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(54) Title: INSULATING STRUCTURE WITH AN INSULATING ELEMENT AND THE METHOD FOR THEIR FORMATION

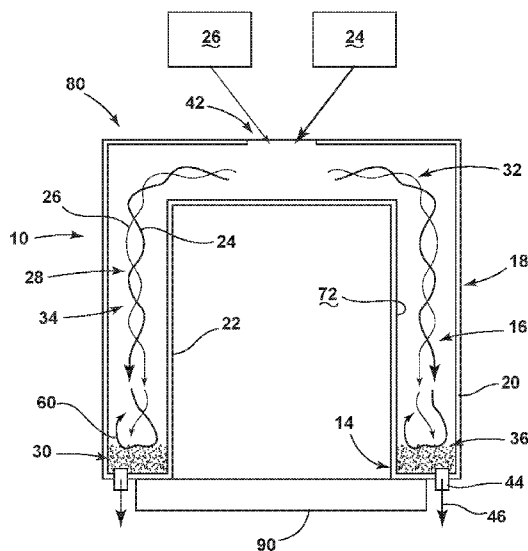


FIG. 3

(57) Abstract: An insulation structure for an appliance in-
cludes a cabinet having an outer wrapper and an inner liner,
with an insulating cavity defined therebetween. Insulating
powder material is disposed substantially throughout the insu-
lating cavity. An insulating gas is disposed within the insu-
lating cavity, wherein the insulating powder material is com-
bined with the insulating gas and cooperatively defines a sus-
pended state and a precipitated state. The suspended state is
defined by the insulating gas in motion and the insulating
powder material being in an aeolian suspension within the in-
sulating gas while in motion. The precipitated state is defined
by the insulating gas being in a deposition state and the insu-
lating powder material being precipitated from the insulating
gas and deposited within the insulating cavity.

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INSULATING STRUCTURE WITH AN INSULATING ELEMENT AND THE METHOD FOR THEIR FORMATION

BACKGROUND

[0001] The device is in the field of insulating materials for various household appliances, specifically, a multi-component insulation material that is uniformly distributed throughout an insulating cavity for the appliance.

SUMMARY

[0002] In at least one aspect, an insulation structure for an appliance includes a cabinet having an outer wrapper and an inner liner, with an insulating cavity defined therebetween. A plurality of hollow insulating spheres is disposed within the insulating cavity, wherein a secondary insulating volume is defined between the plurality of hollow insulating spheres and an interior surface of the cabinet. The interior surface of the cabinet defines the insulating cavity. An insulating fill material disposed within the secondary insulating volume, wherein the insulating fill material and the plurality of hollow insulating spheres define a substantially uniform insulating material.

[0003] In at least another aspect, a method of forming an insulating structure includes forming an insulating member, wherein the insulating member includes an interior surface that defines an interior insulating cavity. The method also includes forming a plurality of hollow insulating spheres and forming a fill material, wherein the fill material is defined by a nano-sized particulate or powder material. The method also includes disposing the hollow insulating spheres and the nano/micro-sized particulate material within the interior insulating cavity. The method also includes dispersing the nano/micro-sized particulate material throughout a secondary insulating volume defined within the interior insulating cavity and within the interstitial space defined between the plurality of hollow insulating spheres, wherein the nano/micro-sized particulate material and the hollow insulating spheres at least partially define a substantially uniform insulating material.

[0004] In at least another aspect, a method of forming an insulating material to be used in an insulating structure of an appliance includes forming a plurality of hollow insulating spheres, wherein a secondary insulating volume is defined within an interstitial space defined between the plurality of hollow insulating spheres. The method also includes

forming a fill material, wherein the fill material is defined by a nano/micro-sized particulate material. The method also includes dispersing the nano/micro-sized particulate material throughout a secondary insulating volume, wherein the nano/micro-sized particulate material and the hollow insulating spheres at least partially define a substantially uniform insulating material.

[0005] These and other features, advantages, and objects of the present device will be further understood and appreciated by those skilled in the art upon studying the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the drawings:

[0007] FIG. 1 is a front perspective view of an appliance incorporating an aspect of the multi-component insulation material;

[0008] FIG. 2 is a schematic section view of a device for depositing and evenly distributing an aspect of the multi-component insulation material evenly throughout the insulating cavity;

[0009] FIG. 3 is a schematic section view of a device for depositing and evenly distributing an aspect of the multi-component insulation material evenly throughout the insulating cavity;

[0010] FIG. 4 is an enlarged cross-sectional view of an aspect of the multi-component insulation material;

[0011] FIG. 5 is an enlarged cross-sectional view of an aspect of the multi-component insulation material;

[0012] FIG. 6 is a schematic section view of a device for depositing and evenly distributing an aspect of the multi-component insulation material evenly throughout the insulating cavity;

[0013] FIG. 7 is a schematic section view of a device for depositing and evenly distributing an aspect of the multi-component insulation material evenly throughout the insulating cavity;

[0014] FIG. 8 is an enlarged perspective view illustrating an aspect of a multi-component insulating material incorporating a particulate material and an insulating gas;

- [0015] FIG. 9 is a perspective view of a multi-component insulating material incorporating multiple forms of particulate material and an insulating gas;
- [0016] FIG. 10 is a schematic cross-sectional view of an insulating structure for an appliance;
- [0017] FIG. 11 is a schematic cross-sectional view of an insulating structure for an appliance being injected with at least one component of a multi-component insulation material;
- [0018] FIG. 12 is a schematic cross-sectional view of the insulating structure of FIG. 11 showing the injection of a second component of the multi-component insulation material;
- [0019] FIG. 13 is a schematic cross-sectional view of the insulating structure of FIG. 12 illustrating the injection of a third component of the multi-component insulation material;
- [0020] FIG. 14 is an enlarged cross-sectional view of an aspect of the multi-component insulation material installed within an insulating cavity for an appliance;
- [0021] FIG. 15 is a schematic flow diagram illustrating a method for forming an insulating structure;
- [0022] FIG. 16 is a schematic flow diagram illustrating a method for forming insulating material to be used in an insulating structure of an appliance;
- [0023] FIG. 17 is a schematic flow diagram illustrating a method for forming an insulated structure; and
- [0024] FIG. 18 is a schematic flow diagram illustrating a method for forming an insulating member within an insulating structure.

DETAILED DESCRIPTION OF EMBODIMENTS

- [0025] For purposes of description herein the terms “upper,” “lower,” “right,” “left,” “rear,” “front,” “vertical,” “horizontal,” and derivatives thereof shall relate to the device as oriented in FIG. 1. However, it is to be understood that the device may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific

dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

[0026] As illustrated in FIGS. 1-9, reference numeral 10 generally refers to an insulating structure for an appliance 12, where the insulating structure 10 includes a multi-component insulating material 14 having thermal and/or acoustical insulating properties. According to the various embodiments, the individual components of the multi-component insulating material 14 are disposed within the insulating cavity 16 to be placed in a substantially uniform configuration throughout the insulating cavity 16 of the insulating structure 10. According to the various embodiments, an insulating structure 10 for an appliance 12 includes a cabinet 18 having an outer wrapper 20 and an inner liner 22, where the insulating cavity 16 is defined therebetween. An insulating powder material 24 can be disposed throughout the insulating cavity 16. It is contemplated that an insulating gas carrier 26 can also be disposed within the insulating cavity 16, where the insulating powder material 24 is combined with the insulating gas carrier 26 to cooperatively define a suspended state 28 and a precipitated state 30.

[0027] According to the various embodiments, the suspended state 28 is defined by the insulating gas carrier 26 in motion or in an active state 32 and the insulating powder material 24 being an aeolian suspension 34 within the insulating gas carrier 26 while in motion in the active state 32. Typically, the active state 32 of the insulating gas carrier 26 is defined within the insulating cavity 16 before the insulating cavity 16 is sealed and enclosed.

[0028] Referring again to FIGS. 1-9, the precipitated state 30 of the insulating powder material 24 and the insulating gas carrier 26 is defined by the insulating gas carrier 26 being substantially in a deposition state 36 and the insulating powder material 24 being precipitated from the insulating gas carrier 26 and deposited within the insulating cavity 16. It is contemplated that in addition to the insulating powder material 24, a plurality of hollow insulating spheres 38 can also be disposed in the insulating cavity 16, where various combinations of the insulating powder material 24, insulating gas carrier 26, and plurality of hollow insulating spheres 38 cooperatively define the multi-component insulating material 14 disposed within the insulating cavity 16. It is further contemplated that these components can be disposed in a substantially uniform configuration throughout the entire insulating cavity 16 such that the instance of pockets, sections or

other portions of only one component of the multi-component insulating material 14 is substantially minimized. Various methods for achieving the uniform distribution of the individual components of the multi-component insulating material 14 will be discussed in greater detail below.

[0029] According to the various embodiments, as exemplified in FIGS. 1-9, it is contemplated that the insulating gas carrier 26 can be at least one of argon, neon, carbon dioxide, xenon, krypton, combinations thereof, and other similar insulating gasses that typically have insulating properties greater than that of air. In addition, the hollow insulating spheres 38 can be made of various organic and/or inorganic materials that include, but are not limited to, glass, ceramic, polymers, combinations thereof, and other similar organic and/or inorganic materials. It is further contemplated that the insulating powder material 24 can be defined by various particulate material that can include, but is not limited to, fumed silica, precipitated silica, nano-sized and/or micro-sized aerogel powder, rice husk ash powder, pearlite, cenospheres, diatomaceous earth, combinations thereof, and other similar insulating particulate material. The insulating powder material 24 can be disposed within the insulating cavity 16 of the cabinet 18 in various configurations, where such configurations include an uncompressed powder state, or can be disposed where the insulating powder material 24 includes compressed portions that define a densified insulating granular material. In such an embodiment, the insulating granular material can be surrounded by uncompressed portions of the insulating powder material 24, the insulating gas carrier 26, hollow insulating spheres 38, combinations thereof, and other similar insulating materials. In the various configurations of the insulating powder material 24, the insulating powder material 24 defines porous areas 40 defined between the individual particles and/or granules of the insulating powder material 24. It is contemplated that the insulating gas carrier 26 can occupy the various porous areas 40 that are defined between the particles of the insulating powder material 24. It is further contemplated that individual particles of the insulating powder material 24 can occupy the porous areas 40 between the hollow insulating spheres 38 and/or granular portions of the insulating powder material 24.

[0030] Referring again to FIGS. 2-9, it is contemplated that in order to deposit the various components of the multi-component insulating material 14 into the insulating cavity 16 of the cabinet 18, the cabinet 18 can include one or more inlet ports through which the

insulating powder material 24 and the insulating gas carrier 26 are injected into the insulating cavity 16. During injection of the insulating powder material 24 and the insulating gas carrier 26 that combine to form the aeolian suspension 34, one or more vacuum ports 44 of the cabinet 18 can be used to express portions of gas 46, such as air, that may be present within the insulating cavity 16. It is also contemplated that during the expression of gas 46 through the vacuum port 44, portions of the insulating gas carrier 26 can also be expressed. In this manner, as the aeolian suspension 34 of the insulating gas carrier 26 and insulating powder material 24 flow through the insulating cavity 16, the expression of the insulating gas carrier 26 provides for substantially continuous flow of the aeolian suspension 34 through the entire insulating cavity 16. In this manner, precipitation of the insulating powder material 24 from the aeolian suspension 34 can be substantially consistent throughout the insulating cavity 16. In this manner, the aeolian suspension 34 can be used to distribute, in a substantially uniform pattern, at least the insulating gas carrier 26 and the insulating powder material 24. As the insulating gas carrier 26 is expressed, it is contemplated that at least a portion of the expressed insulating gas carrier 26 can be recycled for later use in combining with the insulating powder material 24 to form the aeolian suspension 34 for further deposition of the insulating powder material 24.

