

WALL ASSEMBLY WITH IMPROVED THERMAL INSULATION PROPERTIES

BACKGROUND

[0001] Increasing energy costs have driven a desire for buildings with increased energy efficiency. Increased energy efficiency is especially desirable in extreme climates, such as in hot deserts or in areas that frequently endure artic temperatures. While advances have been made in energy efficient buildings, further advances are sought in energy efficiency. Additionally, advances are sought in cost efficiency as well as construction time efficiency.

SUMMARY

[0002] One or more embodiments provide for a wall. The wall includes a thermal chamber assembly. The thermal chamber assembly includes a radiant panel layer including a first range of thermal conductivity. The thermal chamber assembly also includes a thermal generation system connected to the radiant panel layer. The thermal chamber assembly also includes a first insulation layer connected to the radiant panel layer opposite the thermal generation system and including a second range of thermal conductivity below the first range of thermal conductivity. The thermal chamber assembly also includes a radiant barrier layer connected to the first insulation layer between the first insulation layer and the radiant panel layer, the radiant barrier layer including the first range of thermal conductivity. The wall also includes a ventilated cavity assembly connected to the thermal chamber assembly. The ventilated cavity assembly includes a second insulation layer connected to the first insulation layer opposite the radiant barrier layer, the second insulation layer including the second range of thermal conductivity. The ventilated cavity assembly also includes a gas barrier layer connected to the second insulation layer opposite the radiant barrier layer. The gas barrier layer is connected a first distance from the second insulation layer to establish a first gas layer between the second insulation layer and the gas barrier layer.

The ventilated cavity assembly also includes an exterior layer connected to the gas barrier layer opposite the second insulation layer. The exterior layer is connected a second distance from the gas barrier layer to establish a second gas layer between the gas barrier layer and the exterior layer.

[0003] One or more embodiments provide for a manufacturing method. The method includes manufacturing wall segments. Each of the wall segments includes a thermal chamber assembly. The thermal chamber assembly includes a radiant panel layer including a first range of thermal conductivity. The thermal chamber assembly also includes a thermal generation system connected to the radiant panel layer. The thermal chamber assembly also includes a first insulation layer connected to the radiant panel layer opposite the thermal generation system. The first insulation layer includes a second range of thermal conductivity below the first range of thermal conductivity. The first insulation layer also includes a first end and a second end opposite the first end relative to a length of the first insulation layer. The first insulation layer also includes a tongue extending from the first end. The first insulation layer also includes a groove extending into the second end. The thermal chamber assembly also includes a radiant barrier layer connected to the first insulation layer between the first insulation layer and the radiant panel layer, the radiant barrier layer including the first range of thermal conductivity. The wall also includes a ventilated cavity assembly connected to the thermal chamber assembly. The ventilated cavity assembly includes a second insulation layer connected to the first insulation layer opposite the radiant barrier layer, the second insulation layer including the second range of thermal conductivity. The ventilated cavity assembly also includes a gas barrier layer connected to the second insulation layer opposite the first insulation layer. The gas barrier layer is connected a first distance from the second insulation layer to establish a first gas layer between the second insulation layer and the gas barrier layer. The ventilated cavity assembly also includes an exterior layer connected to the gas barrier layer opposite the second insulation layer. The exterior layer is connected a second distance

from the gas barrier layer to establish a second gas layer between the gas barrier layer and the exterior layer. The method also includes transporting the wall segments to a construction site. The method also includes connecting the wall segments by connecting the tongue of a first wall segment of the wall segments to the groove of a second wall segment of the wall segments.

[0004] One or more embodiments also provide for a method of thermal insulation. The method includes constructing a building including a wall. The wall includes a thermal chamber assembly. The thermal chamber assembly includes a radiant panel layer including a first range of thermal conductivity. The thermal chamber assembly also includes a thermal generation system connected to the radiant panel layer. The thermal chamber assembly also includes a first insulation layer connected to the radiant panel layer opposite the thermal generation system. The thermal chamber assembly includes a second range of thermal conductivity below the first range of thermal conductivity. The thermal chamber assembly also includes a first end and a second end opposite the first end relative to a length of the first insulation layer. The thermal chamber assembly also includes a tongue extending from the first end. The thermal chamber assembly also includes a groove extending into the second end. The thermal chamber assembly also includes a radiant barrier layer connected to the first insulation layer between the first insulation layer and the radiant panel layer, the radiant barrier layer including the first range of thermal conductivity. The wall also includes a ventilated cavity assembly connected to the thermal chamber assembly. The ventilated cavity assembly includes a second insulation layer connected to the first insulation layer opposite the radiant barrier layer, the second insulation layer including the second range of thermal conductivity. The ventilated cavity assembly also includes a gas barrier layer connected to the second insulation layer opposite the first insulation layer. The gas barrier layer is connected a first distance from the second insulation layer to establish a first gas layer between the second insulation layer and the gas barrier layer. The ventilated cavity assembly also includes an exterior layer connected to the gas

barrier layer opposite the second insulation layer. The exterior layer is connected a second distance from the gas barrier layer to establish a second gas layer between the gas barrier layer and the exterior layer. The method also includes generating heat or cooling with the thermal generation system and directing the heat or cooling towards the radiant panel layer.

[0005] Other aspects of the one or more embodiments will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0006] FIG. 1 shows a wall assembly, in accordance with one or more embodiments.

[0007] FIG. 2, FIG. 3, FIG. 4, FIG. 5, FIG. 6, and FIG. 7 show details of the wall assembly shown in FIG. 1, in accordance with one or more embodiments.

[0008] FIG. 8 shows a manufacturing method, in accordance with one or more embodiments.

[0009] FIG. 9 shows a method for thermal insulation, in accordance with one or more embodiments.

[0010] Like elements in the various figures are denoted by like reference numerals for consistency.

