Using low thermal conductivity material is a substantial component to the achievement of such a high R-value, but the largest contributing factor to achieving very large R-values is vacuum sealing the VIP. A vacuum seal may be defined as an internal pressure less than 1 atm at sea level, though, typically, vacuum sealing refers to an absence of matter (gas molecules) and connotes an internal pressure much less than 1 atm. For the purpose of this disclosure, vacuum pressure is essentially defined as any pressure obtained by a vacuum pump because, practically speaking, a perfect vacuum cannot be obtained. Vacuum pressure may also be referred to as negative pressure because pressure gauges are calibrated to measure atmospheric pressure as 0 psig and any pressure less than atmospheric would measure as a negative value. Partial filling may be defined as the total volume of gas being less than the total free volume inside the panel. Partial filling may also be defined as a pressure inside the panel of less than 1 atmosphere (atm) at sea level, but generally greater than

0.05 atm. Partial back-filling refers to creating a vacuum and then replacing some of the empty space with a gas.

[0023] To demonstrate the effectiveness that vacuum sealing a VIP has on the R-value, two identically constructed panels are compared; one with a vacuum seal and one without a vacuum seal. In an embodiment, a 1 square meter rectangular vacuum sealed panel comprised of 6AL-4V Ti sides, 6AL-4V Ti springs, 8 layers of polished copper foil having a thickness of .003-.005 inches and with a thermal emissivity of 0.02, yields an R-value of approximately 174 in the center of the panel with an overall thickness of 1.678 inches (103.6 R per inch thickness).

Compared to a panel with an air-filled interior, the R-value is calculated to be approximately 10.

[0024] However, a vacuum sealed interior is not required to achieve substantial R-values with a thin panel. For example, if, in the previous example, air were to be replaced with Xenon gas, then the calculated R-value would increase to approximately 48. Thus, a vacuum sealed panel at least partially back-filled with a low specific heat gas ($c_p \leq .60$), such as Argon, Krypton, Xenon, and so forth, will yield acceptable R-values.

[0025] In another embodiment, titanium components of the previous vacuum sealed example are replaced with 316L sides, 17-7 stainless steel H900 temper springs, and consumer grade aluminum foil. This combination of materials yields a calculated R-value of 124 (73.9 per inch thickness) in the center of the panel.

[0026] Turning now to the drawings, FIG. 1 is a perspective view with a layered cross-section of an embodiment vacuum insulated panel **100**. Here, internal sections are cut in a curved shape to more easily illustrate how the layers interact. A person having ordinary skill in the art will appreciate that the exemplary embodiment VIP may include more, less, or different components than the ones illustrated, which are shown merely as one example. Therefore, modifications,

changes, and different configurations may be made without departing from the spirit and scope of this disclosure. In an embodiment, the first layer **101**, otherwise called a first panel or an internal panel, may support an end of the helically coiled compression springs **104**. These springs **104** may act as spacers to displace the first and second panels **101**, **102** apart.

Theoretically, a perfect spacer for a VIP would be one that tapers at each end to an infinitesimally small point that contacts a surface of the first panel **101** and a surface of a second panel **102**. However, in practice, a double-ended sharp pointed spacer will either pierce the panels **101**, **102**, thereby relieving internal vacuum, or cause the spacer tip to collapse under load because the tip would plastically deforms to a much broader point, thus defeating the effectiveness of a sharp pointed spacer.

[0027] Springs **104** surmount this problem two-fold. First, the springs **104** may support a large area between the first panel **101** and the second panel **102** upon vacuum sealing the panel **100**. The supported area may, generally, be the outer diameter of the spring **104**. Thus, a spring **104** may not puncture the panel **100** while under load because the force exerted by the panel **100** onto the spring **104** is spread over a much larger area. This force divided by area, or pressure, creates a stress manageable by most rigid materials' tensile strength, including many plastics or glass. Second, springs **104** are much more effective in preventing conductive heat transfer than other types of spacers because heat must conduct along the entire length of the spring coil. Heat flow rate via conduction is governed by Fourier's Law, or $Q = -kA\Delta T/\Delta x$, where Δx is the length of spring wire between the ends of the coil, ΔT is the temperature delta, A is the cross-sectional area of the coil's wire, and k is the thermal conductivity of the material. Thus, the R-value of a VIP increases as coil wire length increases, coil wire cross-sectional area decreases, and thermal conductivity decreases.

[0028] A spring may be manufactured in many varieties and its properties may be tailored for a specific application. For a panel **100** as shown in FIG. 1, a spring **104** may have a diameter larger than 1 inch, may have more than 5 coils, may have a coil diameter larger than 0.125 inch, may and be made from a low thermal conductivity metal such as 6AL-4V titanium, 17-7 H900 temper stainless steel, 316L stainless steel, and so forth. Thermal conductivity has units of $\text{W/m}\cdot\text{K}$ and a low value is generally considered to be less than 20. Metal may be required as a structural material for the enclosure **101**, **102**, **103** or the springs **104** because the load on an individual spring **104** may exceed 1000 lbf and metal, generally, can withstand higher stress before plastic deformation occurs. Although, using plastic does afford some advantages over a metal structure. First, plastics have a much lower thermal conductivity than most metals; usually less than $1 \text{ W/m}\cdot\text{K}$. Second, plastics are much lighter than most metals and could significantly reduce the overall weight by 4 or 5 times. Third, a plastic cavity can be easily sealed under vacuum with a heat-weld process. Thus, plastic is envisioned as a substitute for the metal structure when certain functional application requirements are met. Such requirements may be, for example, the interior or exterior temperature to be insulated, the amount of pressure within the enclosure, the structural requirements of the building, and so forth. Yet another material option may be structural carbon fiber because it has a thermal conductivity through-the-thickness that ranges from 2 to $21 \text{ W/m}\cdot\text{K}$, and has higher tensile strength than more metals.

[0029] In an embodiment, springs **104** may have axes of compression substantially perpendicular to the plates **101**, **102**, said axes may be uniformly distributed between the plates **101**, **102**. Uniform distribution of springs **104** may have the effect of evenly dividing the load to each spring **104**, said load created by reducing the internal pressure of the panel **100**. Spacing between the springs' axes of compression may depend on manufacturing tolerance and

techniques known to those skilled in the art. Spacing between the axes may be controlled during the manufacturing process by temporary fixtures. Spacing between the axes may be controlled by joining the springs **104** to the plates **101**, **102** through welding, adhesives, tabs, or other joining means known to those skilled in the art. Spacing between the axes may be controlled by cups (see FIG. 5 or FIG. 6), grooves (see FIG. 4), bores (see FIG. 5), or other means known to those skilled in the art.

[0030] Returning to FIG. 1, in an embodiment, intermediate layers **107**, **108** may be used to prevent radiative heat transfer. It is contemplated that there may be none, one, or more than one intermediate layers **107**, **108** between the plates **101**, **102**. Intermediate layers **107**, **108** may comprise low emissivity foil such as polished copper or silver (.02-.03), consumer grade aluminum foil (.04), and so forth. Emissivity, a dimensionless quantity, is the value given to materials based on the ratio of heat emitted and absorbed compared to a blackbody, on a scale from zero to one. A blackbody would have an emissivity of 1 and a perfect reflector would have a value of 0. Low emissivity is widely considered to be less than 0.05. Thus, as the number of layers increase, the total radiative heat transfer between the plates **101**, **102** decreases exponentially because a high percentage of the heat is emitted back toward the heat source at each successive layer. Emissivity of the plates **101**, **102** themselves may also be lowered by polishing the interior surfaces.