[0031] According to the various embodiments, the aeolian suspension 34 of the insulating gas carrier 26 and the insulating powder material 24 can occur as the insulating gas carrier 26 moves past, through, or proximate to the insulating powder material 24. The fine particle size of the insulating powder material 24 makes the individual particles of the insulating powder material 24 light enough that they can be carried through movement of the insulating gas carrier 26, and suspended within the insulating gas carrier 26 to form the aeolian suspension 34. Due to the movement of the aeolian suspension 34 within the insulating cavity 16 of the cabinet 18, deposition of the insulating powder material 24 from the aeolian suspension 34 occurs. This deposition can be caused by various eddys 60, areas of turbulence within the insulating cavity 16, and other aerodynamic features that slow, re-direct or otherwise modify the flow of the aeolian suspension 34 through the insulating cavity 16. These eddys 60 can be produced by structures disposed within the insulating cavity 16 such as hollow insulating spheres 38, structures attached to the inner liner 22 and/or the outer wrapper 20, combinations

thereof and other similar turbulence producing features. Such modification of the flow of the aeolian suspension 34 results in the deposition of the insulating powder material 24 from the aeolian suspension 34. As a result of the injection of the aeolian suspension 34, the insulating cavity 16 is eventually filled with the precipitated insulating powder material 24 to fill all of, or substantially all of, the insulating cavity 16 of the cabinet 18. As will be described more fully below, the aeolian suspension 34 can be injected into a substantially hollow insulating cavity 16, or can be injected into an insulating cavity 16 that includes one or more components of the multi-component insulating material 14, where such components can include, but are not limited to, hollow insulating spheres 38, granular portions of the insulating powder material 24, foam insulation, organic fiber, inorganic fiber, combinations thereof or other insulating material that includes various porous areas 40 between individual particles.

[0032] Referring again to FIGS. 5-14, the insulation structure for the appliance 12 can include a cabinet 18 having the outer wrapper 20 and the inner liner 22, with the insulating cavity 16 defined therebetween. According to various embodiments, a plurality of hollow insulating spheres 38 can be disposed within the insulating cavity 16. In such an embodiment, a secondary insulating volume 70 is defined between the plurality of hollow insulating spheres 38 and the interior surface 72 of the cabinet 18. The interior surface 72 of the cabinet 18 serves to define the insulating cavity 16. An insulating fill material 74 is disposed within the secondary insulating volume 70, where the insulating fill material 74 and the plurality of hollow insulating spheres 38 define the uniformly distributed multi-component insulating material 14. The insulating fill material 74 can be made of various particulate and gaseous matter that can include, but is not limited to, nano-sized and/or micro-sized porous material in the form of any one or more of fumed silica, precipitated silica, aerogel powder, pearlite, rice husk ash powder, diatomaceous earth, cenospheres, combinations thereof, and other nano/micro-sized particulate material 76, such as the insulating powder material 24. The nano-sized porous material can also include at least one opacifier, including, but not limited to carbon black, silicon carbide, combinations thereof and other opacifiers. The insulating fill material 74 can also include an insulating gas carrier 26, where the insulating gas carrier 26 includes, but is not limited to, argon, neon, carbon dioxide, xenon, krypton, combinations thereof, and other similar insulating gasses.

[0033] According to the various embodiments, the hollow insulating spheres 38 can include an interior region 78 that is filled with one or more insulating gasses, sulfur, other gaseous material, or can include a low pressure region that defines a partial vacuum within the interior region 78 of the hollow insulating sphere 38.

[0034] According to the various embodiments, it is contemplated that the insulating cavity 16 that contains the uniform distribution of the multi-component insulating material 14 is hermetically sealed to contain the multi-component insulating material 14 within the insulating cavity 16. In such an embodiment, it is contemplated that the insulating cavity 16 further defines an at least partial vacuum to create a vacuum insulated structure 80. It is further contemplated that the vacuum insulated structure 80 can be a vacuum insulated cabinet 18 for an appliance 12, a vacuum insulated panel that can be disposed within a cabinet 18 of an appliance 12, various vacuum insulated structures 80 for appliances 12 and other fixtures, as will be described more fully below.

[0035] Referring again to FIGS. 5-14, where the hollow insulating spheres 38 are one of the components of the multi-component insulating material 14, it is contemplated that each hollow insulating sphere 38 can include an outside diameter in a range of from approximately 50 nanometers to approximately 300 microns. It is also contemplated that the hollow insulating spheres 38 can be defined by various nano-spheres that can include a diameter in a range of from approximately 50 nanometers to approximately 1000 nanometers. It is further contemplated that other sized microspheres and nano-spheres can be included individually or in combination with other sized microspheres and nano-spheres to provide a better fill rate within the insulating cavity 16 of the hollow insulating spheres 38 and also the other components of the multi-component insulating material 14. In the various embodiments, it is contemplated that the secondary insulating volume 70 defined between the adjacent hollow insulating spheres 38 in a closed packed situation within the insulating cavity 16 can include a thickness in a range of from approximately 40 nanometers to approximately 200 microns. Sub-nanometer thicknesses of portions of the secondary insulating volume 70 are also contemplated. It is also contemplated that this secondary insulating volume 70 is large enough to receive other components of the multi-component insulating material 14, such as the insulating powder material 24 in the powder or granular form, as well as the insulating gas carrier 26. According to various embodiments, it is further contemplated that the secondary

insulating volume 70 includes areas that are large enough to receive and allow the aeolian suspension 34 to pass between the individual hollow insulating spheres 38 to allow for precipitation of the insulating powder material 24 from the aeolian suspension 34 into the secondary insulating volume 70.

[0036] According to the various embodiments, in addition to the use of the aeolian suspension 34, various vibrating mechanisms 90 can be used to ensure that the multi-component insulating material 14 is tightly packed and substantially evenly distributed throughout the insulating cavity 16. Rotating mechanisms and air-pump mechanisms for generating an at least partial vacuum can also be implemented to tightly pack the multi-component insulating material 14 within the insulating cavity. In this manner, it is contemplated that the various hollow insulating spheres 38 of the plurality of hollow insulating spheres 38 that are disposed within the multi-component insulating material 14 are positioned to be in direct physical contact with at least one other adjacent hollow insulating sphere 38 of the plurality of hollow insulating spheres 38. It is also contemplated that at least a portion of the hollow insulating spheres 38 are separated from adjacent hollow insulating spheres 38 where the multi-component insulating material 14 includes larger proportions of the insulating powder material 24 and smaller proportions of the hollow insulating spheres 38.

[0037] According to the various embodiments, it is contemplated that the components of the multi-component insulating material 14 can be disposed within the insulating cavity 16 in a pattern, one at a time, or other sequential method. By way of example, and not limitation, it is contemplated that larger particles, such as the hollow insulating spheres 38, can be disposed in the insulating cavity 16 first, and progressively smaller particulate material can be disposed within the insulating cavity 16 thereafter. In this manner, as each smaller particle material is disposed within the insulating cavity 16, the spaces between the larger particulate material can be filled by the smaller particulate material. According to various embodiments, it is contemplated that any porous areas 40 that exist between the various particles of the multi-component insulating material 14 can be filled or otherwise occupied by an insulating gas carrier 26. Accordingly, the use of the multi-component insulating material 14 can be used to fill or substantially fill the entire insulating cavity 16. As discussed above, gas 46 disposed within the insulating cavity 16 can be expressed through one or more vacuum ports 44 to create the vacuum

insulated structure 80. As further discussed above, the one or more gas inlets can be used in conjunction with the one or more vacuum ports 44 such that gas 46, such as air, that is expressed from the insulating cavity 16 can be replaced by an insulating gas carrier 26 to increase the insulating properties of the multi-component insulating material 14.

[0038] It is contemplated that the components and component proportions included within the multi-component insulating material 14 can vary depending upon the ultimate design, shape, size, desired performance, and other factors may bear on the ultimate design of the multi-component insulating material 14, and the appliance 12 as a whole.

[0039] Referring now to FIGS. 1-15, having described various aspects of an insulation structure for an appliance 12 and/or a vacuum insulation panel for an appliance 12, a method 400 is disclosed for forming an insulating structure 10. According to the method 400, an insulating member, such as a cabinet 18 or panel, can be formed, where the insulating member includes an interior surface 72 that defines an insulating cavity 16 (step 402). As discussed above, the insulating member can be in the form of a cabinet 18 having an inner liner 22 and an outer wrapper 20, or can be in the form of a panel member that can be formed into a vacuum insulation panel for installation within the insulating cavity 16 of an appliance 12. In addition to forming the insulating member, an insulating powder material 24 can be formed as part of the method 400 (step 404). The insulating powder material 24 can be made of various nano-sized and/or micro-sized particulate material that can include, but is not limited to, fumed silica, precipitated silica, aerogel powder, perlite, rice husk ash powder, diatomaceous earth, cenospheres, combinations thereof, and other similar insulating powders. As discussed above, the insulating powder material 24 can be compacted to form portions of higher density that can take the form of a granular insulation material.

[0040] Referring again to FIGS. 1-4 and 15, according to the method 400, after the insulating member and the insulating powder material 24 are formed, the insulating powder material 24 can be disposed within the insulating cavity 16 of the insulating member (step 406). In order to disperse the insulating powder material 24 throughout the insulating cavity 16, an insulating gas carrier 26 can be disposed into the insulating cavity 16 (step 408). In this manner, when in an active state 32 moving through the insulating cavity 16, the insulating gas carrier 26 carries at least a portion of the insulating powder material 24. This insulating powder material 24 can thereby be suspended

within the insulating gas carrier 26 in the active state 32, which is referred to herein as the aeolian suspension 34. As the insulating gas carrier 26 and the insulating powder material 24 move through the insulating cavity 16, the insulating powder material 24 can be deposited into the insulating cavity 16 by slowing the movement of the insulating gas carrier 26 to define a deposition state 36 (step 410). When the insulating gas carrier 26 defines the deposition state 36, the insulating powder material 24 precipitates from the insulating gas carrier 26 and settles within the insulating cavity 16. In this manner, the insulating powder material 24 is deposited substantially throughout the insulating cavity 16. As discussed above, the step of depositing the insulating powder material 24 can be performed by causing eddys 60, aerodynamic turbulence, and/or other formations that can cause a change in the speed and/or direction of movement of the aeolian suspension 34. These changes in movement can result in the precipitation of the insulating powder materials 24 that are then deposited within the insulating cavity 16.

[0041] Referring again to FIGS. 1-4 and 15, in order to retain the insulating gas carrier 26 within the insulating cavity 16, the insulating member is sealed in an airtight fashion (step 412). According to various embodiments, at least a portion of the insulating gas carrier 26 and/or gasses 46 typically present within the insulating cavity 16, such as air, can be expressed from the insulating cavity 16, wherein the insulating member defines a vacuum insulated structure 80 (step 414).

[0042] Referring again to FIGS. 2-4, it is contemplated that the insulating gas carrier 26 and the insulating powder material 24 can be disposed within the insulating cavity 16 as the aeolian suspension 34. To form the aeolian suspension 34, it is contemplated that the insulating gas carrier 26 can be fed through a container having an amount of the insulating powder material 24. As the insulating gas carrier 26 moves through the insulating powder material 24, the insulating powder material 24 becomes suspended within the insulating gas carrier 26 moving in the active state 32. The insulating gas carrier 26 in the active state 32, within which the insulating powder material 24 is suspended, is then delivered to the insulating cavity 16 of the insulating structure 10 so that the insulating powder material 24 can be deposited therein. It is also contemplated that the aeolian suspension 34 can be formed within the insulating cavity 16 of the insulating structure 10. In such an embodiment, the insulating powder material 24 can be injected, dropped, delivered, or otherwise disposed within the insulating cavity 16 and

the insulating gas carrier 26 can be blown or otherwise injected along separate paths that at least partially intersect within the insulating cavity 16. In this manner, the insulating gas carrier 26 moves through portions of the insulating powder material 24 and forms the aeolian suspension 34 that, in turn, moves through the insulating cavity 16.