DETAILED DESCRIPTION

- [0011]** One or more embodiments are directed to a wall assembly with improved thermal insulation properties. The wall assembly provides quantifiably improved thermal insulation properties, relative to prior wall assemblies. Additionally, the wall assembly of one or more embodiments may be manufactured at a manufacturing facility, and then transported to a construction site for rapid assembly. Thus, the wall assembly of one or more embodiments also provide for increased cost efficiency and construction time efficiency.
- [0012]** The wall assembly of one or more embodiments include a first set of layers that form a thermal generation chamber and a second set of layers that form a ventilated cavity. Combined, the two sets of layers serve not only as a thermal barrier to extreme temperature differentials between the interior and exterior portions of the wall assembly, but also provide for active heating or cooling of the interior of a building constructed using the wall assembly of one or more embodiments.
- [0013]** The thermal generation chamber includes a radiant panel layer having a first range of thermal conductivity. The first range of thermal conductivity may be in a range considered to be a high thermal conductivity in some embodiments, such as a thermal conductor (*e.g.*, metals) as defined by an engineer. While high thermal conductivity materials may transmit heat efficiency when in direct contact with other materials, high thermal conductivity materials also tend to reflect radiative energy (*e.g.*, infrared light), and thus may form part of a wall assembly that exhibits improved thermal insulation properties.
- [0014]** The thermal generation chamber also includes a thermal generation system located inside the radiant panel layer, relative to an interior of a building formed partially by the wall. The thermal generation system may be a heated or cooled liquid piping system, or may be some other heater or air conditioning system.

- [0015] An interior finish layer (*e.g.*, drywall, gypsum, *etc.*) may be located inside the thermal generation system, relative to the interior of the building. The interior finish layer may face an inside of the building (*i.e.*, forms the inside wall as seen by persons located inside the building).
- [0016] The thermal generation chamber also includes a first insulation layer connected to the radiant panel layer opposite the thermal generation system (*i.e.*, outside the radiant panel layer, relative to the inside of the building). The first insulation layer has a second range of thermal conductivity below the first range of thermal conductivity of the radiant panel layer. The second range of thermal conductivity may be considered an insulator, and thus has a low thermal conductivity as defined by an engineer.
- [0017] The thermal generation chamber also includes a radiant barrier layer connected to the first insulation layer, between the radiant panel layer and the first insulation layer. The radiant barrier layer also may be a thermal conductor, and thus may have the same first range of thermal conductivity as the radiant panel layer.
- [0018] The wall assembly also includes a ventilated cavity assembly. The ventilated cavity assembly establishes layers of dead air (*i.e.*, air that does not move or moves less than air inside or outside of the wall assembly). Dead air, or some other gas, has low thermal conductivity properties.
- [0019] The ventilated cavity assembly includes a second insulation layer connected to the first insulation layer of the thermal generation chamber. The second insulation layer is therefore outside the first insulation layer, relative to an inside of the building. The second insulation layer may have low thermal conductivity, and thus may be in the second range of thermal conductivity of the first insulation layer. Tubes disposed in the second insulation layer may establish a separation between the first insulation layer and the second insulation layer, thereby establishing a space (filled with a gas such as air) between the two insulation layers.

- [0020] The ventilated cavity assembly also includes a gas barrier layer connected to the second insulation layer opposite the first insulation layer. Thus, the gas barrier layer is outside the second insulation layer, relative to the interior of the building. The gas barrier layer is connected a first distance from the second insulation layer to establish a first gas layer between the second insulation layer and the gas barrier layer.
- [0021] The ventilated cavity assembly also includes an exterior layer connected to the gas barrier layer opposite the second insulation layer. Thus, the exterior layer is outside the gas barrier layer, relative to the interior of the building. The exterior layer may face an exterior of the building (*i.e.*, the exterior layer may face the outside elements.) The exterior layer may be connected a second distance from the gas barrier layer to establish a second gas layer between the gas barrier layer and the exterior layer.
- [0022] Additional layers and components may be added to the wall assembly described above. For example, thermal insulation material such as cork or other materials may be placed between layers described above to act as further thermal insulators between the layers. Electrical systems or ethernet systems may be added between wall layers, possibly with exposed outlets, such as in the interior finish layer or the exterior layer.
- [0023] The wall assembly described above also may be provided with modular features. For examples, tongue and groove features may be added to one or more of the layers described above. The tongue and groove features permit rapid and alignment of wall segments at a construction site. Thus, the wall segments may be efficiently manufactured at a manufacturing facility, and then transported to the construction site for rapid assembly.
- [0024] Additionally, manufacturing the wall assemblies at a manufacturing facility may reduce the carbon footprint of manufacturing and assembling the walls. For example, carbon emissions during the manufacturing process may be controlled at the manufacturing facility. Furthermore, heavy construction equipment at the construction site may burn fuel during construction.

Because construction using the wall assembly of one or more embodiments is time efficient, such equipment operates for less time, and thus further reduces the carbon footprint of building construction.

[0025] The wall assembly described above may be referred to as a “Miralex wall system.” The Miralex wall system is suitable both for new construction and building retrofits. The Miralex wall system may be used for constructing many types of buildings, including houses, multi-unit apartments, condominiums, hospitals, schools, day cares, community centers, commercial buildings, *etc.*

[0026] The Miralex wall system is also sturdy. The Miralex wall system may resist wind forces up to approximately 9,250 Pascals and can be exposed to all types of weather (sun, snow, ice, water, high winds, *etc.*). Energy performance of the Miralex wall system is superior, exceeding an insulation factor of at least R20, even in extreme weather conditions (*e.g.*, hot deserts or arctic climates).

[0027] The radiant liners (*i.e.*, the radiant panel layer and radiant barrier layer described above) permit heat and cold sources to transfer to the inside of the building envelope via thermal generation. In this manner, humidity may be controlled without affecting the envelope and material moisture. Accordingly, the exterior ventilated assembly may remain dry.

[0028] The Miralex wall system also reduces thermal bridging in the wall assembly observed in other wall designs in conventional construction assemblies. The Miralex wall system thus increases the performance of heating and cooling, and thereby continually reduces the energy consumption.

[0029] Solar panels may be located on an exterior of the exterior layer (or elsewhere on a building, formed at least in part by the Miralex wall system). The solar energy may be accumulated into batteries and used by building occupants, or by the thermal generation system in the thermal chamber assembly.

