



(86) Date de dépôt PCT/PCT Filing Date: 2012/06/15  
 (87) Date publication PCT/PCT Publication Date: 2012/12/20  
 (45) Date de délivrance/Issue Date: 2021/08/24  
 (85) Entrée phase nationale/National Entry: 2013/12/16  
 (86) N° demande PCT/PCT Application No.: US 2012/042667  
 (87) N° publication PCT/PCT Publication No.: 2012/174377  
 (30) Priorité/Priority: 2011/06/17 (US61/498,090)

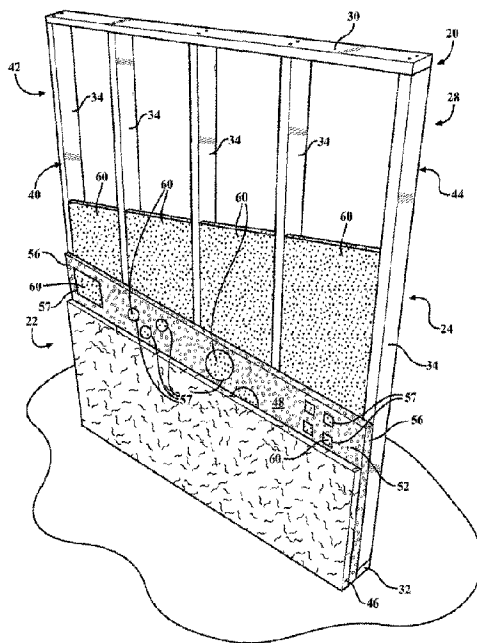
(51) Cl.Int./Int.Cl. *E04B 2/56* (2006.01),  
*E04B 2/00* (2006.01)

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 (54) Title: HIGH PERFORMANCE WALL ASSEMBLY



(57) **Abrégé/Abstract:**

A high performance wall assembly receives an exterior covering of a building. The high performance wall assembly includes a frame assembly having a top member, a bottom member opposite the top member, and a plurality of vertical members. The vertical members are coupled to and extend between the top and bottom members. The high performance wall assembly also includes a rigid foam insulating panel coupled to the frame assembly. A structural foam layer is disposed on the plurality of vertical members and on the rigid foam insulating panel. The structural foam layer couples the rigid foam insulating panel to the frame assembly and couples the plurality of vertical members to the top and bottom members such that the high performance wall is free of fasteners.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property  
Organization  
International Bureau(43) International Publication Date  
20 December 2012 (20.12.2012)(10) International Publication Number  
**WO 2012/174377 A1**

- (51) International Patent Classification:  
*E04B 2/56* (2006.01)
- (21) International Application Number:  
PCT/US2012/042667
- (22) International Filing Date:  
15 June 2012 (15.06.2012)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
61/498,090 17 June 2011 (17.06.2011) US
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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(54) Title: HIGH PERFORMANCE WALL ASSEMBLY

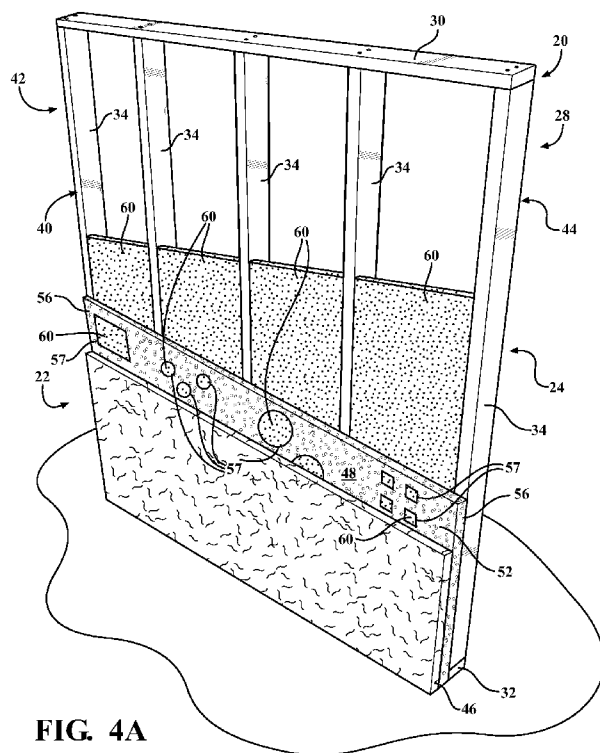


FIG. 4A

(57) Abstract: A high performance wall assembly receives an exterior covering of a building. The high performance wall assembly includes a frame assembly having a top member, a bottom member opposite the top member, and a plurality of vertical members. The vertical members are coupled to and extend between the top and bottom members. The high performance wall assembly also includes a rigid foam insulating panel coupled to the frame assembly. A structural foam layer is disposed on the plurality of vertical members and on the rigid foam insulating panel. The structural foam layer couples the rigid foam insulating panel to the frame assembly and couples the plurality of vertical members to the top and bottom members such that the high performance wall is free of fasteners.

**WO 2012/174377 A1** 

- (84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Declarations under Rule 4.17:**
- *of inventorship (Rule 4.17(iv))*
- Published:**
- *with international search report (Art. 21(3))*
  - *with amended claims and statement (Art. 19(1))*

## HIGH PERFORMANCE WALL ASSEMBLY

### CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and all the advantages of U.S. Provisional Patent Application No. 61/498,090 filed on June 17, 2011, which is incorporated by reference.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

[0002] The invention generally relates to a high performance wall assembly. More specifically, the invention relates to a high performance wall assembly having a structural foam layer.

#### 2. Description of the Related Art

[0003] Wall assemblies for use as walls of a building, such as residential buildings, or commercial buildings, are known in the art. A conventional wall includes a frame assembly. The frame assembly includes a top member, a bottom member spaced from the top member, and a plurality of vertical members disposed between the top and bottom members. Typically, the top, bottom, and vertical members of the frame assembly comprise wood. The top, bottom, and vertical members of the frame assembly are coupled together using fasteners, such as nails or screws.

[0004] The conventional wall assembly also includes an insulating layer coupled to the frame assembly. Typically, the insulating layer comprises preformed panels made from polystyrene. The insulating layer is coupled to the frame assembly by using the fasteners. The use of the fasteners to couple together the vertical members, the top member and the bottom member and to couple together the

insulating layer and the frame member increases a cost to manufacture the conventional wall assembly. The use of fasteners also increase a manufacturing time to construct the conventional wall assembly. Therefore, there remains a need to provide an improved high performance wall assembly.

#### SUMMARY OF THE INVENTION AND ADVANTAGES

[0005] A high performance wall assembly receives an exterior covering of a building. The high performance wall assembly includes a frame assembly. The frame assembly has a top member, a bottom member opposite said top member, and a plurality of vertical members. The vertical members are couple to and extend between the top and bottom members. The frame assembly has an interior side and an exterior side opposite the interior side. The high performance wall assembly also includes a rigid foam insulating panel coupled to the frame assembly and extending from the exterior side of the frame assembly. The rigid foam insulating panel terminates at an exterior surface of the rigid foam insulating panel. The exterior surface of the rigid foam insulating panel is configured to receive the exterior covering of the building.

[0005a] There is provided a high performance wall assembly comprising:  
an exterior covering being at least one of a siding panel, brick, and insulating foam panel;  
a frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members with said frame assembly having an interior side and an exterior side opposite said interior side;  
a rigid foam insulating panel comprising a closed-cell foam having a plurality of

particles of pre-expanded polymers and a binder, said rigid foam insulating panel being disposed adjacent to said exterior side of said frame assembly and extending from said exterior side of said frame assembly and terminating at an exterior surface of said rigid foam insulating panel, with said exterior surface of said rigid foam insulating panel receiving said exterior covering and spacing said exterior covering from said exterior side of said frame assembly;

a structural foam layer disposed between and adhered to said plurality of vertical members and adhered to an interior surface of said rigid foam insulating panel between said plurality of vertical members such that said plurality of vertical members are not encapsulated in said structural foam layer, said structural foam layer being selected from the group of polyurethane foams, polyurea foams, and combinations thereof; and

wherein said structural foam layer adheres said rigid foam insulating panel to said frame assembly such that said rigid foam insulating panel is free of fasteners.

[0006] The high performance wall assembly further includes a structural foam layer adhered to the plurality of vertical members and adhered to the rigid foam insulating panel between said plurality of vertical members. The structural foam layer adheres the rigid foam insulating panel to the frame assembly. The structural foam layer also adheres the plurality of vertical members to the top and bottom members such that the high performance wall is free of fasteners. Eliminating the need for fasteners allows the high performance wall assembly to be constructed fasted and at a reduced cost as compared to conventional wall assemblies.

[0007] Additionally, methods of manufacturing the high performance wall assembly are disclosed.