[0043] According to the various embodiments, it is contemplated that the insulating gas carrier 26 can include, but is not limited to, argon, neon, carbon dioxide, xenon, krypton, combinations thereof, and other similar insulating gasses.

[0044] Referring again to FIGS. 2-4, in order to dispose the insulating gas carrier 26 and the insulating powder material 24 into the insulating cavity 16, either individually, or combined as the aeolian suspension 34, the insulating structure 10 can include at least one inlet port 42 through which the insulating powder material 24 and the insulating gas carrier 26 can be injected into the insulating cavity 16. In order to foster the movement of the insulating gas carrier 26 through the insulating cavity 16, the insulating member can include one or more vacuum ports 44 from which gas 46 and portions of the insulating gas carrier 26 can be expressed from the insulating cavity 16. The expression of the gas 46 and insulating gas carrier 26 from the interior cavity can further the movement of the insulating gas carrier 26 in the active state 32 to allow the aeolian suspension 34 to be delivered throughout the insulating cavity 16 for even deposition of the insulating powder material 24 throughout the insulating cavity 16. In order to further the deposition of the insulating powder material 24, the one or more vacuum ports 44 can be configured to permit expression of the insulating gas carrier 26 and the gas 46 through the vacuum port 44. Each vacuum port 44 is further configured to substantially retain the insulating powder material 24 within the insulating cavity 16. Accordingly, each vacuum port 44 is sized to permit the movement of gas 46 and the insulating gas carrier 26 therethrough, but includes a filter mechanism and/or a sized opening or openings that substantially prevent the movement of the insulating powder material 24 to move therethrough. Accordingly, the insulating powder material 24 can be retained within the insulating cavity 16 to eventually fill, or substantially fill, the insulating cavity 16.

[0045] According to the various embodiments, it is contemplated that the method 400 can be used in conjunction with larger particles that are disposed within the insulating cavity 16 either before the aeolian suspension 34 is introduced or during injection of the

aeolian suspension 34 into the insulating cavity 16. These larger particles can include a granular form of the insulating powder material 24, hollow insulating spheres 38, and other similar larger particle insulating materials. When the aeolian suspension 34 is injected through these larger materials, it is contemplated that the use of the vacuum port 44 to draw gas 46 and the insulating gas carrier 26 out from the insulating cavity 16 can help to move the aeolian suspension 34 in the pores and spaces defined between the larger particle material of the multi-component insulating material 14. In this manner, the combination of the larger particle materials and the aeolian suspension 34 can serve to uniformly distribute the various components of the multi-component insulating material 14 through the insulating cavity 16.

[0046] Referring now to FIGS. 2-4 and 16, a method 500 is disclosed for forming an insulation member within an insulating structure 10. According to the method 500, an insulating powder material 24 is formed (step 502) and the insulating powder material 24 is suspended within an insulating gas carrier 26 to form an aeolian suspension 34 (step 504). In such an embodiment, the insulating gas carrier 26 is moved through the insulating powder material 24 such that the insulating powder material 24 can become suspended within the insulating gas carrier 26. The aeolian suspension 34 is then deposited within an insulating cavity 16 defined within an insulating structure 10 (step 506). At least a portion of the gas 46 and at least a portion of the insulating gas carrier 26 can then be expressed from the insulating cavity 16 to promote airflow and to circulate the aeolian suspension 34 through the entirety of the insulating cavity 16 (step 508). The movement of the aeolian suspension 34 is slowed such that the insulating powder material 24 can precipitate from the aeolian suspension 34 (step 510). In this manner, the insulating powder material 24 is deposited throughout the insulating cavity 16. When the insulating powder material 24 is deposited in the insulating cavity 16, the insulating gas carrier 26, having its movement slowed, changed in direction, or in some cases, stopped, can occupy various porous spaces defined between the particles of the insulating powder material 24. Once the insulating powder material 24 and the insulating gas carrier 26 are uniformly distributed through the insulating cavity 16, the insulating powder material 24 and insulating gas carrier 26 can be sealed within the insulating cavity 16 to define a vacuum insulated structure 80 (step 512).

[0047] Referring now to FIGS. 5-14 and 17, a method 600 is disclosed for forming an insulating structure 10. The method 600 includes forming an insulating member (step 602). As discussed above, the insulating member can include an interior surface 72 that defines an interior insulating cavity 16. According to the method 600, a plurality of hollow insulating spheres 38 can be formed (step 604), where the hollow insulating spheres 38 are formed by moving micro- and/or nano-sized particles of organic and/or inorganic material along with a blowing agent through a flame, where the flame causes the blowing agent to decompose and release a high-temperature gas 46 that causes the particles of organic and/or inorganic material to expand, thereby forming the hollow insulating spheres 38. As discussed above, these hollow insulating spheres 38 can include nano-spheres, microspheres, and other sized hollow insulating spheres 38 that have an outside diameter in the range of from approximately 50 nanometers to approximately 300 microns.

[0048] Referring again to FIGS. 5-14 and 17, in addition to forming the hollow insulating glass spheres 38, a fill material 74 is also formed (step 606). According to various embodiments, the fill material 74 can be defined by a nano/micro-sized particulate material. The hollow insulating spheres 38 and the nano/micro-sized particulate material can then be disposed within the interior insulating cavity 16 (step 608). It is contemplated that the hollow insulating spheres 38 and the nano/micro-sized particulate material can be disposed within the interior insulating cavity 16 at the same time. Alternatively, it is contemplated that the hollow insulating spheres 38, typically being larger, can be disposed within the insulating cavity 16 before the nano/micro-sized particulate material. In this manner, the nano/micro-sized particulate material can infiltrate the secondary insulating volume 70 defined between adjacent hollow insulating spheres 38. As discussed above, the thickness of the secondary insulating volume 70 in a closed pack situation within the insulating cavity 16 can be in the range of from approximately 40 nanometers to approximately 200 microns. Sub-nano level thicknesses within the secondary insulating volume 70 are also contemplated. Because the nano/micro-sized particulate material is smaller than the gaps that define the secondary insulating volume 70, the nano/micro-sized particulate material can be dispersed throughout the secondary insulating volume 70 defined within an interior insulating cavity 16 and within the interstitial space defined between the plurality of hollow

insulating spheres (step 610). In this manner, the nano/micro-sized particulate material and the hollow insulating spheres at least partially define the uniformly distributed multi-component insulating material 14.

[0049] Referring again to FIGS. 5-14, it is contemplated that the nano/micro-sized particulate material can be distributed into the secondary insulating volume 70 through the use of a vibrating mechanism 90. In this manner, the vibrating mechanism 90 can cause a vibration of the insulating structure 10 and, in turn, the various components of the multi-component insulating material 14 such that the nano/micro-sized particulate material can be shaken between the interstitial space defined between the hollow insulating spheres 38 such that the nano/micro-sized particulate material can occupy substantially all of the secondary insulating volume 70 between the hollow insulating spheres 38. It is also contemplated that the dispersion of the nano/micro-sized particulate material can be performed by injecting the insulating gas carrier 26 into the interior insulating cavity 16. In this manner, the insulating gas carrier 26 can cause the nano/micro-sized particulate material to become suspended therein to form the aeolian suspension 34. The aeolian suspension 34 of the insulating gas carrier 26 and the nano/micro-sized particulate material can circulate through the insulating cavity 16 and cause the deposition of the nano/micro-sized particulate material throughout the secondary insulating volume 70. As discussed above, the vacuum port 44 can be used in conjunction with the aeolian suspension 34 to cause the circulation of the aeolian suspension 34 through the secondary insulating volume 70 within the insulating cavity 16.

[0050] According to the various embodiments, it is contemplated that the hollow insulating insulating spheres 38 and the nano/micro-sized particulate material can be combined within the insulating cavity 16 at the same time, such that the hollow insulating spheres 38 and the nano/micro-sized particulate material are disposed through the one or more inlet port 42 at the same time. It is also contemplated that the insulating structure 10 can include multiple inlet ports 42, where each inlet port 42 is dedicated for depositing either the hollow insulating spheres 38 or the nano/micro-sized particulate material into the interior cavity. It is also contemplated that the hollow insulating spheres 38 and the nano/micro-sized particulate material can define a pre-mixed insulating material that is combined before being deposited into the interior

insulating cavity 16. In such an embodiment, it is contemplated that the pre-mixed insulating material can be directly disposed within the insulating cavity 16. It is also contemplated that the pre-mixed insulating material can be disposed into the insulating cavity 16 along with an insulating gas carrier 26, such that the insulating gas carrier 26 provides for the substantially even and uniform movement of the components of the multi-component insulating material 14 throughout the insulating cavity 16.

[0051] According to various embodiments, it is contemplated the use of the insulating gas carriers 26 can cause hollow insulating spheres 38, such as nano-spheres or microspheres, to become suspended within the insulating gas carrier 26. In this manner, the aeolian suspension 34 can be used to distribute the hollow insulating spheres 38, the nano/micro-sized particulate material, and other components of the multi-component insulating material 14 throughout the insulating cavity 16. It is contemplated that certain components of the multi-component insulating material 14 may be too large to be suspended within the insulating gas carrier 26 moving in the active state 32. In such an embodiment, it is contemplated that such a material that may be substantially free of suspension within the insulating gas carrier 26 can be deposited separately, typically before, the aeolian suspension 34 is introduced into the insulating cavity 16.

[0052] Referring again to FIGS. 5-13 and 18, a method 700 is disclosed for forming a multi-component insulating material 14 to be used in an insulating structure 10, such as an appliance 12. According to the method 700, a plurality of hollow insulating spheres 38 are formed, wherein a secondary insulating volume 70 is defined within an interstitial space defined between the plurality of hollow insulating spheres 38 (step 702). As discussed above, the hollow insulating spheres 38 can include microspheres having a diameter of from approximately 15 microns to approximately 300 microns and can also include nano-spheres that have a diameter of from approximately 50 nanometers to approximately 1000 nanometers. It is contemplated that hollow insulating spheres 38 having larger and smaller diameters can be used within the insulating cavity 16 and as part of the multi-component insulating material 14. According to the method 700, a fill material 74 is also formed (step 704). It is contemplated that the fill material 74 can be defined by the nano/micro-sized particulate material, nano/micro-spheres, the insulating powder material 24, combinations thereof, and other nano/micro-sized insulating particulate material. The nano/micro-sized particulate material is then dispersed

throughout the secondary insulating volume 70 defined between the hollow insulating spheres 38 (step 706). In this manner, the nano/micro-sized particulate material and hollow insulating spheres 38 at least partially define the substantially uniform dispersion of the various components of the multi-component insulating material 14 throughout a particular space. It is contemplated that the multi-component insulating material 14 can be formed outside of the insulating cavity 16 and disposed therein after formation of the multi-component insulating material 14. It is also contemplated that the multi-component insulating material 14 can be formed within the insulating cavity 16, such that various components are disposed within the insulating cavity 16 one at a time or in smaller combinations to ultimately form the multi-component insulating material 14.