[0031] In an embodiment, the intermediate layers **107**, **108** may be disposed onto support wires **106**, which may be attached to anchors **105**, shown here, for example, as being disposed along the perimeter. In this manner, the support wires **106** may be placed in tension as the wire **106** spans a central region of the plates **101**, **102**. A support wire **106** may be one continuous wire, or a plurality of wires that separately engage anchors **105** on opposite sides of the perimeter of the

plates **101**, **102**. A continuous support wire **106** may be woven around the perimeter anchors **105** and crisscross the central region of the plates **101**, **102**. Where a plurality of support wires **106** are used, an embodiment would comprise support wires **106** supported by at least two anchors **105**. In addition, the support wire **106** may engage one or more spring **104** coils as the wire **106** traverses a central region of the plates **101**, **102**, which may provide further support for the wire **106**.

[0032] In an embodiment, the intermediate layers **107**, **108** may be joined to the support wire **106** though welding, adhesive, staples, and so forth.

[0033] In an embodiment, the anchors **105** may be cylindrical pins, square posts, trapezoidal braces, and so forth attached to a plate **101** or **102** via welding, pinning, bracing or other attachment means known to those skilled in the art. In this fashion, the anchors **105** may be cantilevered from the plate **101** or **102**. In order to minimize conduction and to improve the R-value, an anchor **105**, if mounted to plate **101**, may not be in thermal contact with plate **102**. Alternatively, an anchor **105**, if mounted on plate **102**, may not be in thermal contact with plate **101**.

[0034] In an embodiment, plates **101**, **102** may be substantially parallel yet have acceptable misalignment due to manufacturing tolerances and techniques known to those skilled in the art. It is understood that the adjective substantially is a term of art, to connote approximate or principally having the shape, direction, form, etc., of the item being modified by the adjective. Accordingly, substantially inherently provides a degree of reasonable flexibility, in appearance and/or function, to the term/item being modified and should be interpreted in the context of its use according to one of ordinary skill in the art.

[0035] Further, when viewed from a side, plates **101**, **102** may not appear completely flat as they may bow away from each other, where the bow may be caused by the springs exerting force to separate the plates **101**, **102**. The bow may also be caused by the panel's internal pressure being lower than atmospheric pressure, which may cause the plates **101**, **102** to bow toward each other. Localized bowing of the plates **101**, **102** may also be visible where the spring **104** engages the plate given the amount of load, type of material, and thickness of plate **101**, **102** material.

[0036] In an embodiment, the shape of the plates **101**, **102** are rectangular and approximately the same size, though it is contemplated that nearly any shape is feasible to manufacture, such as a square, triangle, circle, polygon, and so forth. Plates **101**, **102** may have acceptable size differences given manufacturing tolerances and techniques known to those skilled in the art.

[0037] In an embodiment, a plate **101** may have a larger perimeter than plate **102** and vice versa. A larger perimeter may create an additional area, wherein this additional area may act as a flange that facilitates construction techniques, such as attaching to a stud wall, hanging onto I-beams, and so forth.

[0038] In an embodiment, an edge sealing membrane **103** is joined to the plates **101**, **102** to create a sealed, hollow cavity. Joining the membrane **103** to the plates may occur through manufacturing processes known to those skilled in the art such as welding, adhesives, o-rings, RTV sealants, and so forth. The membrane **103** may have a small cross-sectional area to minimize heat transfer via conduction through the membrane. In the case of a thin membrane **103**, the edge membrane **103** may be flexible, and may have a radius of curvature flexing inward toward the closed cavity, or bulging outward away from the closed cavity, to accommodate spacing variation between the plates **101**, **102**. Spacing variation may be inherent in the manufacturing process or may be caused by pressure fluctuations within the closed cavity,

particularly if the closed cavity is partially filled with gas. Spacing may also be affected by atmospheric pressure fluctuation. Pressure may fluctuate as gas temperature increases or decreases, following the ideal gas law of thermodynamics, $PV=nRT$. Thus, the membrane **103** may assume a concave or convex shape as viewed from a side perspective.

[0039] In an embodiment, the membrane **103** may be made of a low thermal conductivity material such as 6AL-4V titanium, 17-7 H900 temper stainless steel, 316L stainless steel, plastic, carbon fiber, and so forth.

[0040] FIG. 2 is a zoomed in view of a section of the panel shown in FIG. 1. In an embodiment, a plurality of safety clasps **109**, **110** may be used to capture and control spacing between the adjacent plates **101**, **102**. A panel **100** embodied with springs **104** and a closed cavity at less than atmospheric pressure may contain potential energy in each compressed spring **104**. If the closed cavity of a panel **100** ruptures, then the safety clasps **109**, **110** would restrict separation of the plates **101**, **102**. Safety clasps **109**, **110** may comprise a clasp plug **110** and a clasp receptacle **109**, whereby the clasp plug **110** may be joined to the second plate **102** and the clasp receptacle **109** may be joined to the first plate **101**, or vice versa. The safety clasps **109**, **110** may be joined to the plates **101**, **102** through welding, adhesive, forceful press, or other joining means known to those skilled in the art.

[0041] In an embodiment, the safety clasps **109**, **110** may not be in thermal communication in order to improve R-value. Reducing pressure inside the panel's closed cavity, typically performed during the manufacturing process, may cause the plates **101**, **102** to move toward each other, thereby causing the clasp plug **110** and clasp receptacle **109** to thermally disengage. The clasp plug may limit the travel of the plates **101**, **102** to prevent over-deflection, to prevent the springs **104** from reaching their solid height, and so forth.

[0042] Turning now to FIG. 3, a top view of another embodiment vacuum insulated panel, showing an internal frame **200** is illustrated. The panel enclosure is not shown for clarity, but may be joined to the frame **200** through welding, adhesives, screws, or other joining means known to those skilled in the art. The frame **200** may be comprised of a first perimeter member **201** and a second perimeter member (not shown), whereby the first **201** and second perimeter members are separated by springs **202**. The perimeter members may comprise an entire plate, though overall VIP weight may be undesirable. The springs **202** may have axes of compression substantially perpendicular to the perimeter member **201**, said axes may be evenly distributed between the perimeter member **201**. As explained above, even distribution of springs **202** may have the effect of evenly dividing the load to each spring **202**. Spacing between the springs' axes of compression and the perpendicularity may depend on manufacturing tolerance and techniques known to those skilled in the art. Spacing between the axes may be controlled during the manufacturing process by temporary fixtures. Spacing between the axes may be controlled by joining the springs **202** to the perimeter member **201** through welding, adhesives, tabs, or other joining means known to those skilled in the art. Spacing between the axes may be controlled by cups, grooves, bores, or other means known to those skilled in the art.

[0043] In an embodiment, the frame **200** may have a plurality of cross-members **203**, **206**, where the cross-members **203**, **206** may be joined to the first perimeter member **201** through welding, adhesives, screws, pins, and so forth. The perimeter member **201** and plurality of cross-members **203**, **206** may be formed from a single piece of material as in a stamping operation, laser-cut, water-jet, mold, casting, or other forming process known to those skilled in the art. The cross-members **203**, **206** may support the springs **202** in the central/open region of the frame **200**.

Additionally, the cross-members **203**, **206** may support the frame from lateral compressive or tensile forces.

[0044] In an embodiment, the frame **200** may only comprise a perimeter member **201**. Springs **202** may only engage the plates which are not shown in FIG. 3 (see **101**, **102** in FIG. 1).