[0007a] Additionally, there is provided a method of manufacturing the

high performance wall assembly as defined herein for receiving an exterior covering of a building, with said high performance wall assembly comprising a frame assembly, a rigid foam insulating panel comprising a plurality of particles and a binder, and a structural foam layer coupling the rigid foam insulating panel to the frame assembly and coupling the plurality of vertical members to the top and bottom members such that the high performance wall is free of fasteners, said method comprising the steps of:

providing the frame assembly with a plurality of vertical members coupled between a top member and a bottom member;

positioning the rigid foam insulating panel adjacent the frame assembly;

applying the structural foam layer to the frame assembly and the rigid foam insulating panel between the plurality of vertical members;

curing the structural foam layer to couple the frame assembly together and to couple the rigid foam insulating panel to the frame assembly to form the high performance wall assembly such that the high performance wall assembly is free of fasteners.

**[0007b]** Additionally, there is provided a method of manufacturing the high performance wall assembly as defined in herein, comprising the steps of:

providing the exterior covering;

providing the frame assembly;

positioning the rigid foam insulating panel adjacent the exterior side of the frame assembly and in contact with the plurality of vertical members of said frame assembly,

applying the structural foam layer to the frame assembly and the rigid foam insulating panel between the plurality of vertical members such that the plurality of vertical members are not encapsulated in the structural foam layer; and

curing the structural foam layer to couple the frame assembly together and to couple the rigid foam insulating panel to the frame assembly to form the high performance wall assembly such that the high performance wall assembly is free of fasteners.

[0007c] Additionally, there is provided a wall assembly comprising:

a frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members with said frame assembly having an interior side and an exterior side opposite said interior side, wherein said top member, said bottom member, and said vertical members are made of wood;

a rigid foam insulating panel coupled to said exterior side of said frame assembly and contacting said plurality of vertical members and extending from said exterior side of said frame assembly and terminating at an exterior surface of said rigid foam insulating panel;

a structural foam layer disposed between and adhered to said plurality of vertical members and adhered to an interior surface of said rigid foam insulating panel between said plurality of vertical members such that said plurality of vertical members are not encapsulated in said structural foam layer;

wherein said rigid foam insulating panel comprising a plurality of pre-expanded polymeric beads having multiple bead sizes and a binder, wherein said pre-expanded polymeric beads are selected from the group of polystyrene, styrene based-copolymers, polyethylene, polypropylene, polyesters, polyvinylchloride, cellulose acetate, and combinations thereof, wherein said binder is a polymer selected from the group of acrylic-based polymers or copolymers, styrene-acrylic-based copolymers, styrenebutadiene-based copolymers, vinyl acrylic-based copolymers, vinyl acetate based polymers or copolymers, polyvinylidene chloride, neoprene, natural rubber



latex, and combinations thereof for binding the particles together, wherein said rigid foam insulating panel has a thickness of from about 0.5 to about 12 inches and a density of from about 0.5 to about 5.00 pounds per cubic foot; wherein said frame assembly has a first end and a second end spaced from said first end defining a length of the wall assembly; an exterior covering disposed directly adjacent said exterior surface of said outer foam layer, said exterior covering being at least one of a siding panel, brick, and insulating foam panel; and wherein said structural foam layer adheres said rigid foam insulating panel to said frame assembly such that said rigid foam insulating panel is free of fasteners.

**[0007d]** Additionally, there is provided a wall assembly comprising:

a frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members with said frame assembly having an interior side and an exterior side opposite said interior side, wherein said top member, said bottom member, and said vertical members are made of wood;

a rigid foam insulating panel disposed adjacent to said exterior side of said frame assembly and extending from said exterior side of said frame assembly and terminating at an exterior surface of said rigid foam insulating panel;

a structural foam layer disposed between and adhered to said plurality of vertical members and adhered to an interior surface of said rigid foam insulating panel between said plurality of vertical members such that said plurality of vertical members are not encapsulated in said structural foam layer;

wherein said rigid foam insulating panel comprising a plurality of pre-expanded polymeric beads having multiple bead sizes and a binder, wherein said pre-expanded

polymeric beads are selected from the group of polystyrene, styrene-based copolymers, polyethylene, polypropylene, polyesters, polyvinylchloride, cellulose acetate, and combinations thereof, wherein said binder is a polymer selected from the group of acrylic-based polymers or copolymers, styrene-acrylic-based copolymers, styrenebutadiene-based copolymers, vinyl acrylic-based copolymers, vinyl acetate based polymers or copolymers, polyvinylidene chloride, neoprene, natural rubber latex, and combinations thereof for binding the particles together, wherein said rigid foam insulating panel has a thickness of from about 0.5 to about 12 inches and a density of from about 0.5 to about 5.0 pounds per cubic foot;

an intermediate substrate disposed between said rigid foam insulating panel and said frame assembly with said rigid foam insulating panel bonded to said intermediate substrate and said intermediate substrate bonded to said structural foam layer for coupling to said frame assembly, wherein said intermediate substrate has a thickness of from about 0.125 to about 1.00 inches;

wherein said frame assembly has a first end and a second end spaced from said first end defining a length of the wall assembly;

an exterior covering disposed directly adjacent said exterior surface of said rigid foam insulating panel, said exterior covering being at least one of a siding panel, brick, and insulating foam panel; and

wherein said structural foam layer adheres said rigid foam insulating panel to said frame assembly such that said rigid foam insulating panel is free of fasteners.

[0007e] Additionally, there is provided a high performance wall assembly for receiving an exterior covering of a building, said high performance wall assembly comprising a frame assembly, a rigid foam layer having particles and a binder, a structural polymeric foam layer wherein the thermal resistance of the wall assembly

has a R-value per inch of thickness of from about 10 to about 53;

the frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members;

the rigid foam insulating panel coupled to said frame assembly with an exterior surface of said rigid foam insulating panel configured to receive the exterior covering of the building, the rigid foam insulating panel comprising a plurality of particles and a binder, the particles comprising greater than 80 percent by volume of the rigid foam insulating panel; and

a structural foam layer disposed on said plurality of vertical members and on said rigid foam insulating panel between said plurality of vertical members, the structural foam layer comprising a foam selected from the group of polyurethane foams, polyurea foams, and combinations thereof; and

wherein said structural foam layer couples said rigid foam insulating panel to said frame assembly such that said rigid foam insulating layer is free of fasteners.

[0007f] Additionally, there is provided a method of manufacturing the high performance wall assembly as defined herein, said method comprising the steps of:

providing the frame assembly;

positioning the rigid foam insulating panel adjacent the frame assembly;

applying the structural foam layer to the frame assembly and the rigid foam insulating panel between the plurality of vertical members;

curing the structural foam layer to couple the rigid foam insulating panel to the frame assembly to form the high performance wall assembly such that the high performance wall assembly is free of fasteners.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings wherein:

[0009] Figure 1 is a perspective view of an exterior face of a high performance wall assembly having a frame assembly and an rigid foam insulating panel;

[0010] Figure 2 is a perspective view of an interior face of the high performance wall assembly having a frame assembly and an rigid foam insulating panel;

[0011] Figure 3 is a partial cutaway perspective view of the exterior face of the high performance wall assembly having an exterior covering coupled to the frame assembly;

[0012] Figure 4 is a perspective view of an exterior face of the high performance wall assembly with the rigid foam insulating panel coupled to an intermediate substrate;

[0013] Figure 4A is a partial cutaway perspective view of the high performance wall assembly of Figure 4;

[0014] Figure 5 is a cross-sectional view of the high performance wall assembly taken along line 5-5 of Figure 1;

[0015] Figure 6 is a cross-sectional view of the high performance wall assembly taken along line 6-6 of Figure 4;

[0016] Figure 7 is a perspective view of the exterior face of two prefabricated wall assemblies joined together;

[0017] Figure 8 is a top view of a portion of the prefabricated wall assemblies of Figure 8; and

[0018] Figure 9 is a view of the interior face of high performance wall assembly having an opening for receiving a window frame.

#### DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENT

[0019] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a high performance wall assembly is generally shown at 20. The high performance wall assembly 20 is for constructing a building, such as a residential building or a commercial building. For example, the high performance wall assembly 20 is at least one of a plurality of exterior walls of the building. It is to be appreciated that the high performance wall assembly 20 may only be one of the plurality of exterior walls of the building or the high performance wall assembly 20 may be all of the plurality of exterior walls of the building. Said differently, the high performance wall assembly 20 may be used to construct a single exterior wall of the building.

[0020] Alternatively, multiple high performance wall assemblies may be used to construct the exterior walls of building. Said differently, the high performance wall assembly 20 may be coupled to another high performance wall assembly 20 to define a perimeter of the building. Additionally, the high performance wall assembly 20 may be coupled to a traditional field constructed wall to define the perimeter of the building. It is to be appreciated that the high performance wall assembly 20 may be coupled to the traditional field constructed wall or the another high performance wall assembly 20 by any suitable methods. For example, fasteners, such as nails or screws,

an adhesive bead, or straps could be used to couple together the adjacent high performance wall assemblies 20.