[0053] Referring to FIGS. 10-13, according to an exemplary process for forming the multi-component insulating material 14, the insulating cavity 16 of the insulating structure 10 is provided (as exemplified in FIG. 10). It is contemplated that the insulating structure 10 can be a cabinet 18, door, panel, or other unit of an insulating structure 10 for an appliance 12. It is also contemplated that the insulating structure 10 can be a panel member that ultimately forms a vacuum insulated panel that is separately installed within the insulating structure 10. According to the exemplary process illustrated in FIGS. 10-13, FIG. 10 exemplifies the deposition of the hollow insulating spheres 38 within the insulating structure 10. Typically, the hollow insulating spheres 38 represent the component having the largest particle size of the multi-component insulating material 14. As exemplified in FIG. 12, the nano/micro-sized particulate material can be blown into the insulating cavity 16 to occupy the secondary insulating volume 70 defined between the hollow insulating spheres 38. It is contemplated that an insulating gas carrier 26 can be used to blow the nano/micro-sized particulate material into the insulating cavity 16. It is also contemplated that air or some other gaseous material can be used as a carrier for delivering the nano/micro-sized particulate material into the secondary insulating volume 70. According to FIG. 13, an insulating gas carrier 26 can then be injected into the insulating structure 10. Typically, a vacuum port 44 is used in conjunction with the inlet port 42, where the vacuum port 44 expresses gas 46, and at least a portion of the insulating gas carrier 26 from the insulating cavity 16. In this manner, the gas 46 expressed from the interior cavity can be replaced by the insulating gas carrier 26 to increase the insulating characteristics of the insulating structure 10. It is

contemplated that each of the components of the multi-component insulating material 14 can define a homogenous, or substantially homogenous, material. In this manner, the nano/micro-sized particulate material can be substantially homogenous. Alternatively, the nano/micro-sized particulate material can include compressed portions of granulated insulating material spaced within the remainder of the nano/micro-sized particulate material. The result of the combination of the various components, as exemplified in FIG. 14, is a substantially even or uniform distribution of the various components of the multi-component insulating material 14 throughout the insulating cavity 16 of the insulating structure 10. In this manner, the insulating material 14 can provide thermal and/or acoustical insulating properties to the insulating cavity 16 of the appliance 10. Additionally, each of the components, having either gaseous characteristics or having different particle sizes, can, in combination, serve to occupy all, or substantially all, of the interior volume of the insulating cavity 16.

[0054] According to the various embodiments, it is contemplated that the insulating structure 10, when in the form of a cabinet 18, can include an inner liner 22 and outer wrapper 20 that are made up of various materials that can include, but are not limited to, high barrier plastic, metal, polymer, combinations thereof, and other substantially rigid materials that can form a hermetic seal. This seal can be formed by one of varying methods that can include, but are not limited to, crimping, folding, welding, adhering, adhesive bonding, fastening, combinations thereof, and other similar sealing techniques that can form a hermetic seal between like materials or dissimilar materials, depending upon the configuration of the insulating structure 10.

[0055] According to the various embodiments, while a refrigerating appliance 12 is exemplified in FIG. 1, it is contemplated that the various aspects of the device can be utilized within various fixtures and/or appliances 12, wherein the term “appliance” can include cabinets, doors, and/or insulating structures therefor. Such appliances 12 and/or fixtures can include, but are not limited to, freezers, refrigerators, coolers, ovens, dishwashers, laundry appliances, water heaters, household insulation systems, ductwork, piping insulation, acoustical insulation, and other insulating applications.

[0056] It will be understood by one having ordinary skill in the art that construction of the described device and other components is not limited to any specific material. Other

exemplary embodiments of the device disclosed herein may be formed from a wide variety of materials, unless described otherwise herein.

[0057] For purposes of this disclosure, the term "coupled" (in all of its forms, couple, coupling, coupled, etc.) generally means the joining of two components (electrical or mechanical) directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two components (electrical or mechanical) and any additional intermediate members being integrally formed as a single unitary body with one another or with the two components. Such joining may be permanent in nature or may be removable or releasable in nature unless otherwise stated.

[0058] It is also important to note that the construction and arrangement of the elements of the device as shown in the exemplary embodiments is illustrative only. Although only a few embodiments of the present innovations have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements shown as multiple parts may be integrally formed, the operation of the interfaces may be reversed or otherwise varied, the length or width of the structures and/or members or connector or other elements of the system may be varied, the nature or number of adjustment positions provided between the elements may be varied. It should be noted that the elements and/or assemblies of the system may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Accordingly, all such modifications are intended to be included within the scope of the present innovations. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the desired and other exemplary embodiments without departing from the spirit of the present innovations.

[0059] It will be understood that any described processes or steps within described processes may be combined with other disclosed processes or steps to form structures

within the scope of the present device. The exemplary structures and processes disclosed herein are for illustrative purposes and are not to be construed as limiting.

[0060] It is also to be understood that variations and modifications can be made on the aforementioned structures and methods without departing from the concepts of the present device, and further it is to be understood that such concepts are intended to be covered by the following claims unless these claims by their language expressly state otherwise.

[0061] The above description is considered that of the illustrated embodiments only. Modifications of the device will occur to those skilled in the art and to those who make or use the device. Therefore, it is understood that the embodiments shown in the drawings and described above is merely for illustrative purposes and not intended to limit the scope of the device, which is defined by the following claims as interpreted according to the principles of patent law, including the Doctrine of Equivalents.

What is claimed is:

1. An insulation structure for an appliance, the insulation structure comprising:
an insulating structure having at least an outer wrapper, with an insulating cavity defined therein;
an insulating powder material disposed substantially throughout the insulating cavity; and
an insulating gas disposed within the insulating cavity, wherein the insulating powder material is combined with the insulating gas and cooperatively defines a suspended state and a precipitated state, wherein the suspended state is defined by the insulating gas being in motion and the insulating powder material being in an aeolian suspension within the insulating gas while in motion, and wherein the precipitated state is defined by the insulating gas being in a deposition state and the insulating powder material being precipitated from the insulating gas and deposited within the insulating cavity.
2. The insulation structure of claim 1, wherein a plurality of hollow insulating spheres are disposed in the insulating cavity.
3. The insulation structure of any one or more of claims 1 and 2, wherein the insulating gas is at least one of argon, neon, carbon dioxide, xenon and krypton.
4. The insulation structure of any one or more of claims 1-3, wherein the insulating powder material defines porous areas between particles of the insulating powder material, wherein the insulating gas occupies the porous areas.
5. The insulation structure of any one or more of claims 1-4, wherein the insulating powder material includes at least one of fumed silica, precipitated silica and pearlite, rice husk ash powder, diatomaceous earth and cenospheres.
6. The insulation structure of any one or more of claims 1-5, wherein the insulating powder material includes compressed portions that define insulating granular material,

wherein the insulating granular material is surrounded by uncompressed portions of the insulating powder material and the insulating gas.

7. The insulation structure of any one or more of claims 1-6, wherein the insulating structure includes an inlet port through which the insulating powder material and the insulating gas are injected into the insulating cavity, and wherein the insulating structure includes a vacuum port from which gas and portions of the insulating gas are expressed from the insulating cavity.

8. The insulation structure of any one or more of claims 1-7, wherein the insulating structure includes a door of the appliance.

9. The insulation structure of any one or more of claims 1-7, wherein the insulating structure is a cabinet that includes the outer wrapper and an inner liner, wherein the insulating cavity is defined therebetween.

10. The insulation structure of any one or more of claims 1-7, wherein the insulating structure is a vacuum insulated panel.

11. A method of forming an insulating structure, the method comprising steps of:
forming an insulating member, wherein the insulating member includes an interior surface that defines an insulating cavity;
forming an insulating powder material;
disposing the insulating powder material within the insulating cavity;
dispersing the insulating powder material throughout the insulating cavity by disposing an insulating gas carrier into the insulating cavity, wherein an insulating gas in an active state carries at least a portion of the insulating powder material within the insulating gas carrier in the active state, wherein the active state is defined by the insulating gas carrier being moved within the insulating cavity; and
depositing the insulating powder material into the insulating cavity by slowing movement of the insulating gas carrier to define a deposition state, wherein when the insulating gas carrier defines the deposition state, the insulating powder material

precipitates from the insulating gas carrier and settles within the insulating cavity, wherein the insulating powder material is deposited substantially throughout the insulating cavity.

12. The method of claim 11, further including the steps of:
sealing the insulating member; and
expressing at least a portion of the insulating gas carrier from the insulating cavity to define a vacuum insulated structure.

13. The method of any one or more of claims 11 and 12, wherein the insulating member is a cabinet having an outer wrapper and an inner liner sealed together, and wherein the insulating cavity is defined between the outer wrapper and the inner liner, and wherein the vacuum insulated structure is a thermally insulating structure.

14. The method of any one or more of claims 11-13, wherein the insulating member is a panel member and the vacuum insulated structure defines a vacuum insulated panel.

15. The method of any one or more of claims 11-14, wherein the insulating gas carrier is at least one of argon, neon, carbon dioxide, xenon and krypton.

16. The method of any one or more of claims 11-15, wherein the insulating powder material includes at least one of fumed silica, precipitated silica and nano aerogel powder.

17. The method of any one or more of claims 11-16, wherein the step of dispersing the insulating powder material throughout the insulating cavity is performed by blowing the insulating gas carrier through the insulating powder material and into the insulating cavity.

18. The method of any one or more of claims 11-17, wherein the insulating member includes an inlet port through which the insulating powder material and the insulating gas carrier are injected into the insulating cavity, and wherein the cabinet includes a

vacuum port from which gas and portions of the insulating gas are expressed from the insulating cavity.

19. The method of claim 18, wherein during the dispersing step, the gas and at least a portion of the insulating gas carrier are expressed from the vacuum port, wherein the vacuum port is configured to permit expression of the insulating gas carrier, and wherein the vacuum port is configured to substantially retain the insulating powder material within the insulating cavity.

20. The method of any one or more of claims 11-19, wherein the insulating gas carrier and the insulating powder material are combined within the insulating cavity, wherein the insulating powder material becomes suspended within the insulating gas carrier in the active state within the insulating cavity.

21. A method for forming an insulating member within an insulating structure, the method comprising steps of:

- forming a powder insulation material;

- suspending the powder insulation material within an insulating gas carrier to form an aeolian suspension, wherein the insulating gas carrier is moved through the powder insulation material;

- disposing the aeolian suspension within an insulating cavity defined within the insulating structure;

- expressing gas and a portion of the insulating gas carrier from the insulating cavity to circulate the aeolian suspension through the insulating cavity;

- precipitating the powder insulation material from the aeolian suspension, wherein the powder insulation material is deposited throughout the insulating cavity, and wherein the insulating gas carrier occupies porous spaces defined between particles of the powder insulation material; and

- sealing the powder insulation material and the insulating gas carrier within the insulating cavity to define a vacuum insulated structure.

22. The method of claim 21, wherein the vacuum insulated structure is a cabinet for an appliance.

23. The method of any one or more of claims 21 and 22, wherein the aeolian suspension is formed within the insulating cavity.

24. The method of any one or more of claims 21-23, wherein the insulating gas carrier is at least one of argon, neon, carbon dioxide, xenon and krypton.

25. The method of any one or more of claims 21-24, wherein the powder insulation material includes at least one of fumed silica, precipitated silica and nano aerogel powder.