- [0030] Attention is now turned to the Figures. FIG. 1 shows a wall assembly, in accordance with one or more embodiments. The wall assembly (100) includes a thermal generation chamber assembly (102) and a ventilation chamber assembly (104). Each of the assemblies are described in turn.
- [0031] The thermal generation chamber assembly (102) includes a radiant panel layer (106). The radiant panel layer (106) is a high thermal conductivity material in a first range of thermal conductivities. The term “high thermal conductivity” is evaluated by a construction engineer, and may be considered a thermal conductor that also reflects infrared light. Examples of materials that may form the radiant panel layer (106) include aluminum, steel, iron, titanium, *etc.*, though other materials that reflect infrared light may be used.
- [0032] In an embodiment, such as that shown in FIG. 1, the radiant panel layer (106) may be corrugated aluminum. The corrugations in the corrugated aluminum that forms the radiant panel layer (106) may establish a separation between the radiant panel layer (106) and the interior finish layer (120) (described below), or may establish a separation between the radiant panel layer (106) and the first insulation layer (110), or both. The separation may establish spaces within the thermal generation chamber assembly (102). The spaces permit heated or chilled gasses to circulate and also provide additional insulation layers, relative to the exterior of the wall assembly (100).
- [0033] The thermal generation chamber assembly (102) of the wall assembly (100) also includes a thermal generation system (108). The thermal generation system (108) is connected to either a radiant panel layer (106) or to an interior finish layer (120) (described below). The thermal generation system (108) is a heating system, a cooling system, or both a heating system and a cooling system, depending on the type of thermal generation system (108) desired for a climate in which the wall assembly (100) is to be used to construct a building.
- [0034] For example, the thermal generation system (108) may be designed to heat the thermal generation chamber assembly (102) in cold climates. As an

example, the thermal generation system (108) may be an interconnected series of pipes that convey heated water. Heated water may be pumped through the pipes, thereby providing heat. The water may be heated within a furnace located outside the wall assembly (100), and then pumped into the pipes via an inlet into the wall and connected to the pipes, or may be heated by electrical elements contained within the wall assembly (100). As another example, the thermal generation system (108) may be an electrical heating system that uses electricity to heat elements connected to the radiant panel layer (106) or the thermal generation system (108). As yet another example, the thermal generation system (108) may be pipes designed to blow heated gas through the pipes. The gas may be heated by a furnace external to the wall assembly (100), then pumped through the pipes via an inlet into the wall, and connected to the pipes. The heated gas also may be pumped into the pipes and then blown into the interstitial spaces within the thermal generation chamber assembly (102) (e.g., between the radiant panel layer (106) and the thermal generation system (108), between the first insulation layer (110) and the second insulation layer (114), between the radiant panel layer (106) and the interior finish layer (120) (described below), or combinations thereof).

[0035] However, the thermal generation system (108) may be designed to cool the thermal generation chamber assembly (102) in hot climates. For example, the thermal generation system (108) may be a liquid cooling system of pipes or a gas cooling system of pipes, as described above, by pumping chilled liquid or a chilled gas. As another example, the thermal generation system (108) also may be an air conditioning system, or may be attached to an air conditioning system. Thus, for example, the thermal generation system (108) may be pipes connected, via one or more inlets in the wall and connected to the pipes, to an air conditioning compressor located outside the wall assembly (100). The pipes may blow chilled air into the spaces defined within the thermal generation chamber assembly (102) (e.g., between the radiant panel layer (106) and the thermal generation system (108), between the first insulation layer (110) and the second insulation layer (114), between the

radiant panel layer (106) and the interior finish layer (120) (described below), or combinations thereof).

[0036] The thermal generation chamber assembly (102) also includes a radiant barrier layer (112). The radiant barrier layer (112) may be connected to the first insulation layer (110) (described below) between the first insulation layer (110) and the radiant panel layer (106). The radiant barrier layer (112) may be in the first range of thermal conductivity, similar to the radiant panel layer (106). Thus, the radiant barrier layer (112) may be a layer of aluminum, steel, or other materials similar to those described above for the radiant panel layer (106).

[0037] The thermal generation chamber assembly (102) also includes a first insulation layer (110), as mentioned above. The first insulation layer (110) is a material having a second range of thermal conductivity below the first range of thermal conductivity described above for the radiant panel layer (106). The second range of thermal conductivity may be less than the first range of thermal conductivity of the radiant panel layer (106). The first insulation layer (110) may be formed of a material that is considered a thermal insulator. Examples of materials that may form the first insulation layer (110) include fiberglass, cellulose, polystyrene, aerogel, vacuum insulated panels, mica, plastics, rubber, glass wool, certain composite materials, *etc.* Thus, the first insulation layer (110) serves as insulation against the transfer of heat (possibly together with an empty space filled with gas defined between the first insulation layer (110) and the second insulation layer (114)), as indicated by arrows (111).

[0038] The first insulation layer (110) includes a first end (122) and a second end (124) opposite the first end (122), relative to a length of the radiant panel layer (106) along the axis (126). A tongue (128) extends from the first end (122) outwardly, relative to the axis (126). A groove (130) extends into the second end (124) inwardly, relative to the axis (126). In use, the tongue (128) of one wall segment of the wall assembly (100) may fit into the groove (130)

of another wall segment of the wall assembly (100), thereby assisting with the alignment and fitting of the two wall segments together.

[0039] Additionally, when joined, the tongue (128) and the groove (130) may form a vapor barrier installed at each vertical end of the wall panels. The tongue (128) and groove (130) may establish a continuity of a vapor barrier of the interior system, an air barrier assembly, and a connection of thermal breaks into the thermal bridging at the floor and ceiling levels of the wall assemblies.

[0040] The tongue (128) may be an extension of the insulation material that forms the first insulation layer (110). However, the tongue (128) may be a different material object attached to the first end (122) of the first insulation layer (110).

[0041] In an embodiment, an interior finish layer (120) may be connected to the radiant panel layer (106), opposite the radiant barrier layer (112). Thus, the interior finish layer (120) may be inside the radiant panel layer (106), relative to an interior of the building. The interior finish layer (120) may face the interior of the building. The thermal generation system (108), described above, may be disposed between the radiant panel layer (106) and the interior finish layer (120).

[0042] In an embodiment, cork stripping (132) may be disposed around a perimeter of the first insulation layer (110), between the first insulation layer and a second insulation layer (114) (described below). Insulative materials other than cork may be used in place of the cork stripping (132). Thus, one or more embodiments are not limited to the use of cork. The cork stripping (132) (or other insulative stripping) may establish a thermal break between metal components (*e.g.*, the tubes described below) and other components of the wall assembly (100).

[0043] Attention is now turned to the ventilation chamber assembly (104) of the wall assembly (100). The ventilation chamber assembly (104) includes a second insulation layer (114). The second insulation layer (114) is connected

to the first insulation layer (110), opposite the radiant barrier layer (112). The second insulation layer (114) may be a material that has the second range of thermal conductivity, as described above with respect to the first insulation layer (110). In an embodiment, the second insulation layer (114) may be thicker than the first insulation layer (110), along the axis (148).