[0021] Generally, the high performance wall assembly 20 has an exterior face 22, which faces an exterior of the building when the high performance wall assembly 20 is the wall of the building. Additionally, the high performance wall assembly 20 has an interior face 24, which faces an interior of the building when the high performance wall assembly 20 is the wall of the building. The high performance wall assembly 20 can be manufactured in any length L or height H desired for use as the exterior walls of the building. Additionally, the high performance wall assembly 20 may be used completely above grade or extend below grade such that a portion of the high performance wall assembly 20 is embedded within the ground. Furthermore, the high performance wall assembly 20 can be used as interior walls of the building.

[0022] It is to be appreciated that the high performance wall assembly 20 may be manufactured off-site from the location of the building. Said differently, the high performance wall assembly 20 may be manufactured at a location that is different from the location that the building is to be constructed. For example, the high performance wall assembly 20 can be manufactured at a factory or a warehouse and subsequently transported to the location that the building is to be constructed. Manufacturing the high performance wall assembly 20 off-site decreases labor cost for constructing the building and decreases construction time required to construct the building once the high performance wall assembly 20 is on-site.

[0023] Once the high performance wall assembly 20 is delivered on-site, the high performance wall assembly 20 is secured in position on a support structure of the building, such as a footer, foundation wall, or another high performance wall assembly 20. It is to be appreciated that the high performance wall assembly 20 may

be positioned with the assistance of machinery, such as a crane. Alternatively, the high performance wall assembly 20 may be manufactured on-site at the location where the building is to be constructed. However, it is to be appreciated that the high performance wall assembly 20 may receive the exterior covering 26 prior to arriving on-site, i.e., in the factor or the warehouse.

[0024] Typically, once the high performance wall assembly 20 is secured in position, the high performance wall assembly 20 receives an exterior covering 26 of the building, such as siding, brick, and/or an insulating foam panel. The exterior covering 26 may be secured to the high performance wall assembly 20 by exterior fasteners 27, such as nails, screws, or ties. For example, when the exterior covering 26 is brick, the high performance wall assembly 20 may include brick ties as the exterior fasteners 27. Alternatively, the exterior covering 26 may be secured to the high performance wall assembly 20 by an adhesive. For example, when the exterior covering 26 is siding, panels of the siding may be adhesively bonded to the high performance wall assembly 20.

[0025] With reference to Figures 1-3, the high performance wall assembly 20 comprises a frame assembly 28. The frame assembly 28 includes a top member 30 and a bottom member 32 spaced from the top member 30. The frame assembly 28 also includes a plurality of vertical members 34 coupled to and extending between the top and bottom members 30, 32. Although not required, the top, bottom, and vertical members 30, 32, 34 may be coupled together using fasteners 36, such as nails and/or screws. Generally, the top and bottom members 30, 32 are horizontal and the vertical members 34 are perpendicular to the top and bottom members 30, 32. However, it is to be appreciated that the top and bottom members 30, 32 may be vertical with the

vertical members 34 extending horizontally between the top and bottom members 30, 32.

[0026] The top, bottom, and vertical members 30, 32, 34 of the frame assembly 28 present an interior side 38 of the frame assembly 28 and an exterior side 40 of the frame assembly 28 opposite the interior side 38. Generally, when the high performance wall assembly 20 is secured in position on the support structure of the building, the interior side 38 of the frame assembly 28 faces an interior of the building and the exterior side 40 of the frame assembly 28 faces an exterior of the building. Typically, the bottom member 32 is secured in position on the support structure of the building.

[0027] Typically, the top, bottom, and vertical members 30, 32, 34 comprise wood. However, it is to be appreciated that the top, bottom, and vertical members 30, 32, 34 may comprise any suitable material, such as fiberglass, aluminum, or other metals. The top, bottom, and vertical members 30, 32, 34 may be of any desired dimensions. For example, the top, bottom, and vertical members 30, 32, 34 may have a nominal cross-section of 2 inches by 4 inches or a nominal cross-section of 2 inches by 6 inches. It is to be appreciated that the top, bottom, and vertical members 30, 32, 34 may be of different dimensions relative to each other. For example, the top and bottom members 30, 32 may have the nominal cross-section of 2 inches by 6 inches and the vertical members 34 may have the nominal cross-section of 2 inches by 4 inches.

[0028] As best illustrated in Figure 1, the vertical members 34 along with the top and bottom members 30, 32 define the height H of the high performance wall assembly 20. Typically, the height H of the high performance wall assembly 20 is of from about 2 to about 24, more typically of from about 6 to about 12, and even more



typically of from about 8 to about 12 feet. With reference to Figures 5 and 6, a nominal width W of the frame assembly 28 is defined by a width of the top, bottom, and vertical members 30, 32, 34. Typically, the nominal width W of the frame assembly 28 is of from about 1 to about 8, more typically of from about 2 to about 8, and even more typically of from about 4 to about 6 inches.

[0029] With reference to Figures 1 and 2, the frame assembly 28 has a first end 42 and a second end 44 spaced from the first end 42. Typically, one of the vertical members 34 is disposed at the first end 42 of the frame assembly 28 and another one of the vertical members 34 is disposed at the second end 44 of the frame assembly 28 with other vertical members 34 equally spaced between the first and second ends 42, 44 of the frame assembly 28. The length L of the high performance wall assembly 20 is defined between the first and second ends 42, 44 of the frame assembly 28. Additionally, the top and bottom members 30, 32 are generally equal to the length L of the high performance wall assembly 20. Typically, the length L of the high performance wall assembly 20 is of from about 1 to about 52, more typically of from about 5 to about 25, and even more typically of from about 12 to about 16 feet.

[0030] The length L of the high performance wall assembly 20 may vary depending on specific needs of a customer. For example, the length L of the high performance wall assembly 20 may be equal to a length of the exterior wall of the building in which the high performance wall assembly 20 is to be used. Alternatively, the length L of the high performance wall assembly 20 may be shorter than the exterior wall of the building in which the high performance wall assembly 20 is to be used such that multiple prefabricated wall assemblies are joined together, as shown in Figures 7 and 8, to form a unitary wall of the building.

[0031] With reference to Figures 5 and 6, the vertical members 34 are

typically spaced apart from each other a distance DS. A plurality of voids are defined between the vertical members 34. Said differently, the plurality of voids are between the vertical members 34. Typically, the distance DS is measured from a centerline of one of the vertical members 34 to a centerline of another one of the vertical members 34. As alluded to above, the vertical members 34 are typically equally spaced apart throughout the frame assembly 28. However, it is to be appreciated that the distance DS between adjacent vertical members 34 may vary throughout the frame assembly 28. For example, as shown in Figure 9, the distance DS between the vertical members 34 may vary for defining an opening in the frame assembly 28 to receive a window frame. It is to be appreciated that the distance DS between the vertical members 34 may vary for defining other openings in the frame assembly 28 to receive other desired structures, such as door frames. The distance DS between adjacent vertical members 34 is typically of from about 1 to about 30, more typically of from about 10 to about 30 even more typically of from about 12 to about 28 inches.

[0032] With reference to Figures 1-3, the high performance wall assembly 20 comprises a rigid foam insulating panel 46 coupled to the frame assembly 28. The rigid foam insulating panel 46 can be a preformed panel. The rigid foam insulating panel 46 is generally planar. Said differently, an exterior surface 48 of the rigid foam insulating panel 46 is generally parallel to the exterior side 40 of the frame assembly 28. The rigid foam insulating panel 46 extends from the exterior side 40 of the frame assembly 28 to the exterior surface 48 of the rigid foam insulating panel 46. The exterior surface 48 of the rigid foam insulating panel 46 is configured to receive the exterior covering 26 of the building. The rigid foam insulating panel 46 spaces the exterior covering 26 from the exterior side 40 of the frame assembly 28.

[0033] Generally, the rigid foam insulating panel 46 impedes the infiltration

of water vapor into the frame assembly 28 thereby preventing infiltration of the water vapor into the building. Additionally, the rigid foam insulating panel 46 may prevent air from infiltrating the high performance wall assembly 20, which maintains the thermal resistance of the high performance wall assembly 20. For example, the rigid foam insulating panel 46 may be a vapor retarder and an air barrier. Generally, the rigid foam insulating panel 46 meets ASTM E2357, which is related to the determination of air leakage.

[0034] The rigid foam insulating panel 46 comprises a plurality of particles 52 and a binder. Typically, the particles 52 comprise greater than 80, more typically greater than 85, and even more typically greater than 90 percent by volume of the rigid foam insulating panel 46. The particles 52 have a density typically of from about 1000 kg/m<sup>3</sup> or less, more typically of from about 500 kg/m<sup>3</sup> or less, and even more typically less than 300 kg/m<sup>3</sup>.