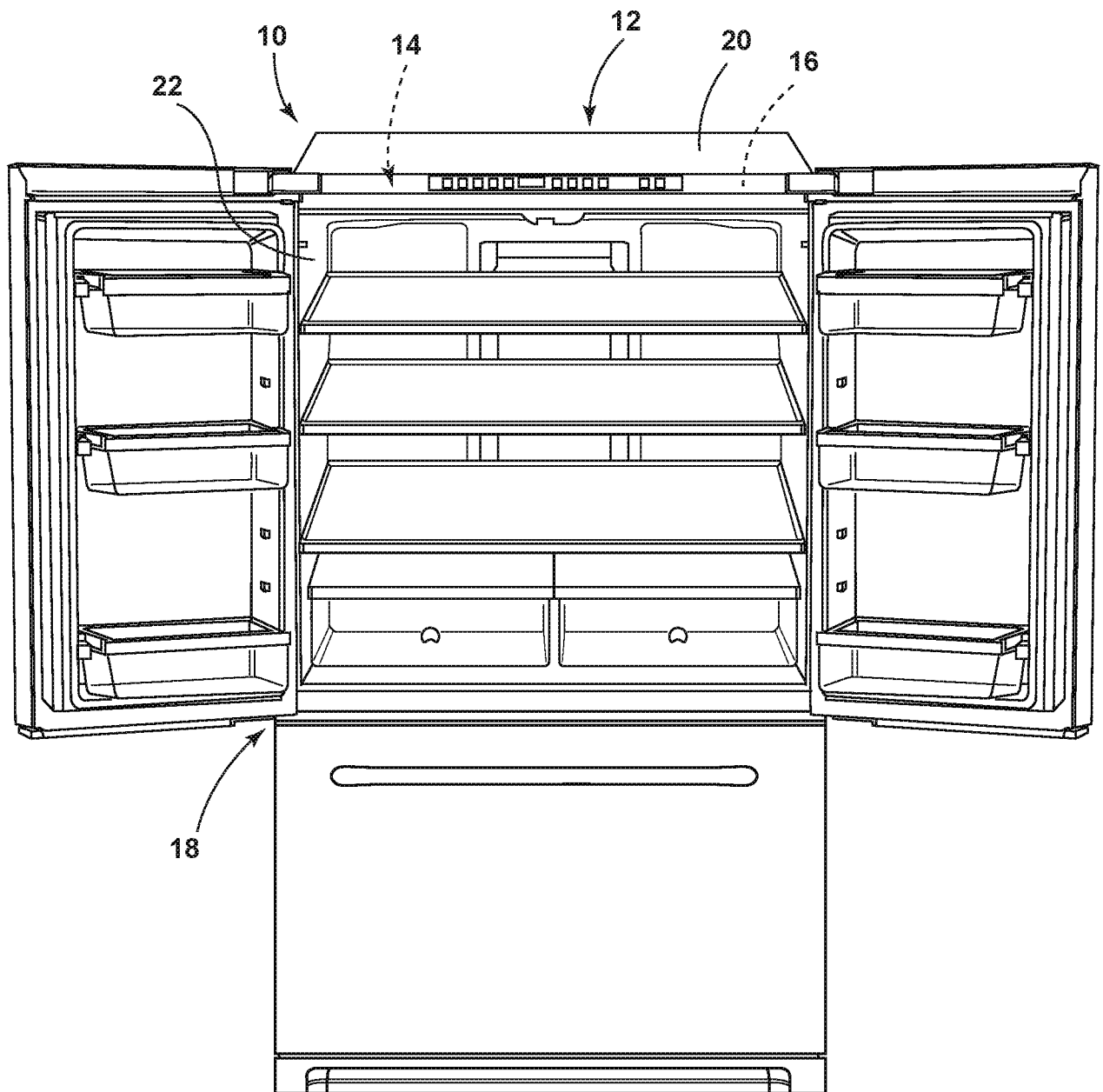
26. The method of any one or more of claims 21-25, wherein the step of dispersing the powder insulation material throughout the insulating cavity is performed by blowing the insulating gas carrier through the powder insulation material and into the insulating cavity.

27. The method of any one or more of claims 21-26, wherein the insulating member includes an inlet port through which the powder insulation material and the insulating gas carrier are injected into the insulating cavity, and wherein the cabinet includes a vacuum port from which gas and portions of the insulating gas are expressed from the insulating cavity.

28. The method of claim 27, wherein during the dispersing step, the gas and at least a portion of the insulating gas carrier are expressed from the vacuum port, wherein the vacuum port is configured to permit expression of the insulating gas carrier, and wherein the vacuum port is configured to substantially retain the powder insulation material within the insulating cavity.

29. The method of any one or more of claims 21-28, wherein the insulating gas carrier and the powder insulation material are combined within the insulating cavity, wherein the powder insulation material becomes suspended within the insulating gas carrier in an active state within the insulating cavity.

1/13

**FIG. 1**

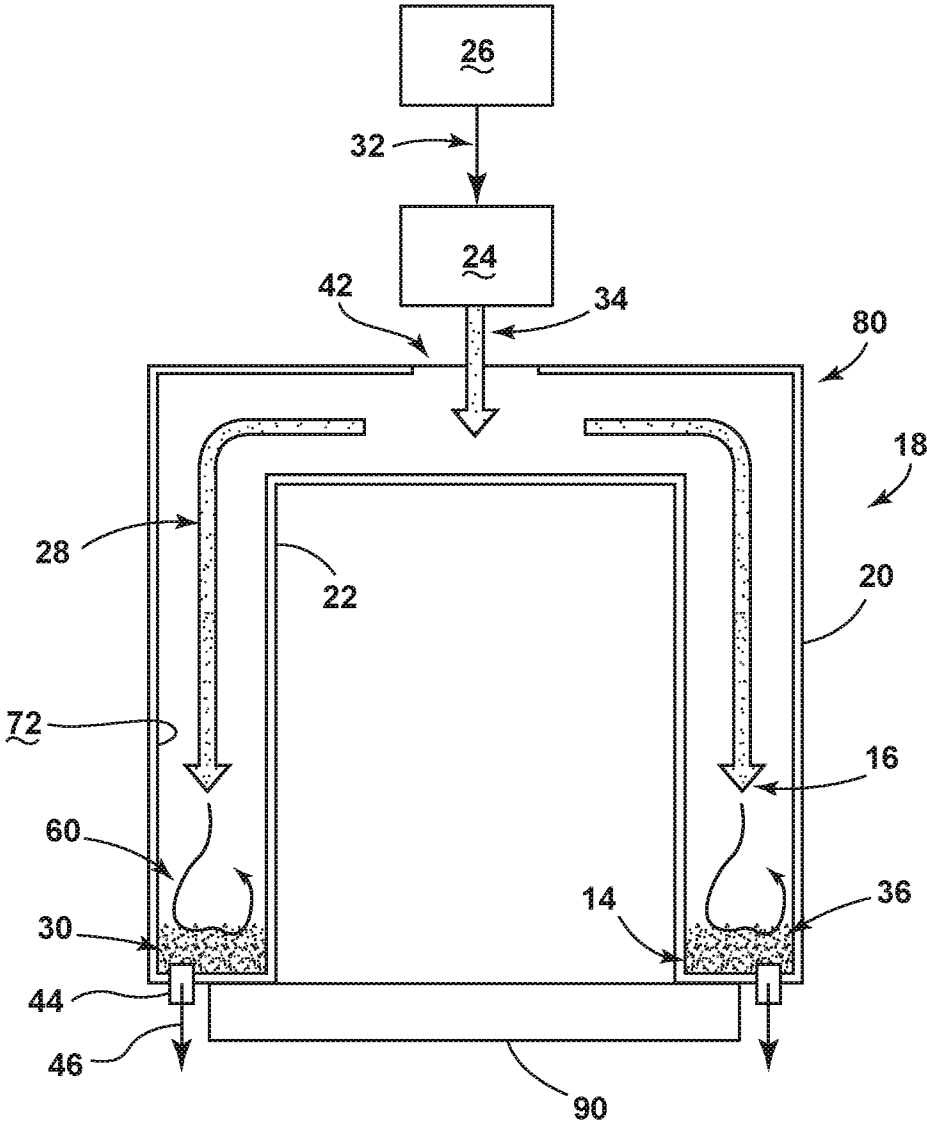
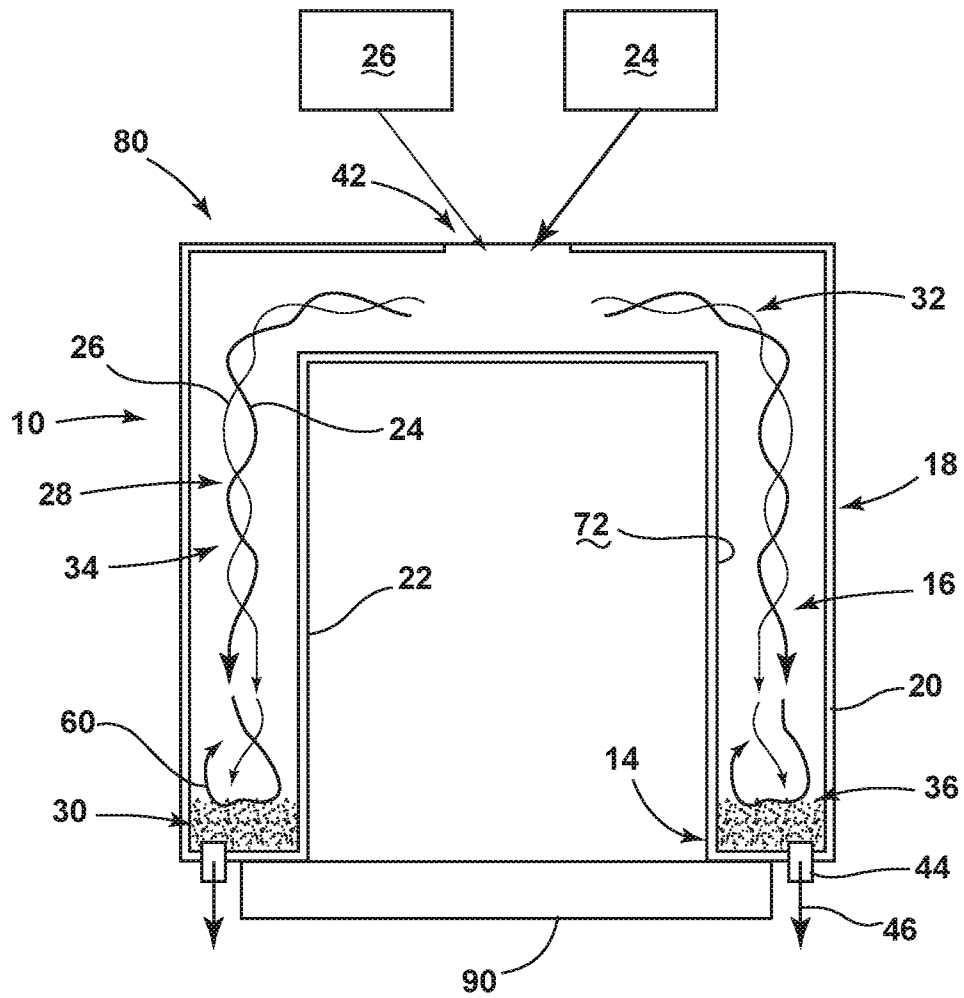