- [0044] A head frame (136) may extend from the second insulation layer (114). Specifically, the head frame (136) may extend upwardly from a top of the second insulation layer (114), relative to a direction of gravity. The direction of gravity, in one embodiment, is shown by the arrowhead of vertical axis (138).
- [0045] One or more tubes may be disposed within or partially within the second insulation layer (114). The tubes may be formed from materials in the first range of thermal conductivity (*e.g.*, metals), or may be formed from other materials (*e.g.*, composite materials) in the second range of thermal conductivity (*e.g.*, insulators such as wood, composite materials, plastics, *etc.*) However, in an embodiment, the tubes may form structural members that both support the wall against compressive forces imposed by the direction of gravity (*i.e.*, along the vertical axis (138)), and also aid in containing the insulative material that forms the second insulation layer (114).
- [0046] For example, a first tube (140) is connected to the second insulation layer (114). The first tube (140) is disposed into the second insulation layer (114) and extends inwardly towards the first insulation layer (110), along the axis (148). (See, *e.g.*, FIG. 4.) The first tube (140) also is disposed along a height of the second insulation layer (114), relative to a direction of gravity, as shown by the vertical axis (138).
- [0047] Similarly, a second tube (142) is connected to the second insulation layer (114). The second tube (142) is disposed into the second insulation layer (114) and extends outwardly towards the gas barrier layer (116), along the axis (148). (See, *e.g.*, FIG. 4.) The second tube (142) also is disposed

along a height of the second insulation layer (114), relative to a direction of gravity, as shown by the vertical axis (138).

[0048] In an embodiment, similar tubes are also disposed on the opposite end of the second insulation layer (114), relative to the axis (126). Thus, for example, a third tube (143) connected to the second insulation layer (114) is shown opposite the second tube (142) in FIG. 1. Likewise, a fourth tube (not shown) connected to the second insulation layer (114) may be disposed opposite the first tube (140).

[0049] A bottom frame (144) may be disposed around the second insulation layer (114). The bottom frame (144) is disposed at a bottom of the second insulation layer (114), relative to a direction of gravity, as indicated by the vertical axis (138). The bottom frame (144) may surround the second insulation layer (114) or the tubes, thereby serving as a bracket that aids in retaining the tubes and the insulative material that forms the second insulation layer (114).

[0050] Similarly, a top frame (145) may be disposed around the second insulation layer (114). The bottom frame (144) is disposed at a top of the second insulation layer (114) relative to a direction of gravity as indicated by the vertical axis (138). The top frame (144) may surround second insulation layer (114) or the tubes, thereby serving as a bracket that aids in retaining the tubes and the insulative material that forms the second insulation layer (114). The head frame (136), described above, may be part of the top frame (145). However, the top frame (145) also may be a separate component to which the head frame (136) is attached, or from which the head frame (136) extends.

[0051] Additional cork stripping (134) may be disposed around a perimeter of the second insulation layer (114), on the side of the second insulation layer (114) facing the gas barrier layer (116) (described below). The additional cork stripping (134) may serve as additional thermal insulation. Insulative materials other than cork may be used in place of the additional cork stripping (134). Thus, one or more embodiments are not limited to the use of cork.

[0052] The ventilation chamber assembly (104) also includes a gas barrier layer (116). The gas barrier layer (116) is connected to the second insulation layer (114), opposite the first insulation layer (110). In an embodiment, the gas barrier layer (116) is directly connected to the second insulation layer (114), or may be indirectly connected to the second insulation layer (114) by way of cork stripping (see, *e.g.*, FIG. 5 and FIG. 6).

[0053] In another embodiment, the gas barrier layer (116) is connected a first distance from the second insulation layer (114) to establish a first gas layer between the second insulation layer (114) and the gas barrier layer (116). For example, a shim (146) may be connected to the second insulation layer (114) and the gas barrier layer (116). In an embodiment, the width of the shim (146) along axis (148) matches or exceeds the distance.

[0054] Other means for establishing the separation between the second insulation layer (114) and the gas barrier layer (116) may exist, either alternatively to the shim (146) or in addition to the shim (146). For example, the tubes (*e.g.*, second tube (142)) may extend outwardly from the second insulation layer (114). In this case, the gas barrier layer (116) may be connected to the tubes. Yet further, the bottom frame (144) also may extend outwardly from the second insulation layer (114) or from the tubes, also establishing the separation between the second insulation layer (114) and the gas barrier layer (116). In this case, the bottom frame (144) may be connected to the gas barrier layer (116) as well as to the second insulation layer (114).

[0055] The second insulation layer (114) serves as insulation against the transfer of heat (possibly together with a gas layer defined between the second insulation layer (114) and gas barrier layer (116)), as indicated by arrows (113). Thus, multiple layers of insulating material, gas, and thermally reflective material are established between an exterior of the wall assembly (100) and the interior of the wall assembly (100).

- [0056] The ventilation chamber assembly (104) also includes an exterior layer (118). The exterior layer (118) is connected (at least indirectly via an exterior frame (152) (described below)) to the gas barrier layer (116) opposite the second insulation layer (114). The exterior layer (118) is connected a second distance, along axis (148), from the gas barrier layer (116) to establish a second gas layer between the gas barrier layer (116) and the exterior layer (118).
- [0057] In an embodiment, a number of clips (such as clip (150)) establish the second distance, along the axis (148), between the gas barrier layer (116) and an exterior frame (152). However, other objects (*e.g.*, a shim (similar to the shim (146))) may be used to establish the second distance, and thus form the second gas chamber. Similarly, tubes (similar to the first tube (140) and the second tube (142)) described above, or other objects) may be so used to establish the distance to form the second gas chamber. The clips may be formed of an insulative material (*e.g.*, plastics or carbon composites), though in other embodiments the clips may be formed from thermal conductors (*e.g.*, metals).
- [0058] In another example, as shown in FIG. 1, because the exterior frame (152) is connected to the clips, and because the exterior layer (118) is connected to the exterior frame (152), the clips and the exterior frame (152) together may establish the second distance. In yet another embodiment, the exterior frame (152) itself may establish the second distance.
- [0059] The exterior frame (152) may be a structural member that helps bear the load born by the wall assembly (100). Thus, the exterior frame (152) may be composed of metals, but may be composed of strong insulative materials, such as carbon composite materials.
- [0060] In an embodiment, a first set of insulation blocks is disposed between at least some of the clips, the gas barrier layer (116), and the exterior layer (118). Additionally, a second set of insulation blocks may be disposed between the second insulation layer (114) and the gas barrier layer (116). The

insulative blocks may provide additional thermal insulation against the transfer of heat energy between the various layers of the ventilation chamber assembly (104).