[0035] Typically, the binder is a polymer. However, it is to be appreciated that the binder may be any suitable material for binding the particles 52 together. Typically, the polymer is selected from the group of acrylic-based polymers or copolymers, styrene-acrylic-based copolymers, styrenebutadiene-based copolymers, vinyl acrylic-based copolymers, vinyl acetate based polymers or copolymers, polyvinylidene chloride, neoprene, natural rubber latex, and combinations thereof. The binder may include a self-crosslinking polymer or a crosslinkable polymer. Generally, the rigid foam insulating panel 46 is substantially free of curing agents or crosslinking agents. However, the binder may further include a crosslinking agent, such as a metal salt of an organic acid. Additionally, the binder may include a curing agent.

[0036] The particles 52, as described herein, can be pre-expanded polymers

that can be fully expanded or partially expanded, for example, with air. For example, the pre-expanded polymer can comprise of from 50 to 90 percent air by volume. The pre-expanded polymer can be selected from the group of polystyrene, styrene based-copolymers, polyethylene, polypropylene, polyesters, polyvinylchloride, cellulose acetate, and combinations thereof. The pre-expanded polymer can include poly(styrene-co-acrylonitrile). The particles 52 can include beads, flakes, granules, fibers, platelets, spheres, microballoons, and combinations thereof. The plurality of particles 52 can be flame retardant. The plurality of particles 52 can further include recycled material. The average particle size of the largest dimension of the particles 52 is typically of from about 0.1 to about 10 mm.

**[0037]** The rigid foam insulating panel 46 may include a filler, such as heat reflective material, fire retardants, and impact modifiers. Examples of suitable heat reflective material include, but are not limited to, graphite, and pigments. The rigid foam insulating panel 46 meets ASTM C578 for the Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation. Examples of suitable foams for use as the rigid foam insulating panel 46 are commercially available from the BASF Corporation under the trade name(s) Neopor, Styropor, Comfort Foam, Walltite, Spraytite, Autofroth, Elastopor, and Enertite.

**[0038]** The rigid foam insulating panel 46 has a thickness T1 of from about 0.5 to about 12, more typically of from about 1 to about 8, and even more typically or from about 1 to about 3 inches. Additionally, the rigid foam insulating panel 46 has a density of from about 0.50 to about 5.00, more typically of from about 0.75 to about 4.00, and even more typically of from about 1.00 to about 3.00 pounds per cubic foot. Furthermore, the rigid foam insulating panel 46 has an R-value of from about 3.5 to about 7.0, more typically of from about 3.5 to about 6.5, and even more typically of

from about 4.0 to about 6.0 per inch.

[0039] With reference to Figures 2-5, the high performance wall assembly 20 includes a structural foam layer 60 disposed on the vertical members 34 of the frame assembly 28 and on the rigid foam insulating panel 46. Generally, the structural foam layer 60 is disposed between the vertical members 30. The structural foam layer 60 may be in contact with the vertical members 30 or, alternatively, the structural foam layer 60 may be spaced from the vertical members 30 while still being disposed between the vertical members 30.

[0040] The structural foam layer 60 couples the rigid foam insulating panel 46 to the frame assembly 28 such that the rigid foam insulating layer 46 is free of fasteners. Said differently, the structural foam layer 60 adheres the rigid foam insulating panel 46 to the frame assembly 28 without the use of fasteners. Said yet another way, fasteners are not needed to couple the rigid foam insulating layer 46 to the frame assembly 28 because the structural foam layer 60 coupled the rigid foam insulating panel 46 to the frame assembly 28. Although not required, it is to be appreciated that the rigid foam insulating panels 46 may be coupled to the frame assembly 28 by fasteners. However, the use of the structural foam layer 60 reduces the number of fasteners or completely eliminates the use of fasteners needed for coupling the rigid foam insulating panel 46 to the frame assembly 28 thereby reducing a manufacturing cost of the high performance wall assembly. Generally, the structural foam layer 60 provides structural support to the frame assembly 28. Said differently, the structural foam layer 60 may couple the top, bottom, and vertical members 30, 32, 34 together thereby reducing the number of fasteners needed to structurally secure the top, bottom, and vertical members 30, 32, 34 together. Furthermore, the structural foam layer 60 may completely eliminate the need for

fasteners to couple together the top, bottom, and vertical members 30, 32, 34 such that the frame assembly 28 is free of fasteners while still meeting structural requirements.

[0041] The structural foam layer 60 has a cohesive strength suitable for coupling the rigid foam insulating layer 46 to the frame assembly 28. Typically, the cohesive strength of the structural foam layer 60 is of from about 5.0 to about 50, more typically, of from about 10 to about 40, and even more typically of from about 12 to about 35 pounds per square foot. Typically, the structural foam layer 60 comprises a foam selected from the group of polyurethane foams, polyurea foams, and combinations thereof. More typically, the structural foam layer 60 comprises a sprayable foam selected from the group of polyurethane foams, polyurea foams, and combinations thereof. Said differently, the structural foam layer 60 may be spray applied to the frame assembly 28 and the rigid foam insulating panel 46. When the sprayable foam is a polyurethane sprayable foam, the sprayable foam may be the reaction product of a polyether polyol and an isocyanate. It is to be appreciated that any polyether polyols may be used. Alternatively, when the sprayable foam is the polyurethane sprayable foam, the sprayable foam may be the reaction product of a polyester polyol and the isocyanate. The use of the polyester polyol imparts the rigid foam insulating panel 46 with a fire retardant. When the sprayable foam is a polyurea sprayable foam, the sprayable foam is the reaction product of a polyamine and an isocyanate. An example of a suitable isocyanate for the sprayable foam is lubrinate.

[0042] Typically, the structural foam layer 60 has a thickness T2 of from about 0.25 to the width W of the frame assembly 28, more typically of from about 0.50 to about 4.0, and even more typically or from about 1.0 to about 3.0 inches. Additionally, the structural foam layer 60 has a density of from about 0.5 to about

5.0, more typically of from about 1.0 to about 4.0, and even more typically of from about 1.5 to about 4.0 pounds per cubic foot. Furthermore, the structural foam layer 60 has an R-value per inch of thickness of from about 3 to about 9, more typically of from about 4 to about 8, and even more typically of from about 5 to about 7.

[0043] The frame assembly 28 may also include an intermediate substrate 56 disposed between the rigid foam insulating panel 46 and the structural foam layer 60 for providing a shear strength to the high performance wall assembly 20. The intermediate substrate 56 provides the high performance wall assembly 20 with the shear strength to resist axial loads, shear loads, and lateral loads applied to the high performance wall assembly 20. For example, the frame assembly 28 may include wind bracing, hurricane straps, and/or up-lifting clips. Typically, the intermediate substrate 56 is a sheet of rigid material, such as plywood or oriented strand board (OSB). When the intermediate substrate 56 is a sheet of rigid material, the intermediate substrate 56 has a thickness T3 typically of from about 0.125 to about 1.00, more typically of from about 0.25 to about 0.75, and even more typically of from about 0.375 to about 0.344 inches.

[0044] With reference to Figure 4A, the intermediate substrate 56 may define a plurality of holes 57 with the structural foam layer 60 disposed through the holes 57 to contact the rigid foam insulating panel. Allowing the structural foam layer 60 to be disposed on and pass through the intermediate substrate 56 results in the structural foam layer 60 to couple both the rigid foam layer 46 and the intermediate substrate 56 to the frame assembly 28.

[0045] Generally, the rigid foam insulating panel 46 and the structural foam layer 60 provide the high performance wall assembly 20 with the thermal resistance. Said differently, the rigid foam insulating panel 46 and the structural foam layer 60

insulate the high performance wall assembly 20. The thickness T1 of the rigid foam insulating panel 46 and the thickness T2 of the structural foam layer 60 may be varied to adjust the thermal resistance of the high performance wall assembly 20. Generally, a desired thermal resistance varies depending on the climate of the location where the building is to be constructed. As such, the thickness T1 of the rigid foam insulating panel 46 and the thickness T2 of the structural foam layer 60 may be adjusted to provide the high performance wall assembly 20 with the desired thermal resistance. Typically, the thermal resistance of the high performance wall assembly 20 has an R-value of from about 10 to about 53, more typically of from about 10 to about 30, and even more typically of from about 12 to about 28 units.

**[0046]** The high performance wall assembly 20 may comprise a barrier layer coupled to the exterior surface 48 of the rigid foam insulating layer 46. The barrier layer may be an additional vapor retarder, and/ or a radiant barrier. For example, the barrier layer may be a sprayable vapor retarder such as acrylic-latex. Typically, the sprayable vapor retarder is applied to the exterior surface 48 of the rigid foam insulating panel 46.