FIG. 2

**FIG. 3**

4/13

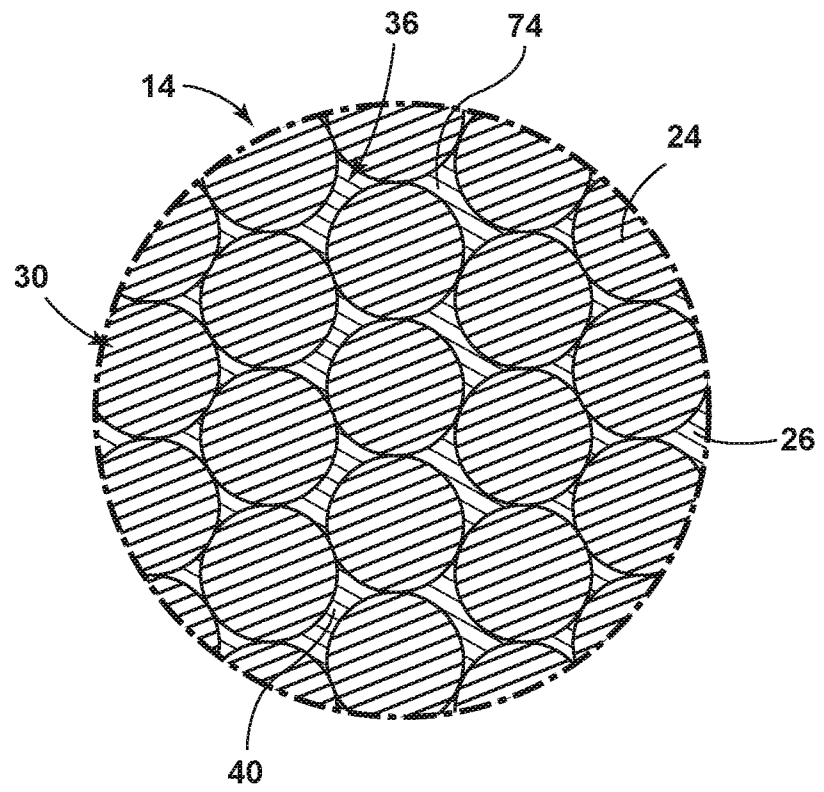


FIG. 4

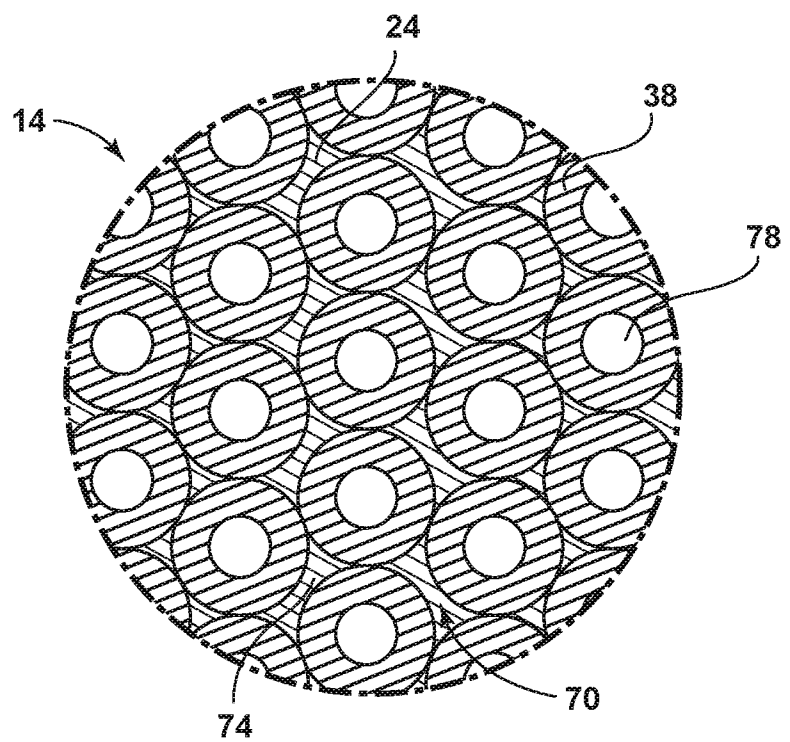


FIG. 5

5/13

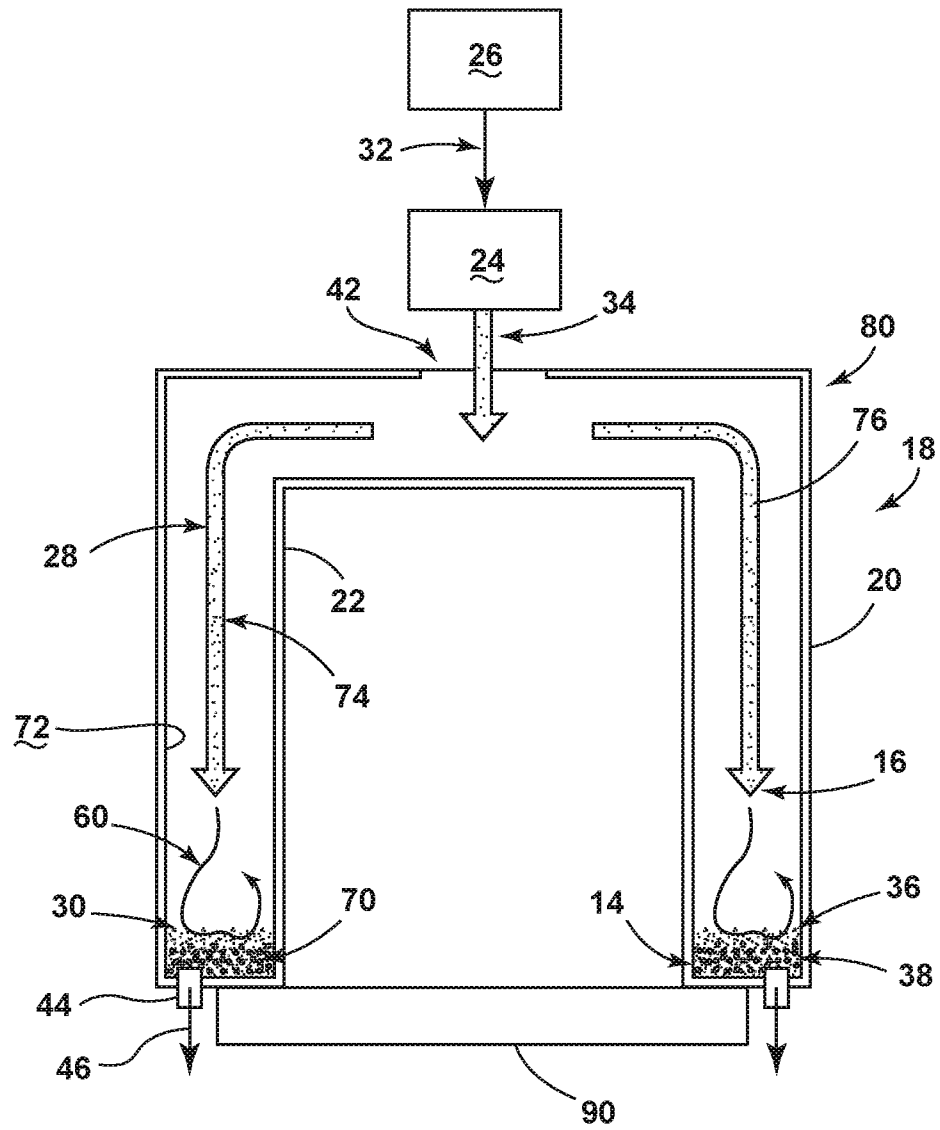


FIG. 6

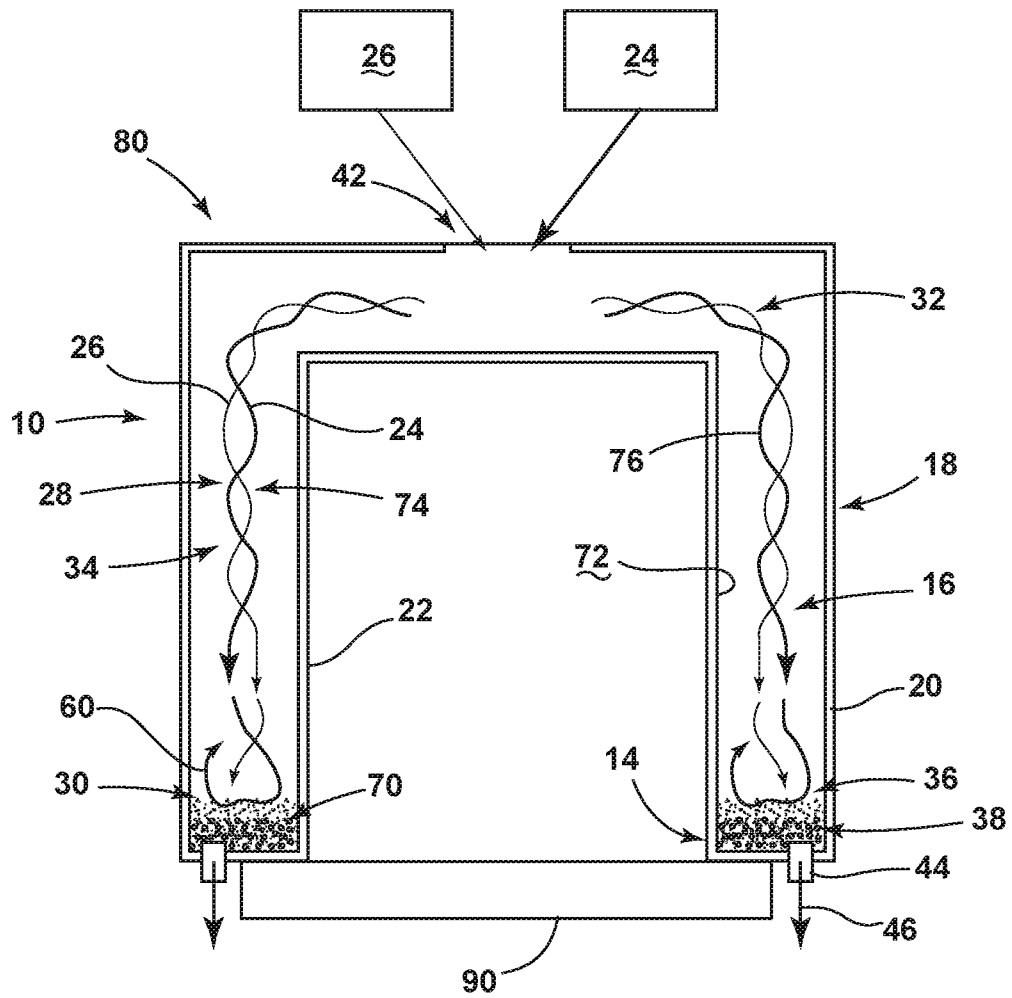


FIG. 7

7/13

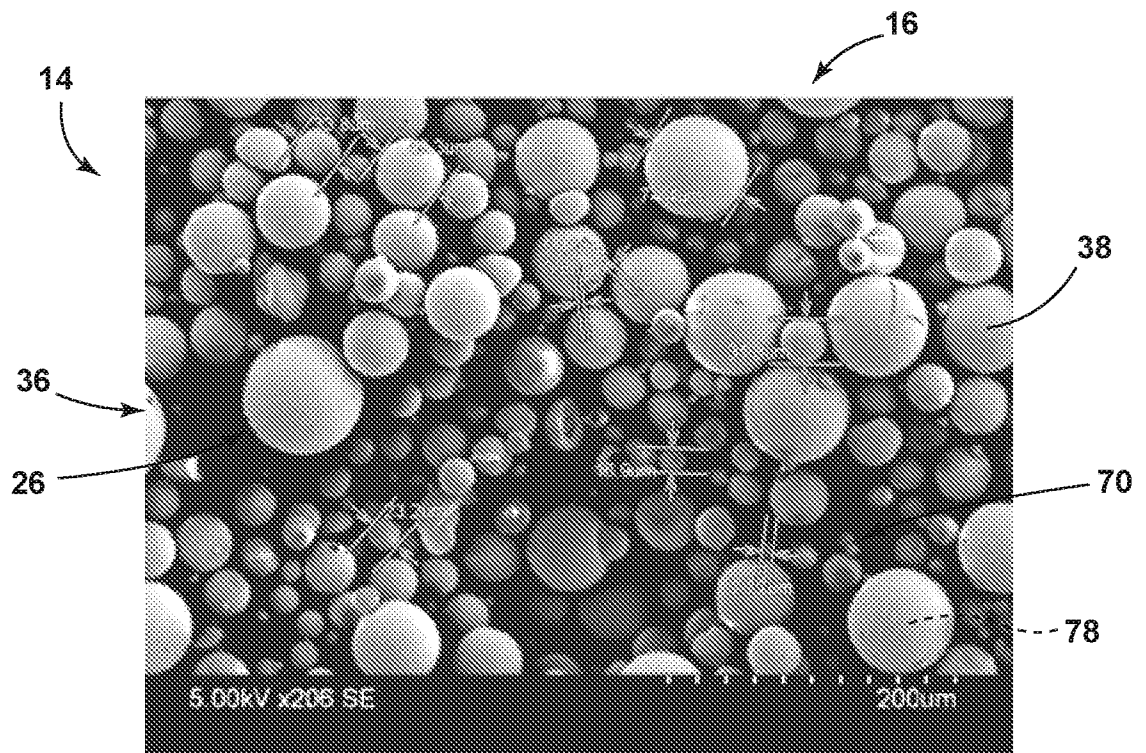


FIG. 8