- [0061] Finally, the ventilation chamber assembly (104) includes an exterior layer (118). The exterior layer (118) is connected to the gas barrier layer (116), at least indirectly (*e.g.*, the exterior layer (118) is connected to the exterior frame (152), which in turn is connected to the gas barrier layer (116) via the clips such as the clip (150)). In the embodiment shown, the exterior layer (118) is connected directly to the exterior frame (152).
- [0062] The exterior layer (118) may be exterior siding (*e.g.*, metal, wood, stone, porcelain, composite materials, *etc.*) suitable for exposure to the outdoor elements. In an embodiment, the exterior layer (118) may be corrugated, as shown in FIG. 1, though the exterior layer (118) may be a flat sheet of material or a series of panels, in other embodiments. The exterior layer (118) may be a rain screen in some embodiments.
- [0063] In an embodiment, flashing (158) may be disposed along a vertical edge of the exterior layer (118) (as defined along the vertical axis (138)). The flashing (158) may extend over any seams that may exist between multiple wall segments when the wall assembly (100) is joined to another wall segment. For example, when one wall assembly (100) segment is connected to another wall assembly (100) segment, then the flashing (158) may extend over and cover the seam between the exterior layer (118) of the two wall assembly segments.
- [0064] The wall assembly (100) may be provided with additional features. For example, an electrical outlet (160) may be connected to or disposed within the interior finish layer (120). Electrical wiring placed in the space between the interior finish layer (120) and the radiant panel layer (106) may be connected to an electrical source (not shown, but, for example, to a power transmission cable). Thus, electrical devices may be connected to the electrical outlet (160) and thereby connected to the electrical source.

[0065] In an embodiment, additional electrical outlets may be connected to or disposed within the exterior layer (118). Similar electrical wiring in the space defined between the gas barrier layer (116) and the exterior layer (118) may connect the electrical outlet to the power source. Thus, electrical devices may be connected to the electrical outlet within the exterior layer (118) and power electrical devices outside the wall assembly (100).

[0066] In an embodiment, a heat generation system outlet (162) may be connected to or disposed within the interior finish layer (120). The heat generation system outlet (162) may be an inlet, manifold, *etc.* for connecting an exterior source of liquid (*e.g.*, a hot water tank) to the thermal generation system (108). The heat generation system outlet (162) also may be an air vent for connecting an exterior source of heated or cooled air (*e.g.*, a furnace or air conditioning compressor) to the thermal generation system (108). The heat generation system outlet (162) also may be a passive vent that allows air to circulate to and from the interior of the building formed, in part, by the wall assembly (100) and the space defined between the interior finish layer (120) and the radiant panel layer (106).

[0067] The wall assembly (100) may be provided with other commodities. For example, interior finishes including electrical distribution, outlets, and other commodities may be provided. In another example, the exterior layer (118) may be high performance glazing, shading and daylighting components (*e.g.*, windows may be disposed within the wall assembly (100)). A window may be disposed through the layers in order to permit light to pass from the exterior to the interior of the building formed, at least in part, by the wall assembly (100). The window may be composed of multiple layers of material to increase the thermal insulation properties of the window. Still other variations are possible.

[0068] For example, solar panels may be connected to the wall assembly (100), or may include electrical wiring connectable to power sources such as solar panels. When the electrical power source is solar panels, the thermal

generation system (108) may be powered by a grid of solar panels mounted via ground mounts, pole mounts, roof mounts, wall mounts, *etc.* Solar panels may be placed into glazing window spandrels. Additional features such as solar shutters and solar blinds may be provided, with solar energy generated being distributed to a hybrid inverter, transformed into usable electricity, and then stored in one or more batteries. When external electrical grids are unavailable or low of power, then the one or more batteries may provide energy to power the thermal generation system (108).

[0069] FIG. 2, FIG. 3, FIG. 4, FIG. 5, FIG. 6, FIG. 7, FIG. 8, and FIG. 9 show details of the wall assembly shown in FIG. 1, in accordance with one or more embodiments. Thus, FIG. 2 through FIG. 9 show different views of the wall assembly (100) or parts of the wall assembly (100) described with respect to FIG. 1. Thus, FIG. 1 through FIG. 9 share common reference numerals that refer to common objects or components described above with respect to FIG. 1.

[0070] FIG. 2 shows a side view of the wall assembly (100) shown in FIG. 1. In particular, the wall assembly (100) shown in FIG. 2 shows the side of the wall assembly (100) that includes the second end (124) of the second insulation layer (114).

[0071] The various layers are shown connected to each other. The layers include the interior finish layer (120), the radiant panel layer (106), the thermal generation system (108), the first insulation layer (110), the radiant barrier layer (112), the second insulation layer (114), the gas barrier layer (116), and the exterior layer (118). Other components are also visible, such as the clip (150), the exterior frame (152), the head frame (136), the first tube (140), the second tube (142), and the heat generation system outlet (162).

[0072] The interior side (200) and the exterior side (202) of the wall assembly (100) are shown for reference. The interior side (200) faces the interior of a building formed, at least in part, by the wall assembly (100). The exterior side (202) faces the exterior of a building form, at least in part, by the wall

assembly (100). However, if multiple wall sections are stacked in front of each other, it is possible that the exterior side (202) of one wall may face the interior side (200) of another wall. Nevertheless, so long as one layer is closer to the interior of the building, relative to another layer, then the one layer may be referred to as interior to the other layer. Similarly, so long as one layer is closer to the exterior of the building relative to another layer then the one layer may be referred to as exterior to the other layer.

[0073] The wall assembly (100) is also marked by sections, used for reference to FIG. 2 through FIG. 7. Thus, for example, section A-A (204) (FIG. 3), section C (206) (FIG. 5), section D (208) (FIG. 6), and section E (210) (FIG. 7) are shown for reference. For additional reference, the detail of section B (300) in FIG. 3 is shown in FIG. 4.