**[0047]** A method of manufacturing the high performance wall assembly 20 includes the step of providing the frame assembly 28. It is to be appreciated that the step of providing the frame assembly 28 may be further defined as assembling the frame assembly 28. It is also to be appreciated that the step of assembling the frame assembly 28 may be further defined as arranging the top member 30, the bottom member 32, and the vertical members 34 to present the frame assembly 28.

**[0048]** The rigid foam insulating panel 46 is positioned adjacent the frame assembly 28. It is to be appreciated that the rigid foam insulating panel 46 may be placed flat on the ground and the frame member placed onto on the rigid foam



insulating panel 46. Additionally, the top member 30, the bottom member 32, and the vertical members 34 may be arranged on top of the rigid foam insulating panel 46. This step is particularly helpful when the structural foam layer 60 is to couple the frame member 28 together and couple the rigid foam insulating panel 46 to the frame member 28.

[0049] The structural foam layer 60 is applied to the frame assembly 28 and the rigid foam insulating panel 46. More specifically, the step of applying the structural foam layer 60 may be further defined as spraying the structural foam layer 60 onto the vertical members 34, the top member 30, and the bottom member 32 of the frame assembly 28.

[0050] As indicated above, the structural foam layer 60 may be spray applied to the frame assembly 28 and the rigid foam insulating layer 46. The structural foam layer 60 is cured to couple the frame assembly 28 together and/or to couple the rigid foam insulating panel 46 to the frame assembly 28 to form the high performance wall assembly 20 such that the high performance wall assembly is free of fasteners. It is to be appreciated that the step of curing the binder may be passive, i.e., there is no need for an affirmative step, such as heating, etc. to cure the binder. Said differently, the binder may cure naturally via a respective curing mechanism of the binder composition. Alternatively, an affirmative step, such as applying heat to the binder, may be required to cure the binder.

[0051] When the intermediate substrate 56 is present, the intermediate substrate 56 is positioned between the rigid foam insulating panel 46 and the structural foam layer 60. Additionally, when the intermediate substrate 56 is present, the step of applying the structural foam layer 60 may be further defined as spraying the structural foam layer 60 onto the frame assembly 28 and through the holes 57 of

the intermediate substrate 56 to contact the rigid foam insulating panel 46. It is to be appreciated that the rigid foam insulating panel 46 and/or the intermediate substrate 56 may be coupled to the frame assembly 28 either on-site where the building is to be constructed or off-site at a factory or warehouse.

[0052] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

## CLAIMS

1. A high performance wall assembly comprising:

an exterior covering being at least one of a siding panel, brick, and insulating foam panel;

a frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members with said frame assembly having an interior side and an exterior side opposite said interior side;

a rigid foam insulating panel comprising a closed-cell foam having a plurality of particles of pre-expanded polymers and a binder, said rigid foam insulating panel being disposed adjacent to said exterior side of said frame assembly and extending from said exterior side of said frame assembly and terminating at an exterior surface of said rigid foam insulating panel, with said exterior surface of said rigid foam insulating panel receiving said exterior covering and spacing said exterior covering from said exterior side of said frame assembly;

a structural foam layer disposed between and adhered to said plurality of vertical members and adhered to an interior surface of said rigid foam insulating panel between said plurality of vertical members such that said plurality of vertical members are not encapsulated in said structural foam layer, said structural foam layer being selected from the group consisting of polyurethane foams, polyurea foams, and combinations thereof; and

wherein said structural foam layer adheres said rigid foam insulating panel to said frame assembly such that said rigid foam insulating panel is free of fasteners.

2. The high performance wall assembly as set forth in claim 1, further comprising an intermediate substrate disposed between said rigid foam insulating panel and said structural foam layer for providing a shear strength to said high performance wall assembly.

3. The high performance wall assembly as set forth in claim 2, wherein said intermediate substrate defines a plurality of holes with said structural foam layer disposed through said holes to contact said rigid foam insulating panel.

4. The high performance wall assembly as set forth in claim 2 or 3, wherein said intermediate substrate has a thickness of from about 0.125 to about 1.00 inches.

5. The high performance wall assembly as set forth in any one of claims 1 to 4, wherein said rigid foam insulating panel is a preformed panel.

6. The high performance wall assembly as set forth in any one of claims 1 to 5, wherein said pre-expanded polymers are selected from the group consisting of polystyrene, styrene based-copolymers, polyethylene, polypropylene, polyesters, polyvinylchloride, cellulose acetate, and combinations thereof.

7. The high performance wall assembly as set forth in any one of claims 1 to 6, wherein said binder is selected from the group consisting of acrylic-based polymers or copolymers, styrene-acrylic-based copolymers, styrenebutadiene-based copolymers, vinyl acrylic-based copolymers, vinyl acetate based polymers or copolymers, polyvinylidene chloride, neoprene, natural rubber latex, and combinations thereof for binding the particles together.

8. The high performance wall assembly as set forth in any one of claims 1 to 7, wherein said rigid foam insulating panel has a thickness of from about 0.5 to about 12 inches.

9. The high performance wall assembly as set forth in any one of claims 1 to 8, wherein said rigid foam insulating panel has a density of from about 0.50 to about 5.0 pounds per cubic foot.

10. The high performance wall assembly as set forth in any one of claims 1 to 9, wherein said closed-cell foam is a sprayable foam.

11. The high performance wall assembly as set forth in any one of claims 1 to 10, wherein a distance between said plurality of vertical members is of from about 1.0 to about 30.0 inches.

12. The high performance wall assembly as set forth in any one of claims 1 to 11,

further comprising a moisture barrier coupled to said exterior surface of said rigid foam insulating panel.

13. The high performance wall as set forth in any one of claims 1 to 12, wherein said structural foam layer couples said plurality of vertical members to said top and bottom members such that said frame assembly is free of fasteners.

14. A method of manufacturing the high performance wall assembly as defined in claim 1, comprising the steps of:

providing the exterior covering;

providing the frame assembly;

positioning the rigid foam insulating panel adjacent the exterior side of the frame assembly and in contact with the plurality of vertical members of said frame assembly,

applying the structural foam layer to the frame assembly and the rigid foam insulating panel between the plurality of vertical members such that the plurality of vertical members are not encapsulated in the structural foam layer; and

curing the structural foam layer to couple the frame assembly together and to couple the rigid foam insulating panel to the frame assembly to form the high performance wall assembly such that the high performance wall assembly is free of fasteners.

15. The method as set forth in claim 14, wherein the high performance wall assembly further comprises an intermediate substrate defining a plurality of hole and said method further comprises the step of positioning the intermediate substrate between the rigid foam insulating panel and the structural foam layer and contacting the plurality of vertical members and the rigid foam insulating panel.

16. The method as set forth in claim 15, wherein said step of applying the structural foam layer is further defined as spraying the structural foam layer onto the frame assembly and through the holes of the intermediate substrate to contact the rigid foam insulating panel.

17. The method as set forth in any one of claims 14 to 16, wherein the step of positioning the rigid foam insulating panel adjacent the frame assembly is further defined as

laying the plurality of vertical members, the top member, and the bottom member of the frame assembly on the rigid foam insulating panel.

18. The method as set forth in claim 17, wherein the step of applying the structural foam layer is further defined as spraying the structural foam layer onto the vertical members, the top member, and the bottom member of the frame assembly.

19. The method as set forth in claim 18, wherein the step of curing the structural foam layer is further defined as curing the structural foam layer on the vertical members, top member, and bottom member of the frame assembly and on the rigid foam insulating panel to couple the vertical members, top member, and bottom member together to form the frame member and to couple the rigid foam insulating panel to the frame assembly to form the high performance wall assembly.

20. The method as set forth in claim 14, further comprising the step of spraying the structural foam layer onto the rigid foam insulating panel.

21. A wall assembly comprising:

a frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members with said frame assembly having an interior side and an exterior side opposite said interior side, wherein said top member, said bottom member, and said vertical members are made of wood;

a rigid foam insulating panel coupled to said exterior side of said frame assembly and contacting said plurality of vertical members and extending from said exterior side of said frame assembly and terminating at an exterior surface of said rigid foam insulating panel;

a structural foam layer disposed between and adhered to said plurality of vertical members and adhered to an interior surface of said rigid foam insulating panel between said plurality of vertical members such that said plurality of vertical members are not encapsulated in said structural foam layer;

wherein said rigid foam insulating panel comprises a plurality of pre-expanded polymeric beads having multiple bead sizes and a binder, wherein said pre-expanded

polymeric beads are selected from the group consisting of polystyrene, styrene based-copolymers, polyethylene, polypropylene, polyesters, polyvinylchloride, cellulose acetate, and combinations thereof, wherein said binder is a polymer selected from the group consisting of acrylic-based polymers or copolymers, styrene-acrylic-based copolymers, styrenebutadiene-based copolymers, vinyl acrylic-based copolymers, vinyl acetate based polymers or copolymers, polyvinylidene chloride, neoprene, natural rubber latex, and combinations thereof for binding the particles together, wherein said rigid foam insulating panel has a thickness of from about 0.5 to about 12 inches and a density of from about 0.5 to about 5.00 pounds per cubic foot;

wherein said frame assembly has a first end and a second end spaced from said first end defining a length of the wall assembly;

an exterior covering disposed directly adjacent said exterior surface of said outer foam layer, said exterior covering being at least one of a siding panel, brick, and insulating foam panel; and

wherein said structural foam layer adheres said rigid foam insulating panel to said frame assembly such that said rigid foam insulating panel is free of fasteners.