[0045] In an embodiment, anchors **204** may be joined to the perimeter member **201** along the outer perimeter edge through welding, screws, pins, and so forth. Support wires **205** may be placed in tension as the wire spans a central region of the frame **200**. The support wire **205** may be continuous or a plurality of wires that separately engage anchors **204** or may be woven around the perimeter anchors **204**, and crisscross the central region of the frame **200**. The support wire **205** may engage one or more spring coils **202** as the wire **205** traverses a central region of the frame **200**, which may provide further support and thermal isolation for the wire **205**.

[0046] In an embodiment, support wires **205** may engage anchors **204** at multiple points to create a plurality of planar layers. The planar layers of support wires **205** may be used as a support for intermediate layers (not shown in FIG. 3) of low thermal emissivity foil to reduce radiative heat transfer. The support wires **205** may not intersect with any other planar layers of support wires **205** to ensure thermal isolation between layers.

[0047] FIG. 4 is a zoomed in view of a panel section illustrated in FIG. 3. Support wires **205** are more easily shown to engage a spring **202** at one of the spring's coils. Through conduction, the temperature of the support wires **205** may be substantially equal to the temperature of the coil of the spring **202** to which it may be engaged.

[0048] FIG. 5 is a cross-section of another embodiment vacuum insulated panel **500**. An enclosure creating a closed cavity may be comprised of a first plate **501**, a second plate **502**, and a perimeter edge membrane **503**. A frame may be disposed within the enclosure between the

plates **501**, **502**, wherein the frame may comprise a first frame and a second frame, the first and second frames may comprise a first perimeter member **504** and a second perimeter member **505**, a plurality of cross-members **506**, anchors **508**, support wires **509**, and springs **507**. The perimeter members **504**, **505** may comprise bores **510**, **511** in which the springs **507** may be restrained from lateral translation in order to maintain equidistant spring axis spacing. The cross-members **506** may be joined to the first perimeter member **504** by welding, forming, pinning, screwing, and so forth. The cross-members **506** may have a jog to accommodate the joining means and provide support for the first plate **501** by being planar with the first perimeter member **504**. In this fashion, the springs **507**, when compressed, can exert force between the first and second frames and evenly distribute that force to the plates **501**, **502**.

[0049] In an embodiment, anchors **508** may be joined to the perimeter member **504** along the outer perimeter edge through welding, screws, pins, and so forth. Support wires **509** may be placed in tension as the wire **509** spans a central region of the panel **500**. The support wire **509** may be continuous or comprise a plurality of wires that separately engage anchors **508**, or may be woven and crisscross the central region of the panel **500**. The support wire **509** may engage one or more spring coils **507** as the wire **509** traverses a central region of the panel **500**. Engagement with a spring coil **507** may include wrapping the wire **509** around an outer portion of the spring coil **507**.

[0050] Turning now to FIG. 6, a cross-section of still another embodiment vacuum insulated panel is illustrated. An enclosure creating a closed cavity may be comprised of a first plate **601**, a second plate **602**, and a flexible perimeter edge membrane **603**. Springs **604** are disposed between the plates **601**, **602** and displace the plates **601**, **602** apart. The springs **604** may be restrained from lateral translation by spring cups **605** in order to maintain equidistant spring axis

spacing. The spring cups **605** may be joined to the plates **601**, **602** through welding, screws, pins, and so forth. Support wires **607** may be placed in tension as the wire **607** spans a central region of the panel **600**. The support wire **607** may be continuous or comprise a plurality of wires that separately engage anchors **606**, or may be woven and crisscross the central region of the panel **600**. The support wire **607** may engage one or more spring coils as the wire **607** traverses a central region of the panel **600**. Engagement with a spring coil may include wrapping the wire **607** around the spring coil's wire or through the coil itself.

[0051] In an embodiment, a plurality of safety clasps **608**, **609** may be used to capture and control spacing between the adjacent plates **601**, **602**. Safety clasps **608**, **609** may comprise a clasp plug **608** and a clasp receptacle **609**, whereby the clasp plug **608** may be joined to the second plate **602** and the clasp receptacle **609** may be joined to the first plate **601**. The safety clasps **608**, **609** may be joined to the plates **601**, **602** through welding, adhesive, forceful press, or other joining means known to those skilled in the art. The clasp plug **608** may engage the clasp receptacle by causing tabs **610** on the clasp receptacle **609** to elastically deform and splay apart, thereby allowing the plunger **611** of the clasp plug **608** to slide past the tabs **610**.

[0052] In an embodiment, a plurality of safety clasps **608**, **609** may be joined to the spring cups **605**. In this fashion, the safety clasps **608**, **609** may be coaxial with the springs **604**.

[0053] Turning now to FIG. 7, a top view of another embodiment vacuum insulated panel without the enclosure is illustrated. A frame **700** may be comprised of a first perimeter member **701**, a second perimeter member (removed for clarity), a plurality of springs **706**, a plurality of anchors **705**, and a plurality of guy wires **707**. Guy wires **707** may have a first end and a second end, whereby the first end may join to the first perimeter member **701** through anchor **705**, and the second end may join to the second perimeter member **702** at point **704**. By joining a plurality

of guy wires in this fashion, the guy wires **707**, being under tension, may prevent parallel translation of the perimeter members **701**, **702**, which may be in any planar direction parallel thereto, while maintaining thermal conductive isolation.

[0054] Referring now to FIG. 8, a sectioned, side view of a panel shown in FIG. 7 is illustrated. The guy wires **707** may now be more easily depicted to show diagonally crossing the central region and joining the first perimeter member **701** to the second perimeter member **702**. The anchors **705** may be lengthened so the guy wires **707** need not pass through radiative baffles in order to simplify the intermediate layering process. The anchors **705** may be formed of suitable means, and attached to the first perimeter member **701** by suitable means, to accommodate strain from guy wire **707** tension.

[0055] Referring now to FIG. 9, a perspective view of an embodiment safety clasp **900** is illustrated. The safety clasp **900** may comprise a clasp plug **901** and a clasp receptacle **902**. The clasp plug **901** may comprise means for adjusting a height, such as a threaded rod **905** and a nut **906**, prior to engagement with the clasp receptacle **902**. The clasp plug **901** may laterally slide or rotate into the clasp receptacle **902** thereby engaging the safety mechanism. The clasp receptacle **902** may act to limit travel of the spring **904** if the clasp plug **901** engages the clasp receptacle **902**, which may occur upon creating a vacuum within the panel **100** cavity. The safety clasp **900** may be coaxial with one or more springs **904** to make efficient use of space within the panel **100** cavity, to simplify manufacture, and/or to improve R-value. The safety clasp **900** may be attached to a plate **101,102**, a frame **201**, a cross-member **203**, or a spring cup **903**.

[0056] What has been described above includes examples of one or more embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies

for purposes of describing the aforementioned embodiments, but one of ordinary skill in the art may recognize that many further combinations and permutations of various embodiments are possible. Accordingly, the described embodiments are intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims.

Furthermore, to the extent that the term “includes” is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim.