[0074] Attention is now turned to FIG. 3. FIG. 3 shows the detail of section A-A (204) in FIG. 3. The section A-A (204) shows the wall assembly (100), as seen from above, relative to the vertical axis (138). Again, various parts of the wall assembly (100) are shown for reference, including the interior finish layer (120), the radiant panel layer (106), the thermal generation system (108), the first insulation layer (110), the radiant barrier layer (112), the second insulation layer (114), the gas barrier layer (116), the exterior layer (118), the first tube (140), the second tube (142), the clip (150), the exterior frame (152), and the heat generation system outlet (162). In addition, the thermal generation chamber (302) (an empty space) is more clearly visible in FIG. 3. Radiant transmission of heat energy is shown by arrows, such as arrows (304).

[0075] However, in a variation to the embodiments shown in FIG. 1, a ventilated cavity (306) is shown disposed between the gas barrier layer (116) and the exterior layer (118), established by a separation between the exterior layer (118) and the gas barrier layer (116). The latter separation may be established by an extension extending in an exterior direction from the exterior frame (152).

[0076] FIG. 4 shows the details of the wall assembly (100) as indicated by the section B (300) shown in FIG. 3. Various layers of the wall assembly (100) are more easily visible in the section B (300) detail shown in FIG. 4. Thus, for example, the radiant panel layer (106), the thermal generation system (108), the first insulation layer (110), the radiant barrier layer (112), the second insulation layer (114), the gas barrier layer (116), the exterior layer (118), the interior finish layer (120), and the exterior frame (152) are shown for reference. Also shown for reference are the tongue (128) extending from the first insulation layer (110), as well as one of the clips (*i.e.*, clip (400)). Also shown for reference are the third tube (143) and a fourth tube (402). The fourth tube (402) is disposed opposite the first tube (140), relative to the axis (126) shown in FIG. 1.

[0077] FIG. 5 shows the details of the wall assembly (100) as indicated by the section C (206) shown in FIG. 2. Again, the interior finish layer (120), the radiant panel layer (106), the thermal generation system (108), the first insulation layer (110), the radiant barrier layer (112), the second insulation layer (114), the gas barrier layer (116), the exterior layer (118), the first tube (140), the second tube (142), the bottom frame (144), the clip (150), the exterior frame (152), the flashing (158), and the heat generation system outlet (162) are shown for reference. Various instances of cork stripping (132) show that cork stripping (or other insulative stripping) may be disposed around or under various components to serve as a thermal break between the above-described layers of the wall assembly (100).

[0078] FIG. 6 shows the details of the section D (208) shown in FIG. 2. Again, the interior finish layer (120), the radiant panel layer (106), the thermal generation system (108), the first insulation layer (110), the radiant barrier layer (112), the second insulation layer (114), the gas barrier layer (116), the exterior layer (118), the first tube (140), the second tube (142), the exterior frame (152), and flashing (158) are shown for reference. Various instances of cork stripping (132) show that cork stripping (or other insulative stripping)

may be disposed around or under various components to serve as a thermal break between the above-described layers of the wall assembly (100).

[0079] FIG. 7 shows the details of the section E (210) shown in FIG. 2. The first insulation layer (110), radiant barrier layer (112), second insulation layer (114), and the gas barrier layer (116) are shown for reference. FIG. 7 also shows that an insulation frame (700) disposed around the outside of the second insulation layer (114) may be used to hold the second insulation layer (114) in place. In the example of FIG. 7, the insulation frame (700) may be strips of metal or other structural material to which the bottom frame (144) shown in FIG. 1 may be attached.

[0080] While FIG. 1 through FIG. 7 show configurations of components, other configurations may be used without departing from the scope of the one or more embodiments. For example, various components may be combined to create a single component. As another example, the functionality performed by a single component may be performed by two or more components.

[0081] FIG. 8 shows a manufacturing method, in accordance with one or more embodiments. The method of FIG. 8 may be a method of manufacturing a building using multiple wall assemblies, such as the wall assembly (100) shown in FIG. 1 through FIG. 7.

[0082] Step (800) includes manufacturing multiple wall segments. Each of the wall segments may be the wall assembly (100) shown in FIG. 1.

[0083] Thus, each of the wall segments may include a thermal chamber assembly. The thermal chamber assembly includes a radiant panel layer having a first range of thermal conductivity. The thermal chamber assembly also includes a thermal generation system connected to the radiant panel layer.

[0084] The thermal chamber assembly also includes a first insulation layer connected to the radiant panel layer opposite the thermal generation system. The first insulation layer has a second range of thermal conductivity below

the first range of thermal conductivity. The thermal chamber assembly also includes a first end and a second end opposite the first end, relative to a length of the first insulation layer. A tongue extends from the first end. A groove extends into the second end.

[0085] The thermal chamber assembly also includes a radiant barrier layer connected to the first insulation layer between the first insulation layer and the radiant panel layer. The radiant barrier layer has the first range of thermal conductivity.

[0086] Each of the wall segments also may include a ventilated cavity assembly connected to the thermal chamber assembly. The ventilated cavity assembly includes a second insulation layer connected to the first insulation layer opposite the radiant barrier layer. The second insulation layer has the second range of thermal conductivity.

[0087] The ventilated cavity assembly also includes a gas barrier layer connected to the second insulation layer opposite the first insulation layer. The gas barrier layer is connected a first distance from the second insulation layer to establish a first gas layer between the second insulation layer and the gas barrier layer.

[0088] The ventilated cavity assembly also includes an exterior layer connected to the gas barrier layer opposite the second insulation layer. The exterior layer is connected a second distance from the gas barrier layer to establish a second gas layer between the gas barrier layer and the exterior layer.

[0089] Step 802 includes transporting multiple wall segments to a construction site. The multiple wall segments may be manufactured at a manufacturing site and then transported via train, truck, *etc.*, to the construction site. Cranes, lifts, and other equipment may lift the multiple wall segments into an approximately final position before continuing the method.

[0090] Step 804 includes connecting the multiple wall segments by connecting the tongue of a first wall segment of the multiple wall segments to the groove

of a second wall segment of the multiple wall segments. The tongue fits within the groove to form a tight fit between the multiple wall segments. Caulk or other adhesives may be used to seal seams between the multiple wall segments. Other components may be added to the multiple wall segments or be used to reinforce the joining of the multiple wall segments.

[0091] FIG. 9 shows a method for thermal insulation, in accordance with one or more embodiments. The method of FIG. 9 may be implemented using one or more of the wall segments, such as the wall assembly (100) shown in FIG. 1 through FIG. 7.