22. A wall assembly comprising:

a frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members with said frame assembly having an interior side and an exterior side opposite said interior side, wherein said top member, said bottom member, and said vertical members are made of wood;

a rigid foam insulating panel disposed adjacent to said exterior side of said frame assembly and extending from said exterior side of said frame assembly and terminating at an exterior surface of said rigid foam insulating panel;

a structural foam layer disposed between and adhered to said plurality of vertical members and adhered to an interior surface of said rigid foam insulating panel between said plurality of vertical members such that said plurality of vertical members are not encapsulated in said structural foam layer;

wherein said rigid foam insulating panel comprises a plurality of pre-expanded

polymeric beads having multiple bead sizes and a binder, wherein said pre-expanded polymeric beads are selected from the group consisting of polystyrene, styrene-based copolymers, polyethylene, polypropylene, polyesters, polyvinylchloride, cellulose acetate, and combinations thereof, wherein said binder is a polymer selected from the group consisting of acrylic-based polymers or copolymers, styrene-acrylic-based copolymers, styrenebutadiene-based copolymers, vinyl acrylic-based copolymers, vinyl acetate based polymers or copolymers, polyvinylidene chloride, neoprene, natural rubber latex, and combinations thereof for binding the particles together, wherein said rigid foam insulating panel has a thickness of from about 0.5 to about 12 inches and a density of from about 0.5 to about 5.0 pounds per cubic foot;

an intermediate substrate disposed between said rigid foam insulating panel and said frame assembly with said rigid foam insulating panel bonded to said intermediate substrate and said intermediate substrate bonded to said structural foam layer for coupling to said frame assembly, wherein said intermediate substrate has a thickness of from about 0.125 to about 1.00 inches;

wherein said frame assembly has a first end and a second end spaced from said first end defining a length of the wall assembly;

an exterior covering disposed directly adjacent said exterior surface of said rigid foam insulating panel, said exterior covering being at least one of a siding panel, brick, and insulating foam panel; and

wherein said structural foam layer adheres said rigid foam insulating panel to said frame assembly such that said rigid foam insulating panel is free of fasteners.

23. A high performance wall assembly for receiving an exterior covering of a building, said high performance wall assembly comprising a frame assembly, a rigid foam layer having particles and a binder, a structural polymeric foam layer wherein the thermal resistance of the wall assembly has a R-value per inch of thickness of from about 10 to about 53;

the frame assembly having a top member, a bottom member opposite said top member, and a plurality of vertical members coupled to and extending between said top and bottom members;



the rigid foam insulating panel coupled to said frame assembly with an exterior surface of said rigid foam insulating panel configured to receive the exterior covering of the building, the rigid foam insulating panel comprising a plurality of particles and a binder, the particles comprising greater than 80 percent by volume of the rigid foam insulating panel; and

a structural foam layer disposed on said plurality of vertical members and on said rigid foam insulating panel between said plurality of vertical members, the structural foam layer comprising a foam selected from the group of polyurethane foams, polyurea foams, and combinations thereof; and

wherein said structural foam layer couples said rigid foam insulating panel to said frame assembly such that said rigid foam insulating layer is free of fasteners.

24. The high performance wall assembly as set forth in claim 23, wherein the binder is a polymer selected from the group consisting of acrylic-based polymers or copolymers, styrene-acrylic-based copolymers, styrenebutadiene-based copolymers, vinyl acrylic-based copolymers, vinyl acetate based polymers or copolymers, polyvinylidene chloride, neoprene, natural rubber latex, and combinations thereof.

25. The high performance wall assembly as set forth in claim 23 or 24, wherein said particles are pre-expanded polymers selected from the group consisting of polystyrene, styrene based-copolymers, polyethylene, polypropylene, polyesters, polyvinylchloride, cellulose acetate, and combinations thereof.

26. The high performance wall assembly as set forth in any one of claims 23 to 25, wherein the rigid foam insulating panel has an R value per inch of from about 3.5 to about 7.0.

27. The high performance wall assembly as set forth in any one of claims 23 to 26, wherein the foam of said structural foam layer is a sprayable foam.

28. The high performance wall assembly as set forth in claim 27, wherein the sprayable foam is the reaction product of an isocyanate with polyether polyol, polyester polyol, and/or polyamine.

29. The high performance wall assembly as set forth in any one of claims 23 to 29, wherein the structural foam layer has an R value per inch of from about 3 to about 9.

30. The high performance wall as set forth in any one of claims 23 to 29, wherein said structural foam layer has a density of from about 0.50 to about 5.0 pounds per cubic foot.

31. The high performance wall assembly as set forth in any one of claims 23 to 30, further comprising an intermediate substrate disposed between said rigid foam insulating panel and said structural foam layer for providing a sheer strength to said high performance wall assembly.

32. The high performance wall assembly as set forth in claim 31, wherein said intermediate substrate includes a plurality of holes with said structural foam layer disposed through said holes to contact said rigid foam insulating panel.

33. The high performance wall assembly as set forth in any one of claims 23 to 32, wherein an average particle size of a largest dimension of the particles is from about 0.1 to about 10 mm.

34. The high performance wall assembly as set forth in any one of claims 23 to 33, wherein the particles have a density of from about 1000 kg/m<sup>3</sup> or less.

35. The high performance wall assembly as set forth in any one of claims 23 to 34, wherein said rigid foam insulating panel has a density of from about 0.50 to about 5.0 pounds per cubic foot.

36. The high performance wall assembly as set forth in any one of claims 23 to 35, wherein said structural foam layer has a cohesive strength of from about 5.0 to about 50.0 pounds per square inch.

37. The high performance wall assembly as set forth in any one of claims 23 to 36, further comprising a vapor retarder coupled to said exterior surface of said rigid foam insulating panel.

38. A method of manufacturing the high performance wall assembly according to claim 23, said method comprising the steps of:

providing the frame assembly;

positioning the rigid foam insulating panel adjacent the frame assembly;

applying the structural foam layer to the frame assembly and the rigid foam insulating panel between the plurality of vertical members;

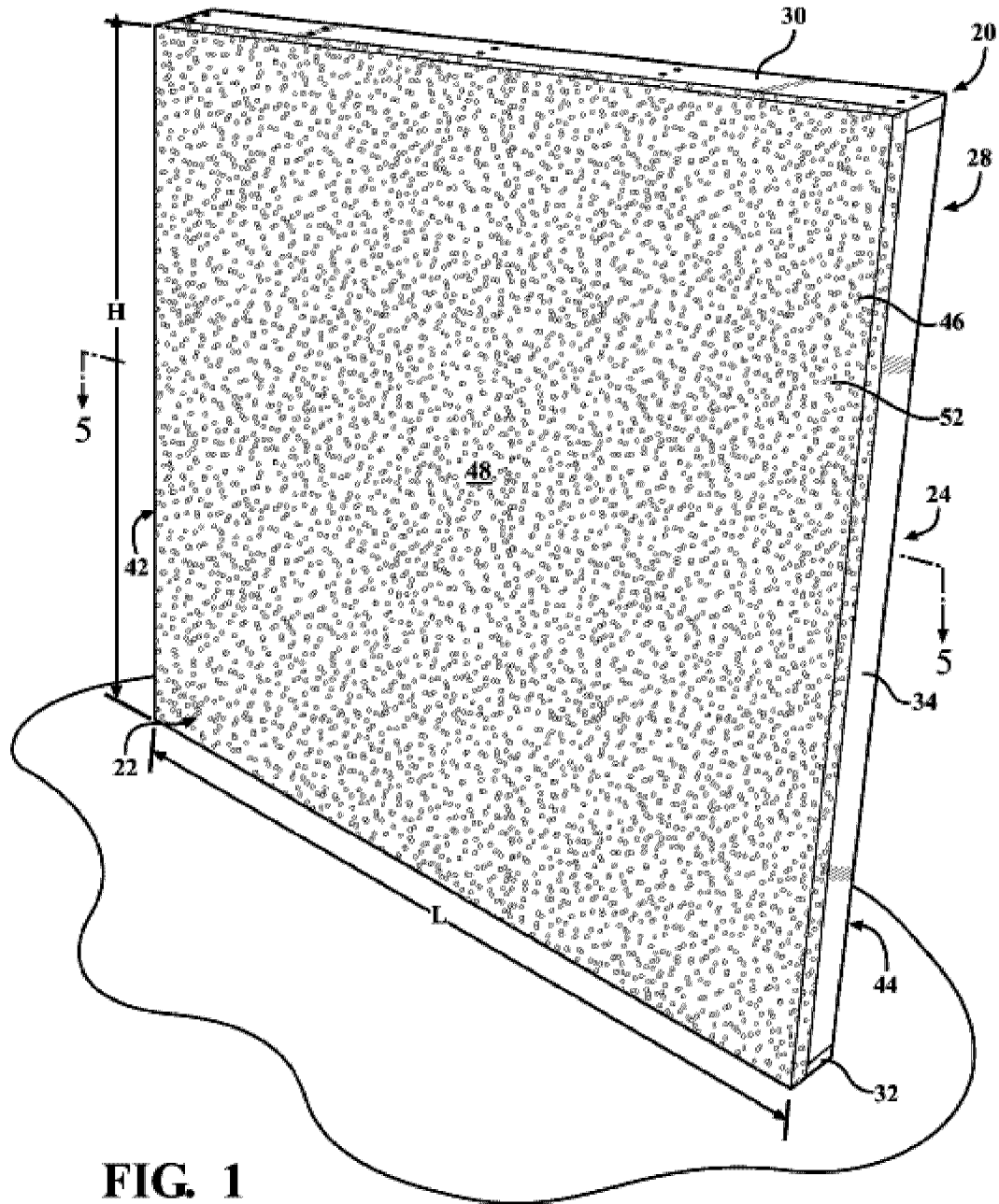
curing the structural foam layer to couple the rigid foam insulating panel to the frame assembly to form the high performance wall assembly such that the high performance wall assembly is free of fasteners.