CLAIMS

What is claimed is:

1. A thermally insulative sealed hollow panel, comprising:
 - a first plate disposed adjacent to a substantially parallel second plate;
 - a plurality of helically coiled springs with axes of compression that are substantially perpendicular to the plates and disposed therebetween, said axes being substantially equidistant from each other;
 - at least one layer of a low thermal emissivity film disposed between the plates and substantially parallel thereto, wherein the film engages the plurality of springs; and
 - a flexible perimeter edge membrane joined to at least one perimeter edge of the first plate and at least one perimeter edge of the second plate, thereby forming a closed cavity with a pressure between 0 and 1 atm.
2. The panel according to claim 1, further comprising a plurality of anchors joined to the first or second plate, each neighboring anchor being disposed substantially equidistant from each other.
3. The panel according to claim 3, further comprising at least one support wire engaging at least two of the plurality of anchors.
4. The panel according to claim 1, further comprising a plurality of clasps disposed between the plates, each clasp comprising a plug and a receptacle, wherein the plug is joined to the first plate and the receptacle is joined to the second plate, whereby the plug and the receptacle engage upon assembling the first plate with the second plate.
5. The apparatus according to claim 4, wherein the clasp plugs and clasp receptacles are not in conductive thermal communication.

6. The panel according to claim 1, wherein the thermal emissivity of the film is between 0 and 0.1.

7. The panel according to claim 1, wherein the closed cavity is held at a pressure between 0 and 0.05 atm, essentially producing a vacuum in the cavity.

8. The panel according to claim 1, wherein the closed cavity is at least partially filled with a gas having a specific heat between 0 and 1.0 kJ/kg·K at constant pressure.

9. The panel according to claim 1, wherein the membrane and plurality of springs are made of metal having a thermal conductivity between 0 and 20 W/m·K.

10. The panel according to claim 1, further comprising a first frame and a second frame, wherein the frames are disposed between the plates and substantially parallel thereto, and displaced from each other by the plurality of springs, and wherein the first frame is joined to the first plate and the second frame is joined to the second plate, each frame comprising at least one perimeter member and a plurality of cross members joined to the at least one perimeter member.

11. The panel according to claim 10, further comprising a plurality of guy wires joining the first frame and second frame, whereby each guy wire diagonally traverses a central region of the closed cavity and is under tension to prevent parallel translation of the frames.

12. A thermally insulative sealed hollow panel, comprising:
a support structure comprising,
1) a first frame disposed adjacent to a substantially parallel second frame, each frame having at least one perimeter member and a plurality of cross members,
2) a plurality of helically coiled springs with axes of compression that are substantially perpendicular to the frames with the springs disposed therebetween,

3) a plurality of guy wires, each guy wire having a first end and a second end, the first end being joined to the first plate and the second end being joined to the second plate, whereby the guy wires diagonally traverse a central region, and

4) at least one layer of low thermal emissivity film disposed between the frames and substantially parallel thereto, wherein the film engages at least one of the plurality of springs; and

an enclosure surrounding the support structure thereby creating a closed cavity with a pressure between 0 and 1 atm, wherein the enclosure is joined to the first frame and the second frame.

13. The panel according to claim 12, further comprising a plurality of anchors joined to the support structure and being evenly distributed along the at least one perimeter member of the first frame.

14. The panel according to claim 13, further comprising a plurality of support wires interconnected to the plurality of anchors wherein each support wire has a first end and a second end, the first end being tied to at least one anchor and the second end being tied to a corresponding opposite anchor so that the support wire spans the central region.

15. The panel according to claim 12, wherein the springs are joined to the at least one perimeter member and the plurality of cross members.

16. The panel according to claim 12, further comprising a plurality of clasps joined to the first frame and the second frame, each clasp comprising a plug and a receptacle, whereby the plug and the receptacle engage upon assembling the frames.

17. The panel according to claim 16, wherein the spring axes are substantially equidistant from each other.

18. The panel according to claim 12, wherein the enclosure and plurality of springs are made of metal having a thermal conductivity between 0 and 20 W/m·K.

19. A thermally insulative sealed hollow panel, comprising:

- means for enclosing a vacuum sealable cavity, wherein the enclosing means comprise at least two substantially parallel sides and at least one flexible edge membrane;
- means for spacing the two sides;
- means for reducing radiative heat transfer between the two sides;
- means for supporting the radiative heat transfer reducing means; and
- means for anchoring the supporting means to the enclosing means, the anchoring means joined to at least one side of the enclosing means.

20. The panel according to claim 19, wherein the spacing means comprise helically coiled springs with a thermal conductivity between 0 and 20 W/m·K.