[0092] Step (900) includes constructing a building including a wall. The wall may be the wall assembly (100) shown in FIG. 1. Thus, the wall may include a thermal chamber assembly. The thermal chamber assembly includes a radiant panel layer having a first range of thermal conductivity. The thermal chamber assembly also includes a thermal generation system connected to the radiant panel layer.

[0093] The thermal chamber assembly also includes a first insulation layer connected to the radiant panel layer opposite the thermal generation system. The first insulation layer has a second range of thermal conductivity below the first range of thermal conductivity. The thermal chamber assembly also includes a first end and a second end opposite the first end relative to a length of the first insulation layer. A tongue extends from the first end. A groove extends into the second end.

[0094] The thermal chamber assembly also includes a radiant barrier layer connected to the first insulation layer between the first insulation layer and the radiant panel layer. The radiant barrier layer has the first range of thermal conductivity.

[0095] The wall also may include a ventilated cavity assembly connected to the thermal chamber assembly. The ventilated cavity assembly includes a second insulation layer connected to the first insulation layer opposite the radiant

barrier layer. The second insulation layer has the second range of thermal conductivity.

- [0096] The ventilated cavity assembly also includes a gas barrier layer connected to the second insulation layer opposite the first insulation layer. The gas barrier layer is connected a first distance from the second insulation layer to establish a first gas layer between the second insulation layer and the gas barrier layer.
- [0097] The ventilated cavity assembly also includes an exterior layer connected to the gas barrier layer opposite the second insulation layer. The exterior layer is connected a second distance from the gas barrier layer to establish a second gas layer between the gas barrier layer and the exterior layer.
- [0098] Step 902 includes generating heat or cooling with the thermal generation system and directing the heat or cooling towards the radiant panel layer. For example, heated or chilled liquid may be pumped through pipes of the thermal generation system. The heated or chilled liquid effect heat transfer towards the radiant panel layer. In another example, heated or chilled gas (*e.g.*, air) may be pumped into the interstitial spaces between the interior finish layer and the radiant panel layer (or into other interstitial spaces located in the thermal generation chamber assembly of the wall assembly). The heated or chilled gas effects heat transfer towards the radiant panel layer.
- [0099] In still another example, electrical elements may compose part or all of the thermal generation system. In this case, electricity may be generated and transferred into the electrical elements. In response, the electrical elements generate heat. The heat, from the electrical elements, effects heat transfer toward the radiant panel layer.
- [00100] The thermal generation system also may operate according to different physical principles. For example, an inductive heating system may be used to heat liquid stored in pipes in the thermal generation system. As a result, the liquid warms the pipes. Heat, emanating from the pipes, effects heat transfer

toward the radiant panel layer. Other methods of heat transfer are also possible, depending on the type of thermal generation system used.

[00101] While the various steps in the flowcharts of FIG. 8 and FIG. 9 are presented and described sequentially, at least some of the steps may be executed in different orders, may be combined or omitted, and some of the steps may be performed in parallel.

[00102] The term “about,” when used with respect to a physical property that may be measured, refers to an engineering tolerance anticipated or determined by an engineer or manufacturing technician of ordinary skill in the art. The exact quantified degree of an engineering tolerance depends on the product being produced and the technical property being measured. For example, two angles may be “about congruent” if the values of the two angles are within a first predetermined range of angles for one embodiment, but also may be “about congruent” if the values of the two angles are within a second predetermined range of angles for another embodiment. The ordinary artisan is capable of assessing what is an acceptable engineering tolerance for a particular product, and thus is capable of assessing how to determine the variance of measurement contemplated by the term “about.”

[00103] As used herein, the term “connected to” contemplates at least two meanings, unless stated otherwise. In a first meaning, “connected to” means that component A was, at least at some point, separate from component B, but then was later joined to component B in either a fixed or a removably attached arrangement. In a second meaning, “connected to” means that component A could have been integrally formed with component B. Thus, for example, a bottom of a pan is “connected to” a wall of the pan. The term “connected to” may be interpreted as the bottom and the wall being separate components that are snapped together, welded, or are otherwise fixedly or removably attached to each other. However, the bottom and the wall may be deemed “connected” when formed contiguously together as a monocoque body.

[00104] In addition, the term “directly connected to” means that component A and component B are connected immediately adjacent to each other. For example, component A and component B may share a common point of contact in at least one area of both components. However, the common point of contact may be a connector (*e.g.*, a bolt, a screw, *etc.*), in which case it is possible that component A is “directly connected to” component B without a direct contact between the surfaces of component A and component B. However, in any case, if component A and component B are “directly connected to” each other, then no intervening parts, other than possibly a connector, exist between component A and component B.

[00105] The figures show diagrams of embodiments that are in accordance with the disclosure. The embodiments of the figures may be combined and may include or be included within the features and embodiments described in the other figures of the application. The features and elements of the figures are, individually and as a combination, improvements to the technology of constructing walls. The various elements, systems, components, and steps shown in the figures may be omitted, repeated, combined, and/or altered as shown from the figures. Accordingly, the scope of the present disclosure should not be considered limited to the specific arrangements shown in the figures.

[00106] In the application, ordinal numbers (*e.g.*, first, second, third, *etc.*) may be used as an adjective for an element (*i.e.*, any noun in the application). The use of ordinal numbers is not to imply or create any particular ordering of the elements nor to limit any element to being a single element unless expressly disclosed, such as by the use of the terms “before”, “after”, “single”, and other such terminology. Rather, the use of ordinal numbers is to distinguish between the elements. By way of an example, a first element is distinct from a second element, and the first element may encompass more than one element and succeed (or precede) the second element in an ordering of elements.

[00107] Further, unless expressly stated otherwise, the word “or” is an “inclusive or” and, as such includes “and.” Further, items joined by an or may include any combination of the items with any number of each item unless expressly stated otherwise.

[00108] In the above description, numerous specific details are set forth in order to provide a more thorough understanding of the one or more embodiments. However, it will be apparent to one of ordinary skill in the art that the one or more embodiments may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the description. Further, other embodiments not explicitly described above can be devised which do not depart from the scope of the one or more embodiments as disclosed herein. Accordingly, the scope of the one or more embodiments should be limited by the attached claims.