39. The method as set forth in claim 38, further comprising positioning an intermediate substrate between the rigid foam insulating panel and the structural foam layer.

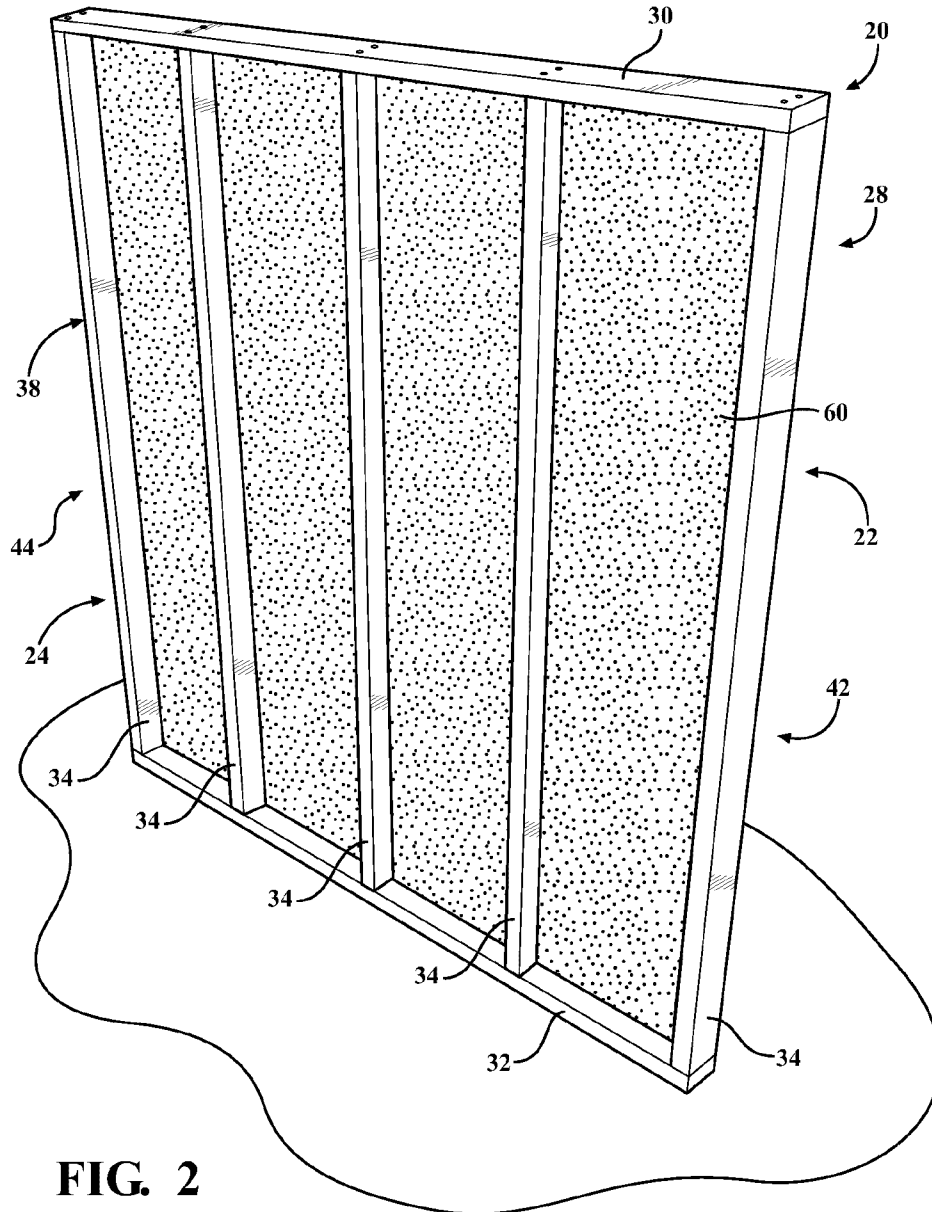
40. The method as set forth in claim 39, wherein said intermediate substrate includes a plurality of holes and said applying the structural foam layer comprises spraying the structural foam layer onto the frame assembly and through the holes of the intermediate substrate to contact the rigid foam insulating panel.

41. The method as set forth in claim 38, wherein said positioning the rigid foam insulating panel adjacent the frame assembly comprises laying a plurality of vertical members, a top member, and a bottom member of the frame assembly on the rigid foam insulating panel.

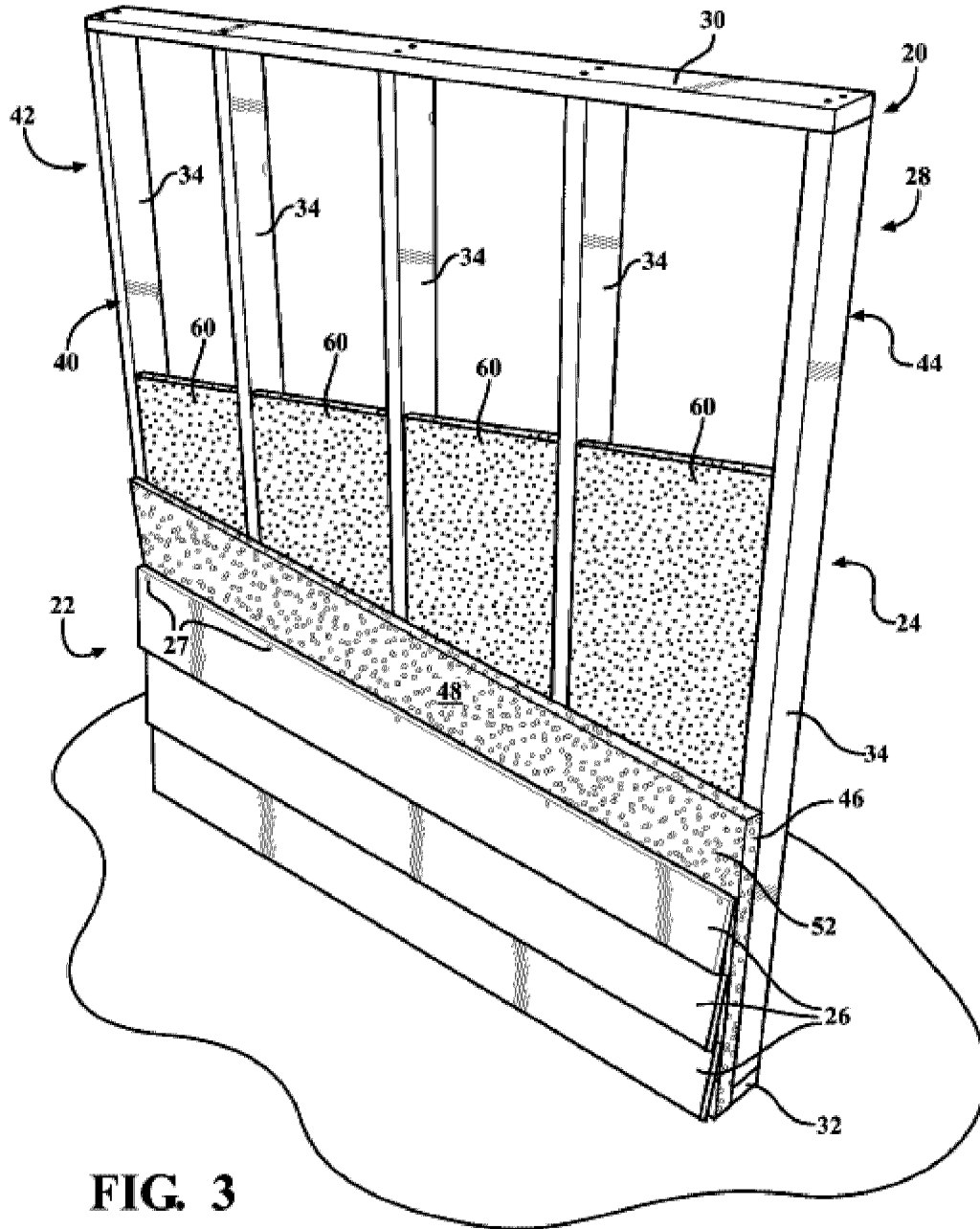
42. The method as set forth in claim 38, wherein said applying the structural foam layer comprises spraying the structural foam layer onto the frame assembly.