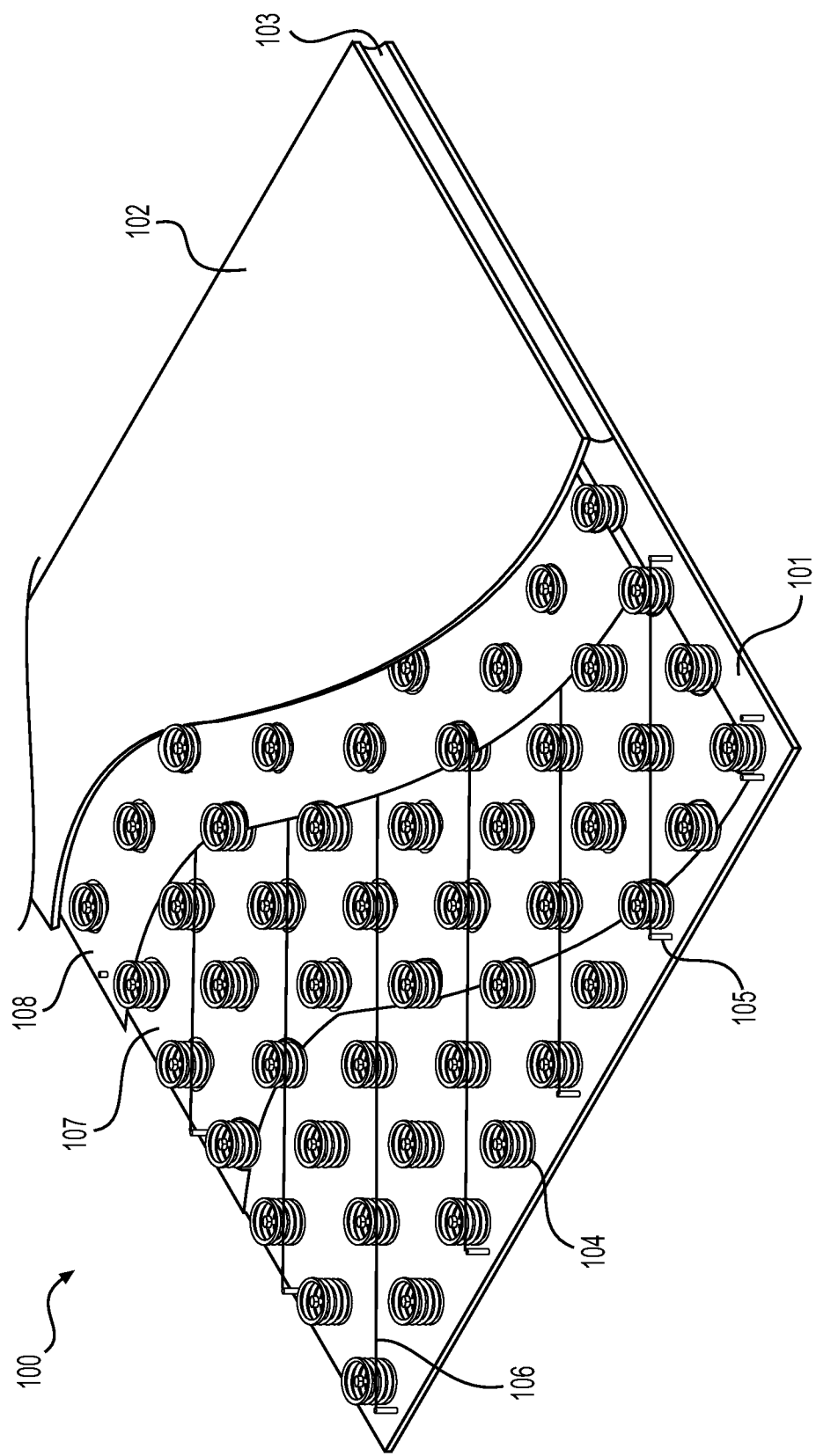


FIG. 1

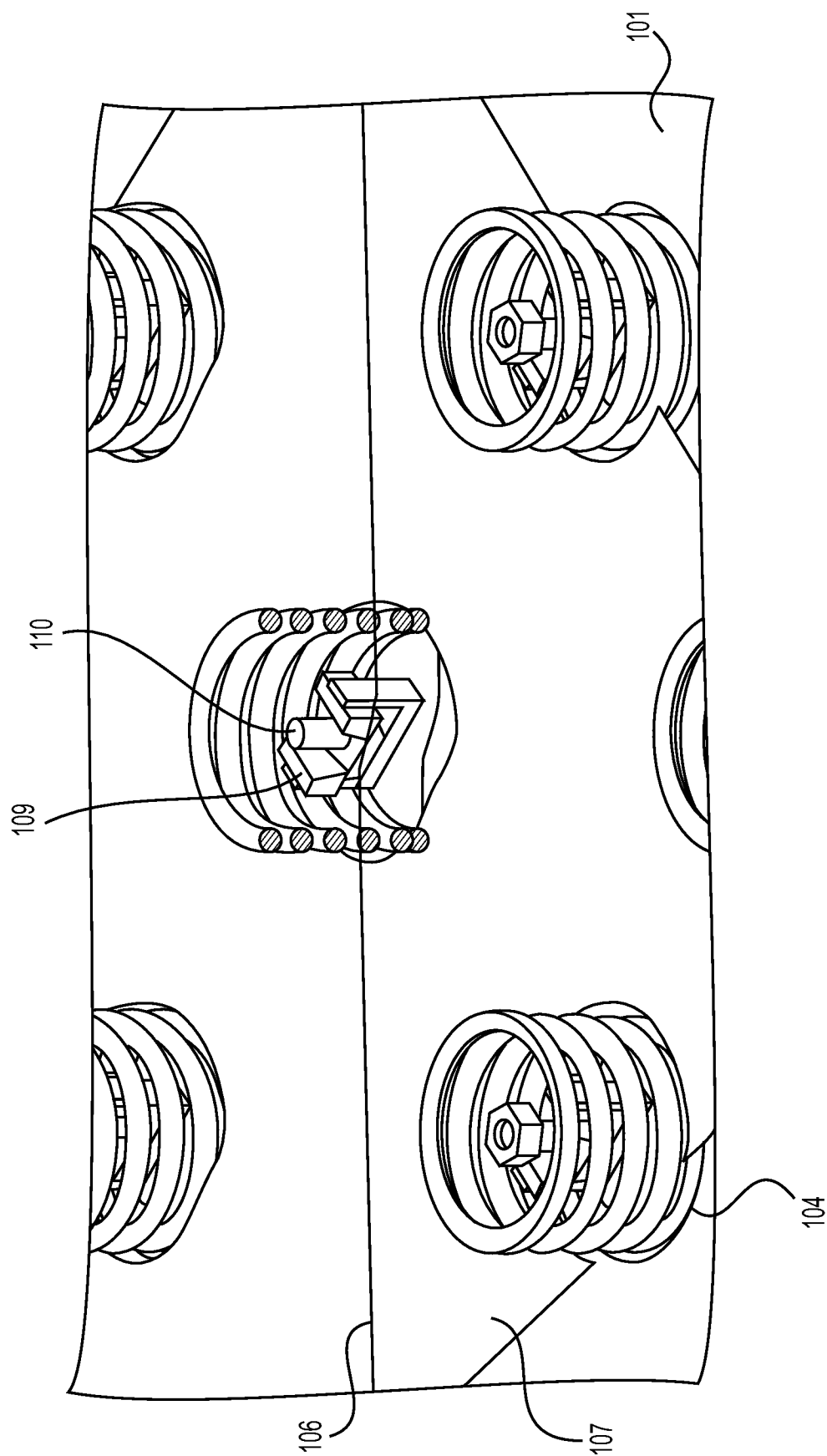