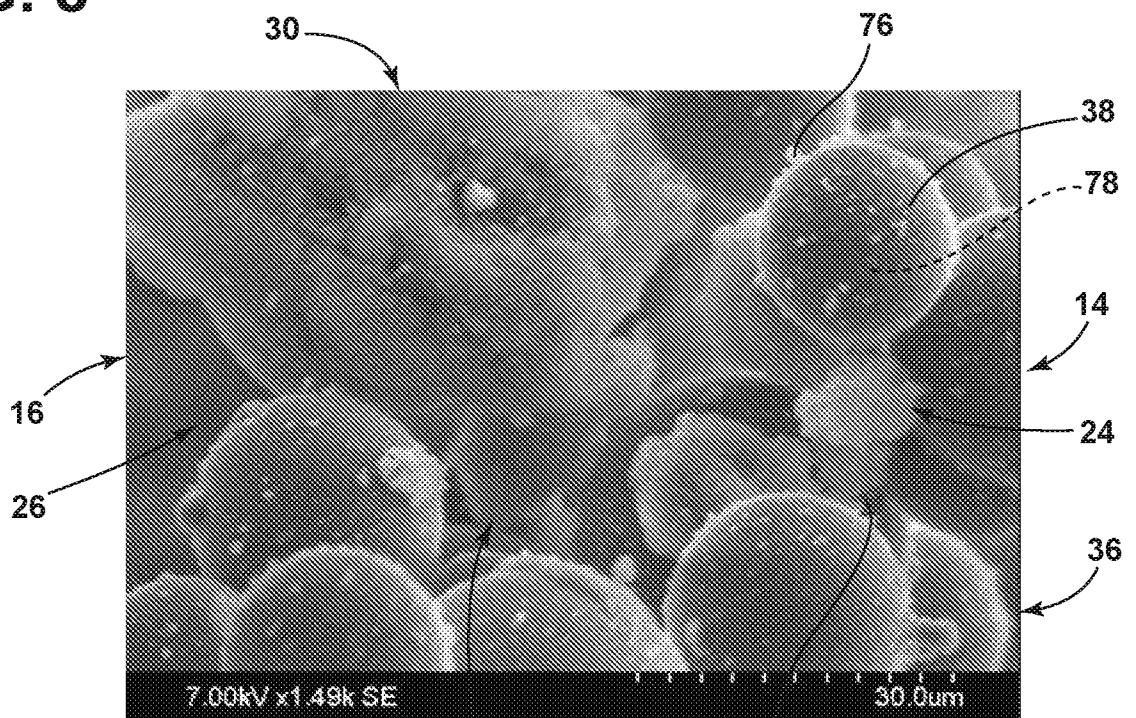
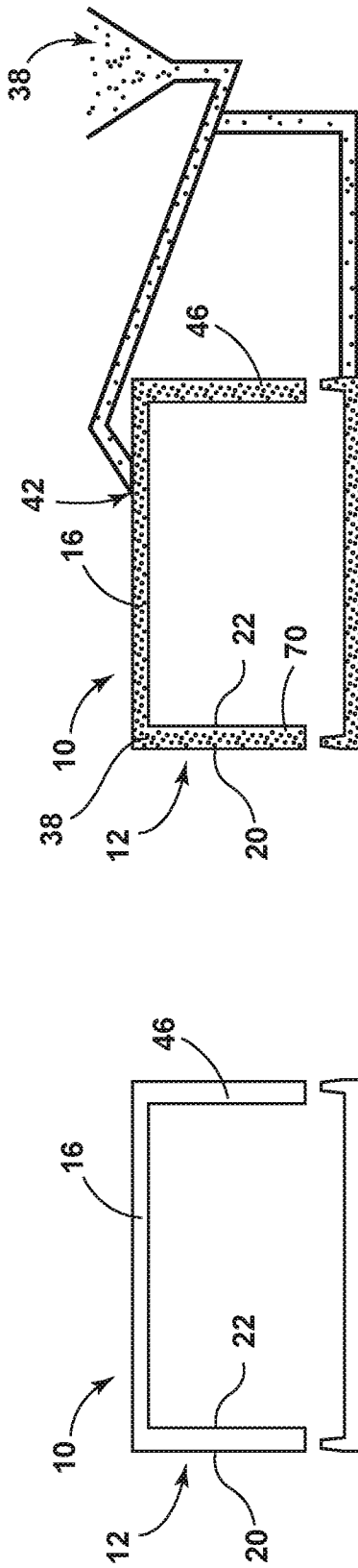
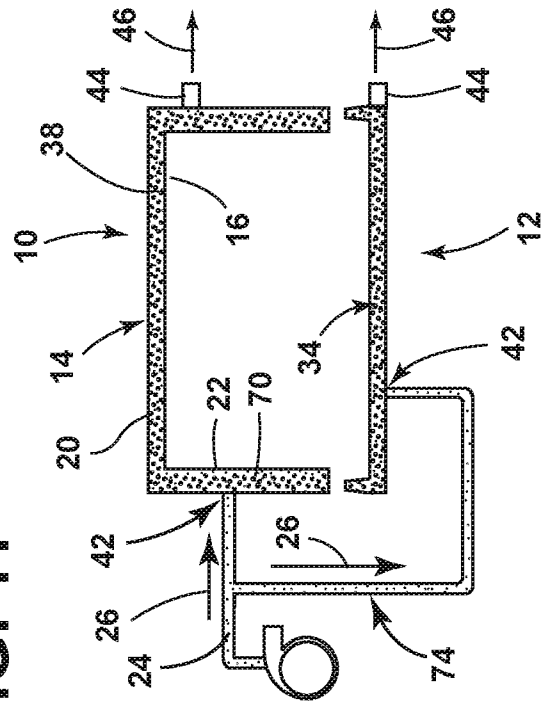


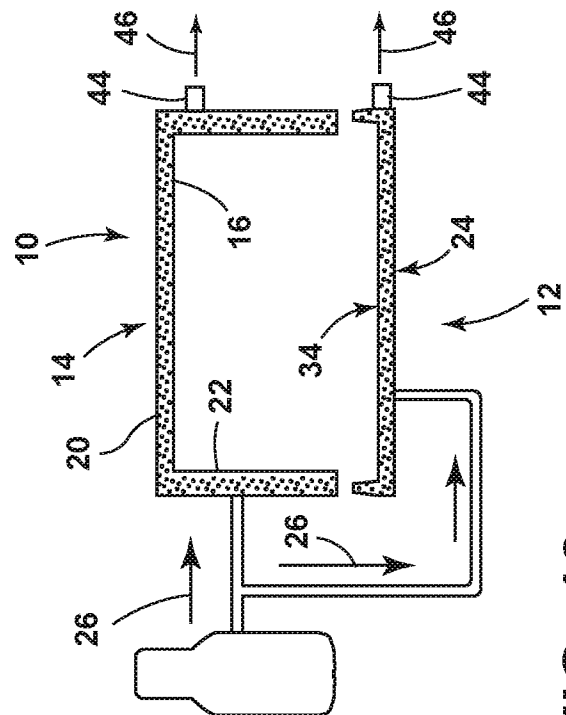
FIG. 9



107



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13. FIG.



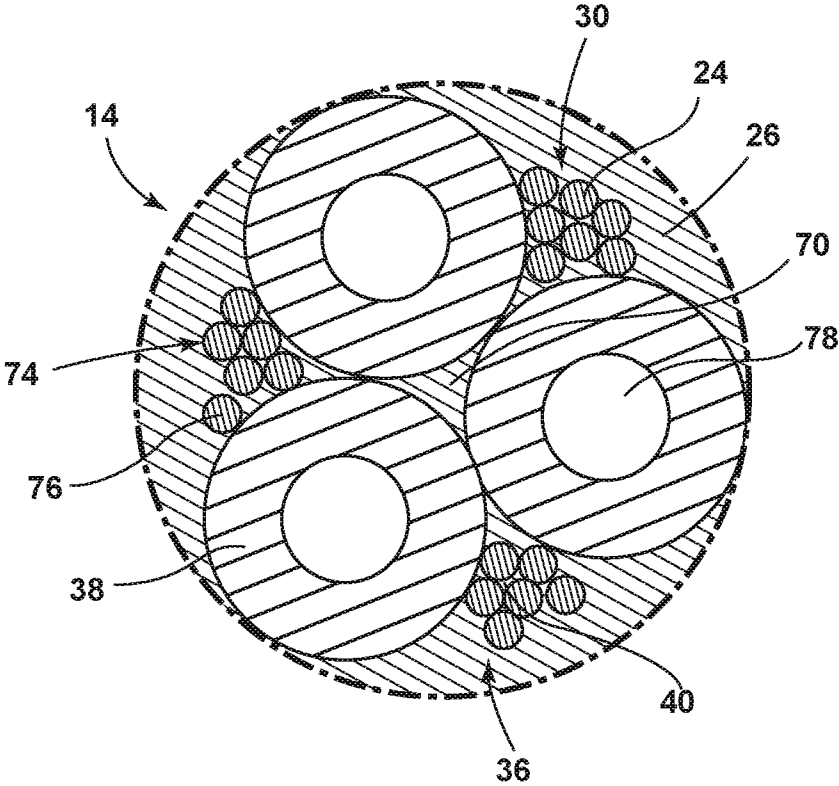
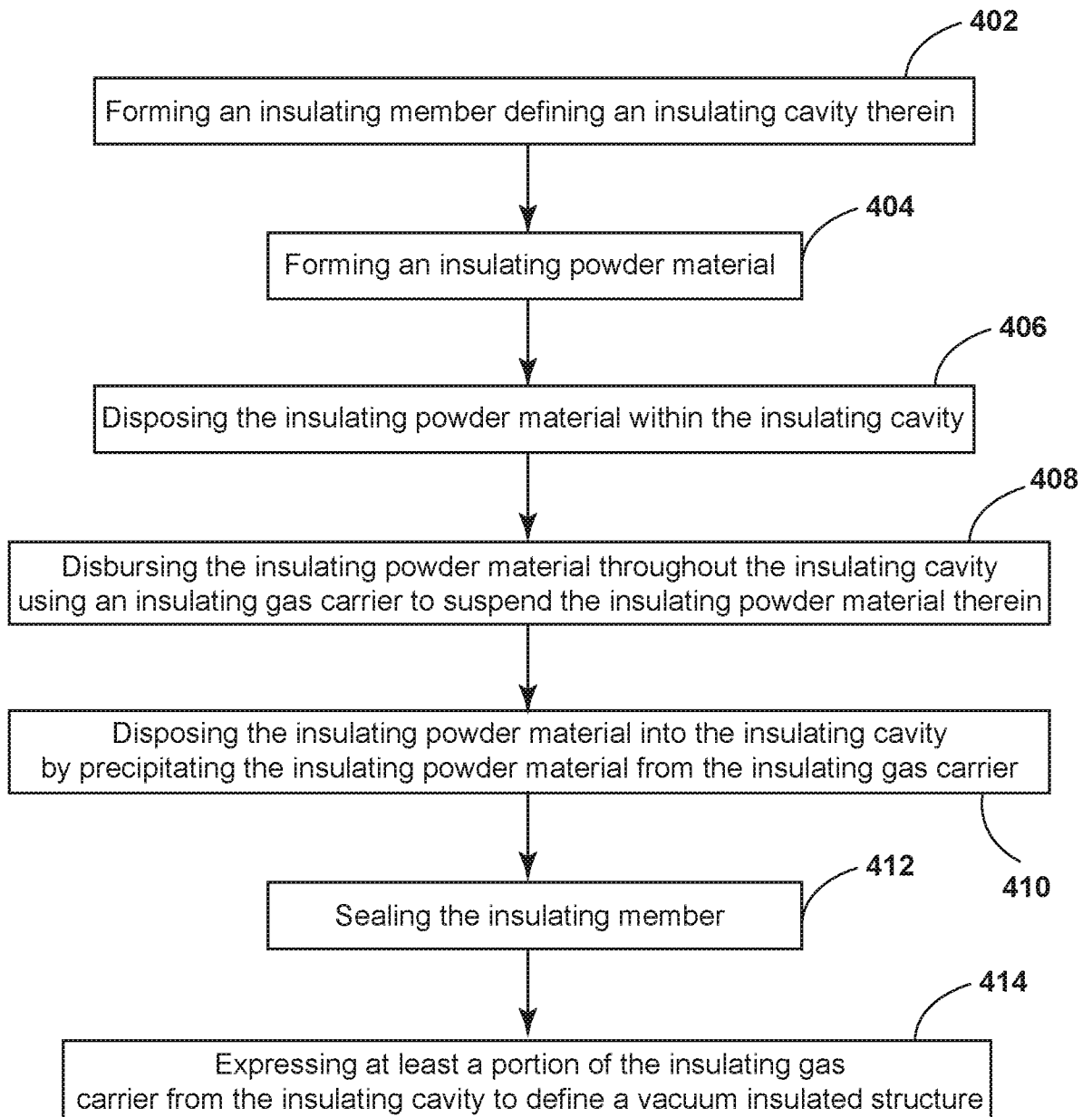