CLAIMS

What is claimed is:

1. A wall comprising:

a thermal chamber assembly comprising:

a radiant panel layer comprising a first range of thermal conductivity,
a thermal generation system connected to the radiant panel layer,
a first insulation layer connected to the radiant panel layer opposite the
thermal generation system and comprising a second range of
thermal conductivity below the first range of thermal
conductivity, and

a radiant barrier layer connected to the first insulation layer between the
first insulation layer and the radiant panel layer, the radiant
barrier layer comprising the first range of thermal conductivity;
and

a ventilated cavity assembly connected to the thermal chamber assembly and
comprising:

a second insulation layer connected to the first insulation layer opposite
the radiant barrier layer, the second insulation layer comprising
the second range of thermal conductivity,

a gas barrier layer connected to the second insulation layer opposite the
radiant barrier layer, wherein the gas barrier layer is connected a
first distance from the second insulation layer to establish a first
gas layer between the second insulation layer and the gas barrier
layer, and

an exterior layer connected to the gas barrier layer opposite the second
insulation layer, wherein the exterior layer is connected a second
distance from the gas barrier layer to establish a second gas layer
between the gas barrier layer and the exterior layer.

2. The wall of claim 1, further comprising:
an interior finish wall layer connected to the radiant panel layer and facing an interior of a building, wherein the thermal generation system is between the interior finish wall layer and the radiant panel layer.
3. The wall of claim 1 or claim 2, wherein the radiant panel layer comprises corrugated aluminum.
4. The wall of any one of claims 1 to 3, wherein the first range of thermal conductivity comprises a thermal conductor and the second range of thermal conductivity comprises a thermal insulator.
5. The wall of any one of claims 1 to 4, wherein the first insulation layer comprises:
a first end and a second end opposite the first end relative to a length of the first insulation layer,
a tongue extending from the first end, and
a groove extending into the second end.
6. The wall of any one of claims 1 to 5, wherein the thermal generation system comprises a liquid heating system.
7. The wall of any one of claims 1 to 6, wherein the thermal generation system comprises an electrical heating system.
8. The wall of any one of claims 1 to 6, wherein the thermal generation system comprises an air conditioning system.
9. The wall of any one of claims 1 to 8, further comprising:
cork stripping disposed around a perimeter of the first insulation layer between the first insulation layer and the second insulation layer.
10. The wall of any one of claims 1 to 9, further comprising:
a head frame extending from the second insulation layer.

11. The wall of any one of claims 1 to 10, further comprising:
 - a first tube connected to the second insulation layer and disposed into the second insulation layer.
12. The wall of claim 11, wherein the first tube is disposed along a height of the second insulation layer, relative to a direction of gravity.
13. The wall of claim 12, further comprising:
 - a second tube connected to the second insulation layer and disposed into the second insulation layer, wherein the second tube is disposed opposite the first tube and is disposed along the height of the second insulation layer.
14. The wall of any one of claims 1 to 13, further comprising:
 - a bottom frame disposed around the second insulation layer, wherein the bottom frame is disposed at a bottom of the second insulation layer relative to a direction of gravity.
15. The wall of any one of claims 1 to 14, further comprising:
 - a shim connected to the second insulation layer and the gas barrier layer, wherein the shim establishes the first distance.
16. The wall of any one of claims 1 to 15, further comprising:
 - a plurality of clips connecting the gas barrier layer to an exterior frame, wherein the exterior layer is connected to the exterior frame; and wherein the plurality of clips establishes the second distance.
17. The wall of claim 16, further comprising:
 - a first set of insulation blocks disposed between at least some of the plurality of clips, the gas barrier layer, and the exterior layer.

18. The wall of claim 17, further comprising:

a second set of insulation blocks disposed between the second insulation layer and the gas barrier layer.

19. A manufacturing method comprising:

manufacturing a plurality of wall segments, wherein each of the plurality of wall segments comprises:

a thermal chamber assembly comprising:

a radiant panel layer comprising a first range of thermal conductivity,

a thermal generation system connected to the radiant panel layer,

a first insulation layer connected to the radiant panel layer opposite the thermal generation system and comprising:

a second range of thermal conductivity below the first range of thermal conductivity,

a first end and a second end opposite the first end relative to a length of the first insulation layer,

a tongue extending from the first end, and

a groove extending into the second end, and

a radiant barrier layer connected to the first insulation layer between the first insulation layer and the radiant panel layer, the radiant barrier layer comprising the first range of thermal conductivity; and

a ventilated cavity assembly connected to the thermal chamber assembly and comprising:

a second insulation layer connected to the first insulation layer opposite the radiant barrier layer, the second insulation layer comprising the second range of thermal conductivity,

a gas barrier layer connected to the second insulation layer opposite the first insulation layer, wherein the gas barrier layer is connected a first distance from the second insulation layer to establish a first gas layer between the second insulation layer and the gas barrier layer, and an exterior layer connected to the gas barrier layer opposite the second insulation layer, wherein the exterior layer is connected a second distance from the gas barrier layer to establish a second gas layer between the gas barrier layer and the exterior layer;

transporting the plurality of wall segments to a construction site; and connecting plurality of wall segments by connecting the tongue of a first wall segment of the plurality of wall segments to the groove of a second wall segment of the plurality of wall segments.

20. A method of thermal insulation comprising:

constructing a building comprising a wall, wherein the wall comprises:

a thermal chamber assembly comprising:

a radiant panel layer comprising a first range of thermal conductivity,

a thermal generation system connected to the radiant panel layer,

a first insulation layer connected to the radiant panel layer opposite the thermal generation system and comprising:

a second range of thermal conductivity below the first range of thermal conductivity,

a first end and a second end opposite the first end relative to a length of the first insulation layer,

a tongue extending from the first end, and

a groove extending into the second end, and

a radiant barrier layer connected to the first insulation layer
between the first insulation layer and the radiant panel
layer, the radiant barrier layer comprising the first range of
thermal conductivity; and

a ventilated cavity assembly connected to the thermal chamber assembly
and comprising:

a second insulation layer connected to the first insulation layer
opposite the radiant barrier layer, the second insulation
layer comprising the second range of thermal conductivity,

a gas barrier layer connected to the second insulation layer
opposite the first insulation layer, wherein the gas barrier
layer is connected a first distance from the second
insulation layer to establish a first gas layer between the
second insulation layer and the gas barrier layer, and

an exterior layer connected to the gas barrier layer opposite the
second insulation layer, wherein the exterior layer is
connected a second distance from the gas barrier layer to
establish a second gas layer between the gas barrier layer
and the exterior layer; and

generating heat or cooling with the thermal generation system and directing the
heat or cooling towards the radiant panel layer.