FIG. 2

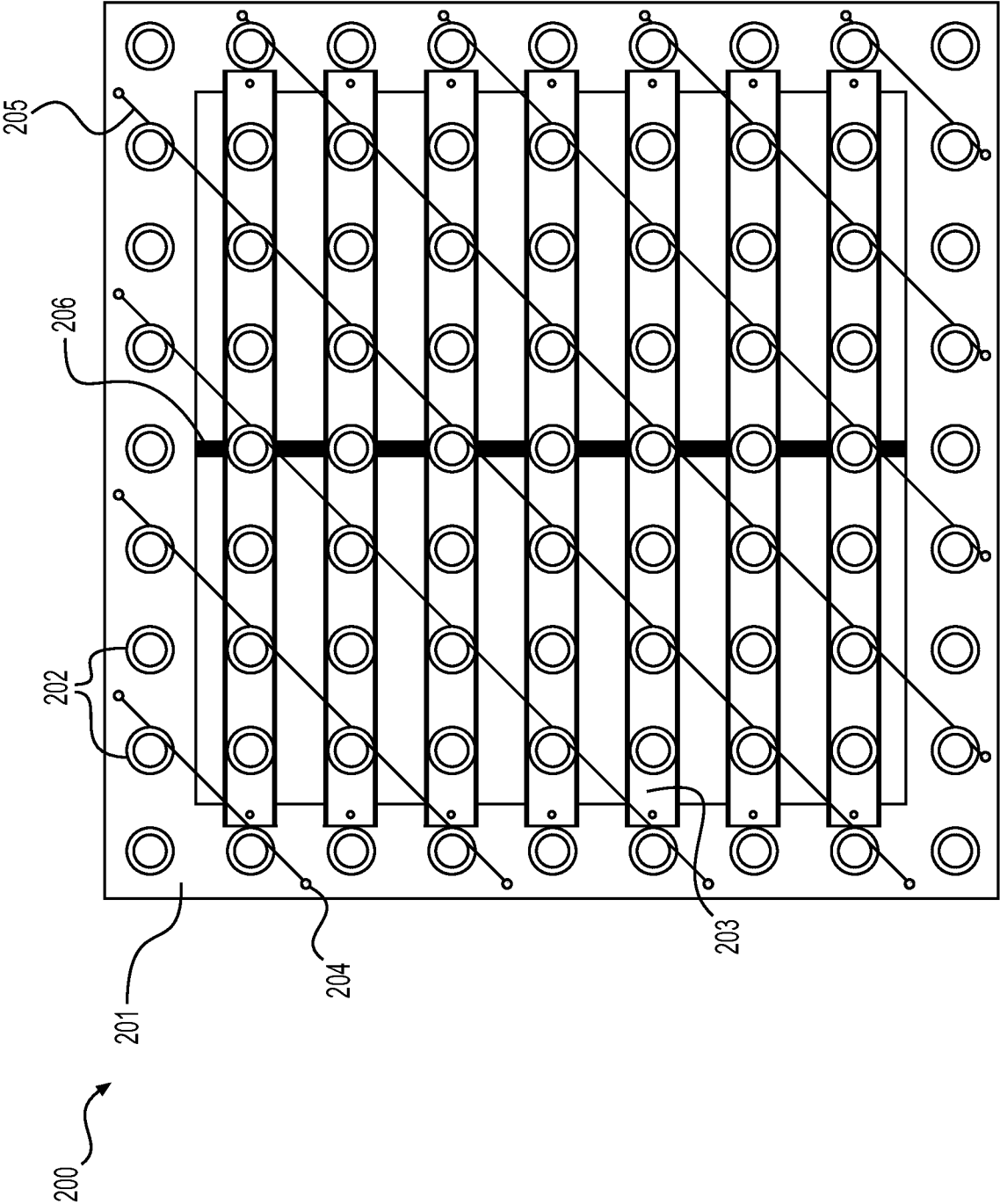
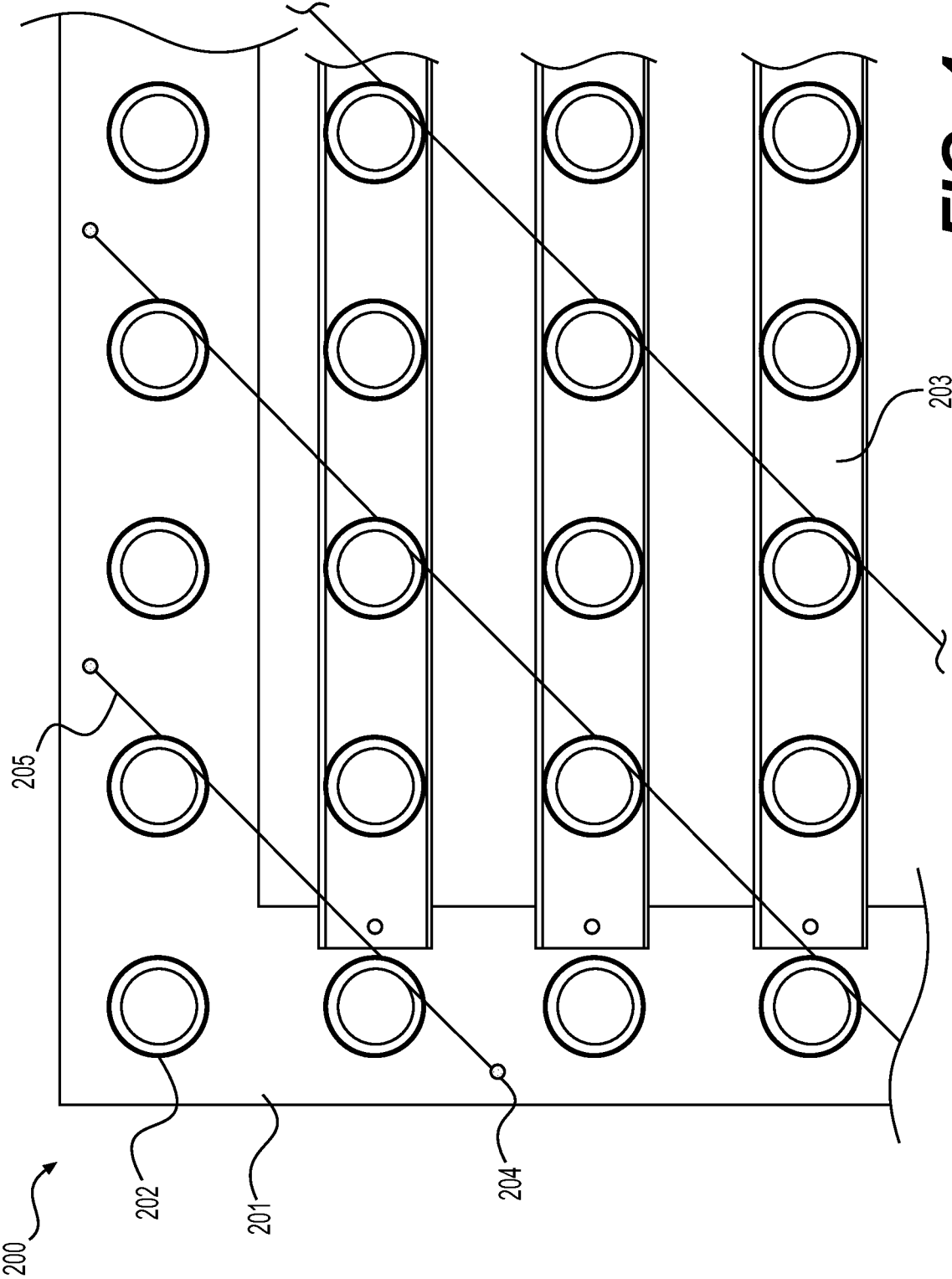