FIG. 14

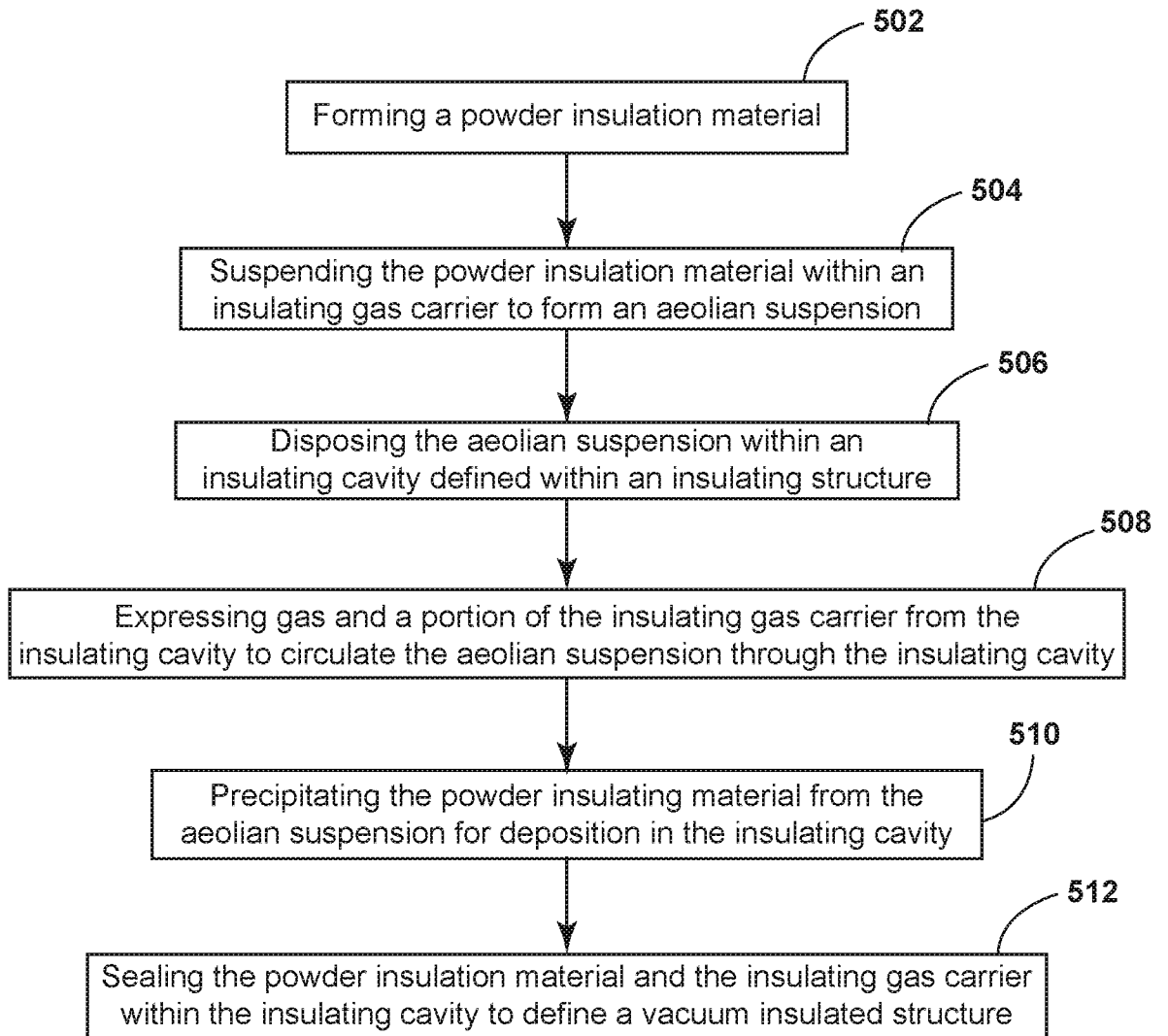
10/13

Method 400 for Forming an Insulating Structure

**FIG. 15**

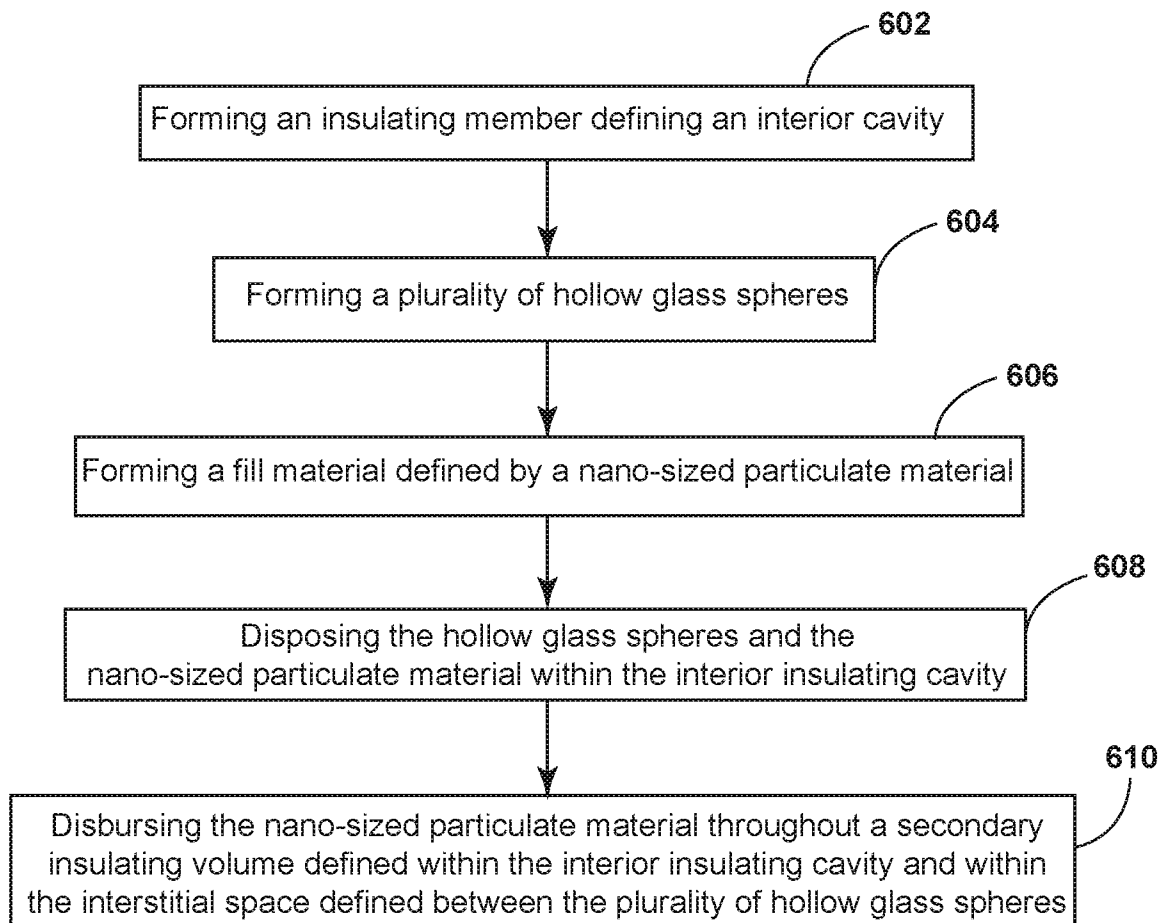
11/13

Method 500 for Forming an Insulation Member within an Insulating Structure

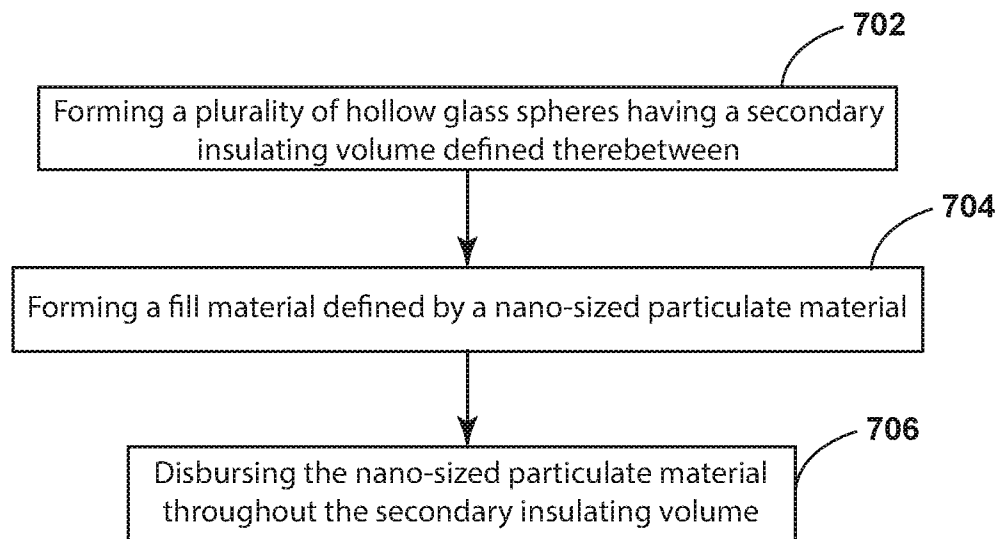
**FIG. 16**

12/13

Method 600 for Forming an Insulating Structure

**FIG. 17**

Method 700 for Forming an Insulating Material to be Used in an Insulating Structure

**FIG. 18**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2016/063355

A. CLASSIFICATION OF SUBJECT MATTER <i>F25D 23/06 (2006.01)</i> <i>F16L 59/06 (2006.01)</i> 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) F25D 11/00-11/02, 3/00, 23/00-23/12, F16L 59/00, 59/06, B32B 5/00, 5/30 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) PatSearch, esp@cenet, USPTO, Google		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RU 2132522 C1 (KRASNODARSKIY NAUCHNO-ISSLEDOVATELSKIY INSTITUT KHRANENIYA I PERERABOTKI SELSKOKHOZYAYSTVENNOY PRODUKTSII) 27.06.1999	1-3, 11-13, 21-23
A	US 4529638 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al.) 16.07.1985	1-3, 11-13, 21-23
A	WO 2009/013106 A2 (BSH BOSCH UND SIEMENS HAUSGERATE GMBH et al.) 29.01.2009	1-3, 11-13, 21-23
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents:	“A” document defining the general state of the art which is not considered to be of particular relevance “E” earlier document but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “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 “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “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 “&” document member of the same patent family	
Date of the actual completion of the international search	Date of mailing of the international search report	
25 January 2017 (25.01.2017)	27 February 2017 (27.02.2017)	
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer T. Darina Telephone No. 8 (495)-531-64-81	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2016/063355

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 4-10, 14-20, 24-29
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.