FIG. 3



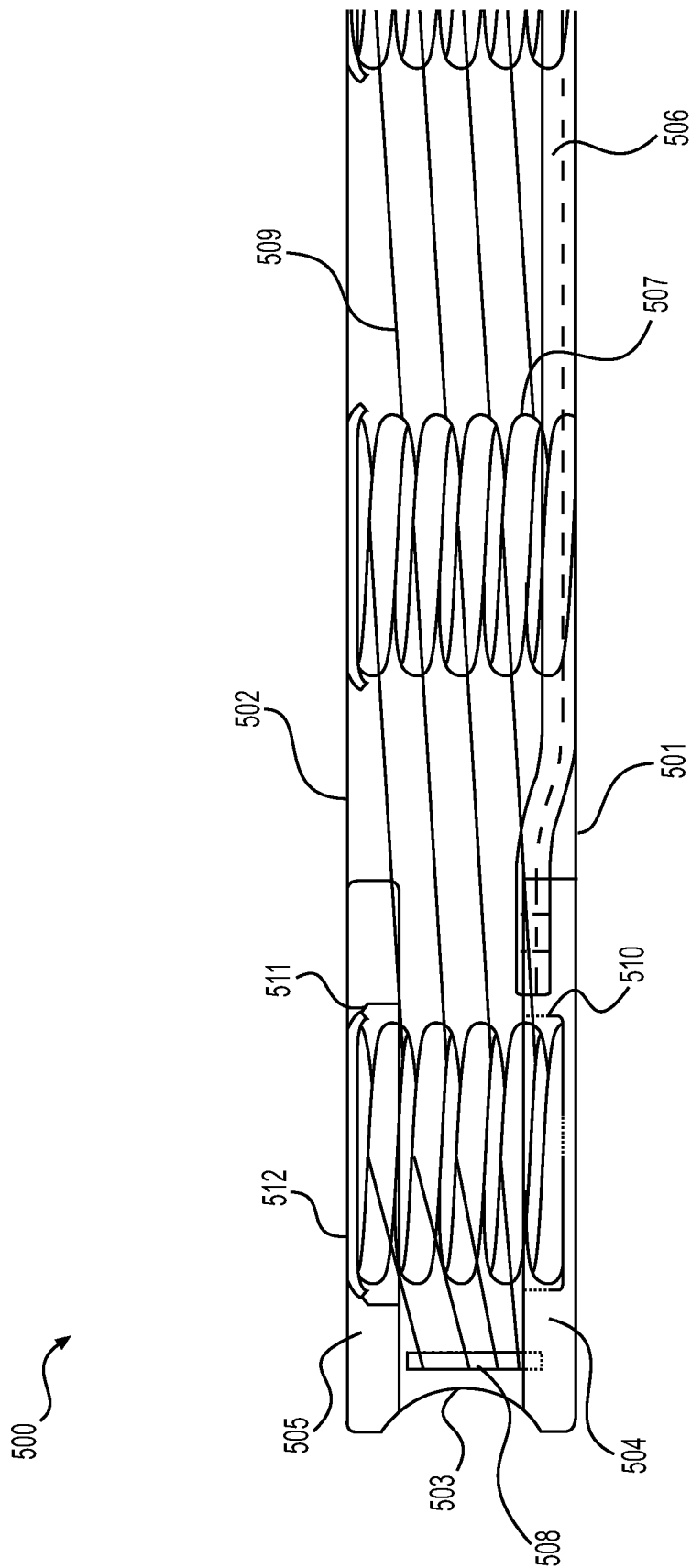


FIG. 5

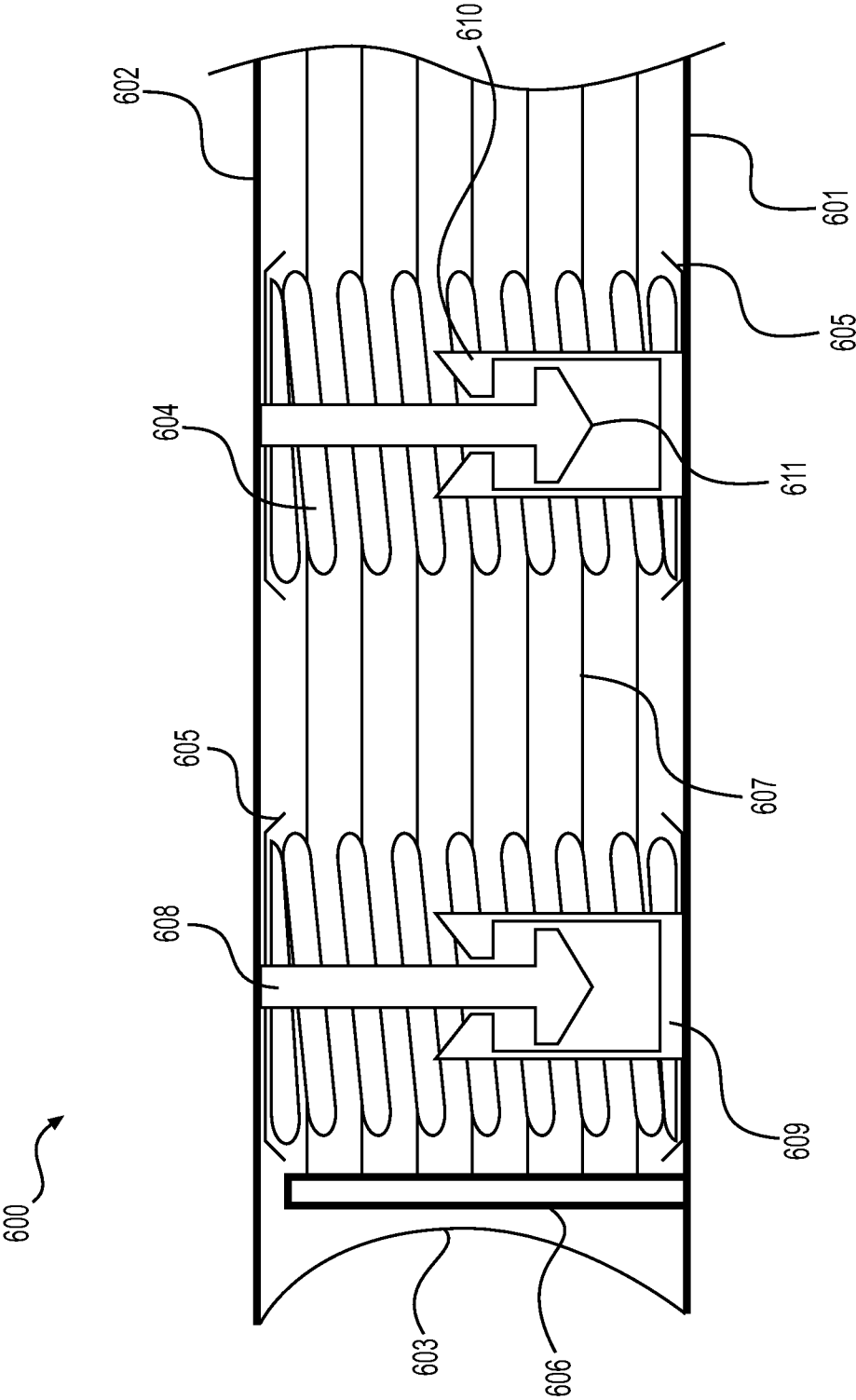
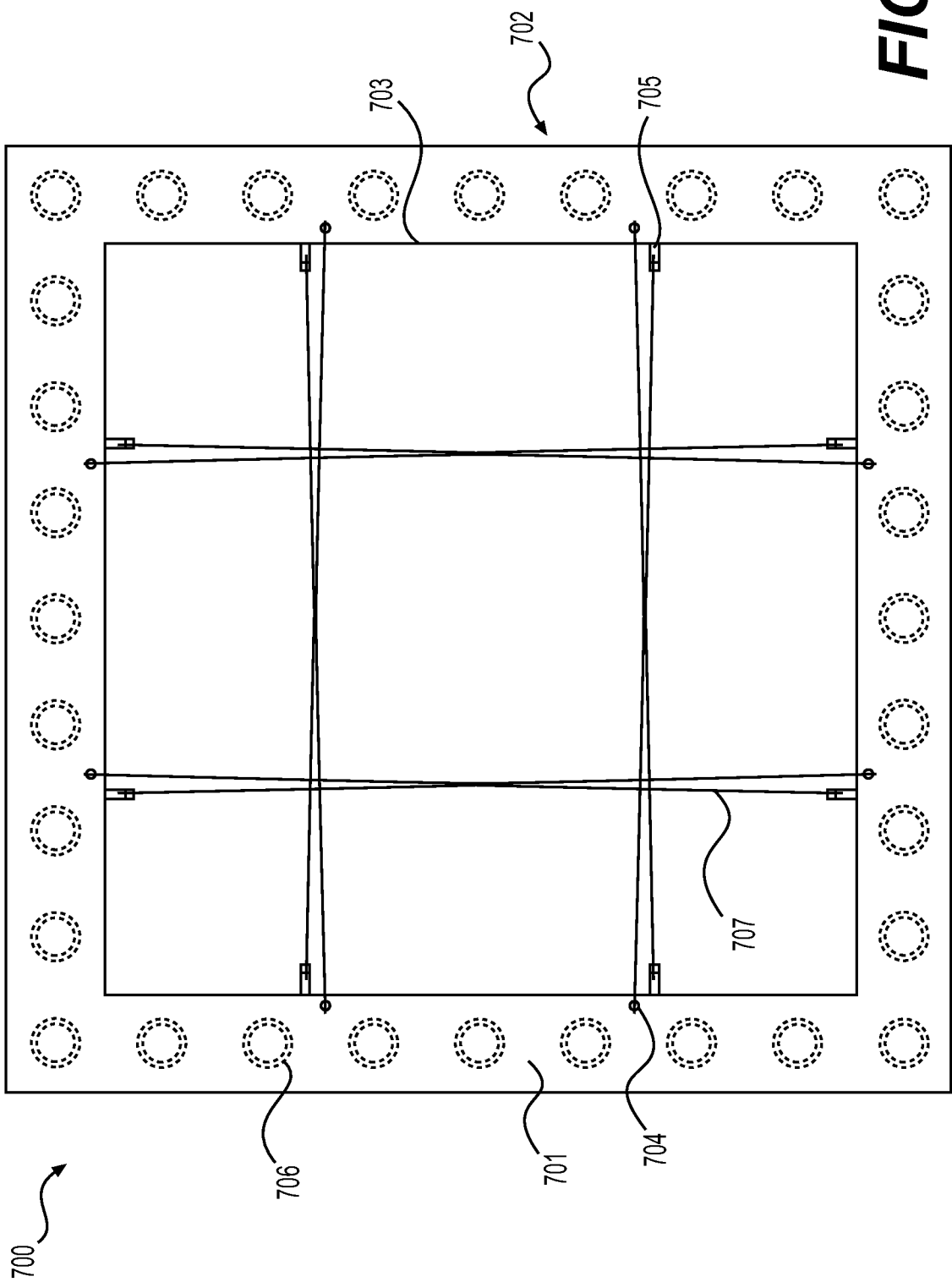


FIG. 6



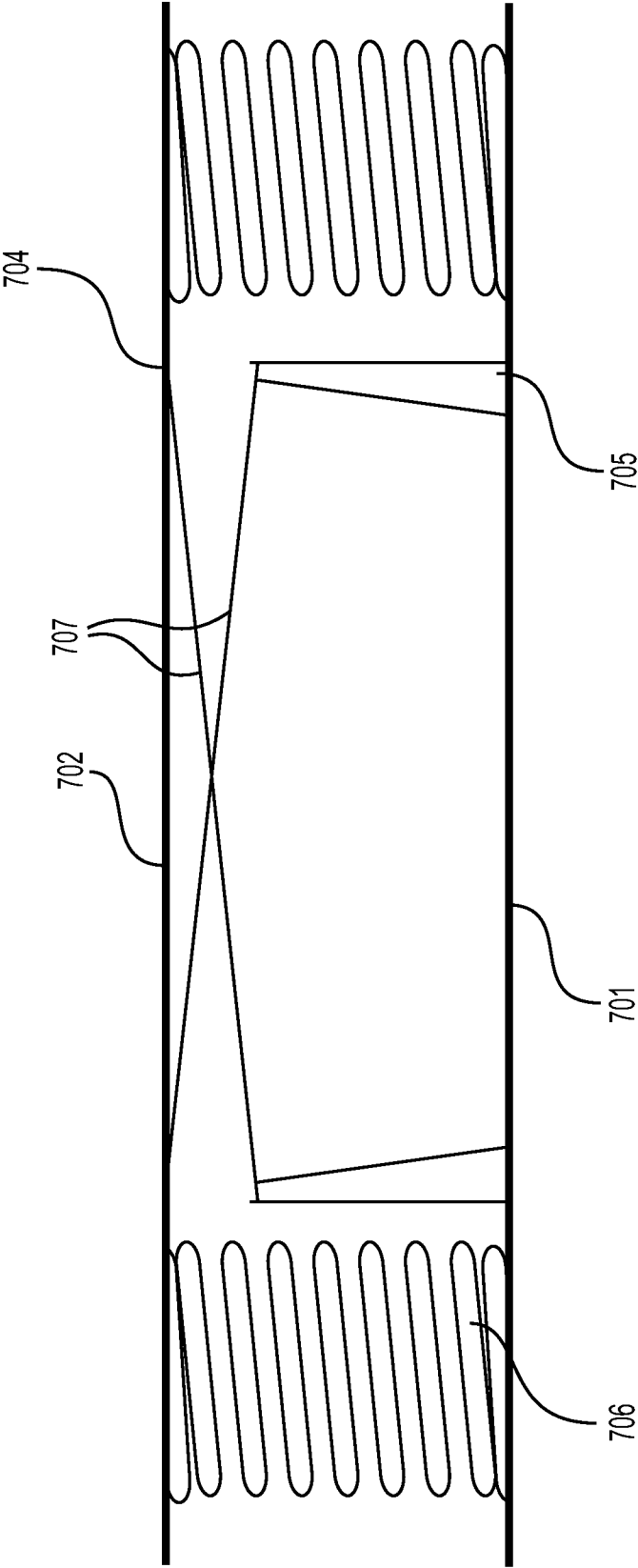
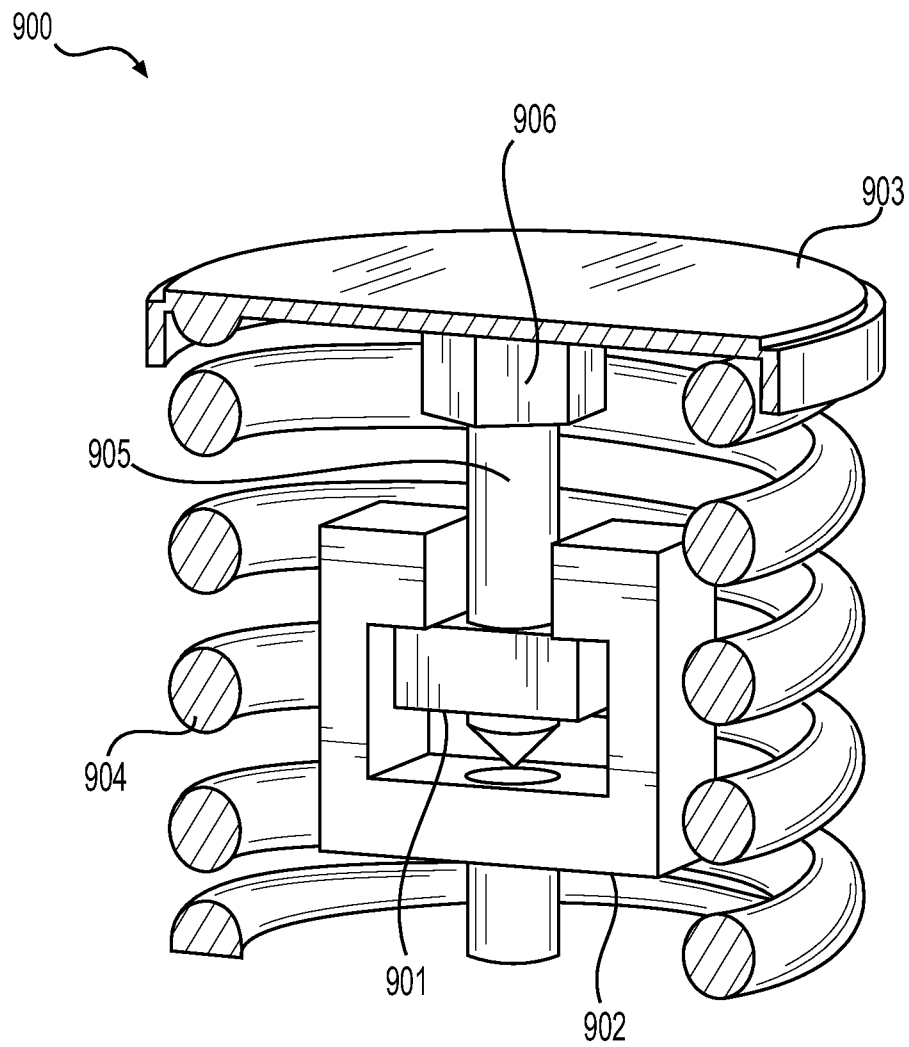


FIG. 8

**FIG. 9**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/015680

A. CLASSIFICATION OF SUBJECT MATTER
INV. E04B1/80 E04B1/76
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E04B F25D F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

16 April 2015

Date of mailing of the international search report

23/04/2015

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INTERNATIONAL SEARCH REPORT

International application No
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