**FIG. 1**



**FIG. 2**



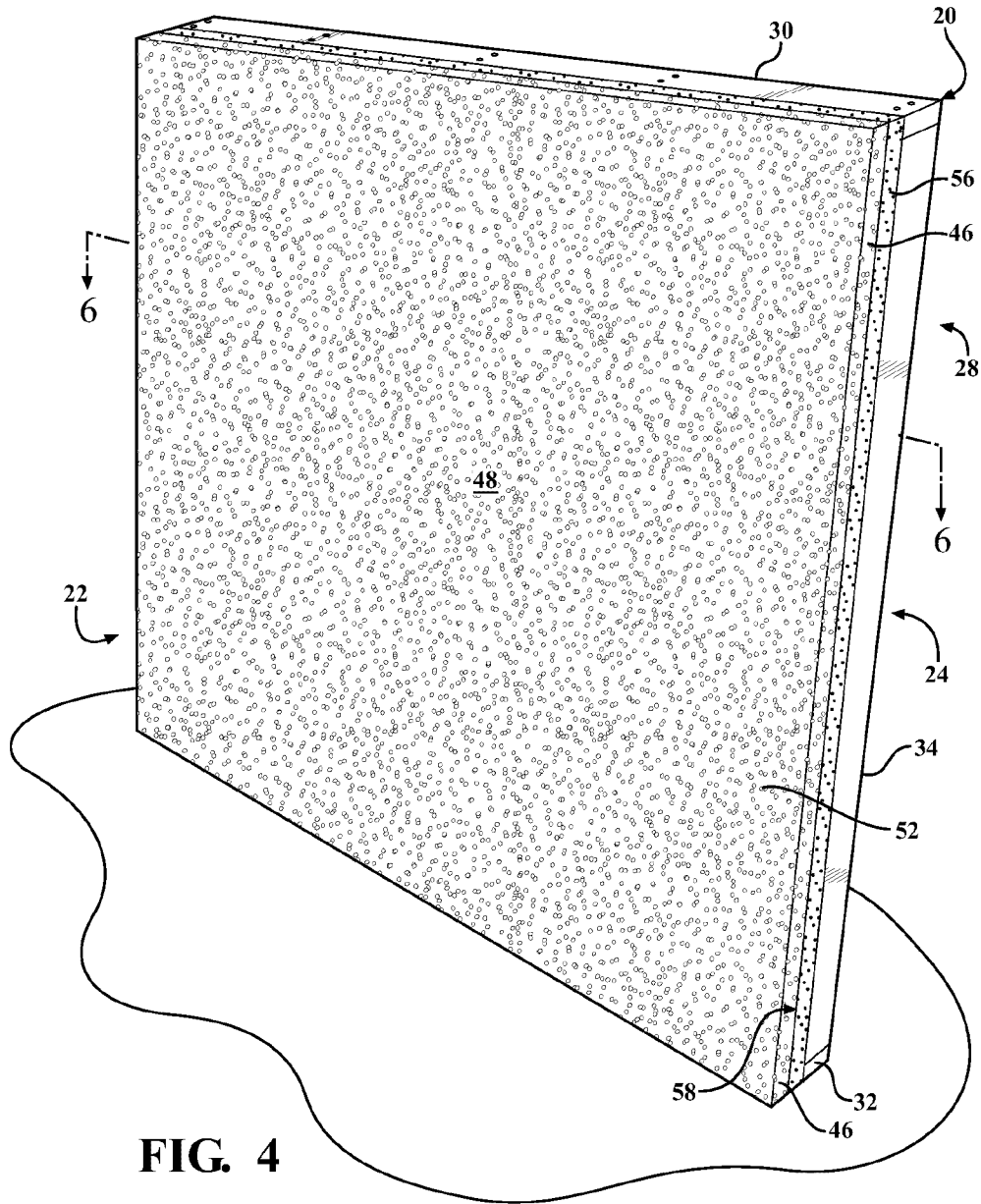


FIG. 4

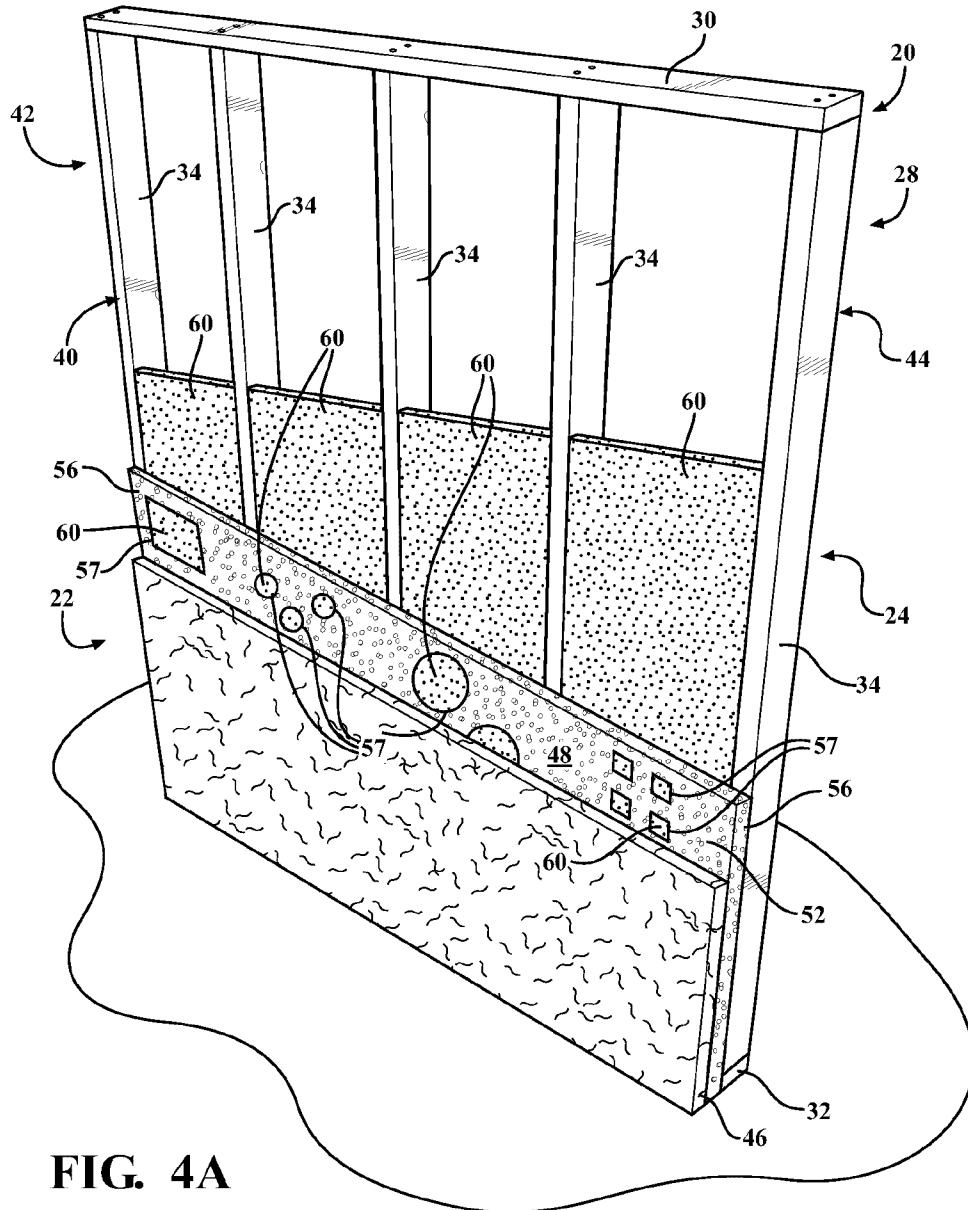
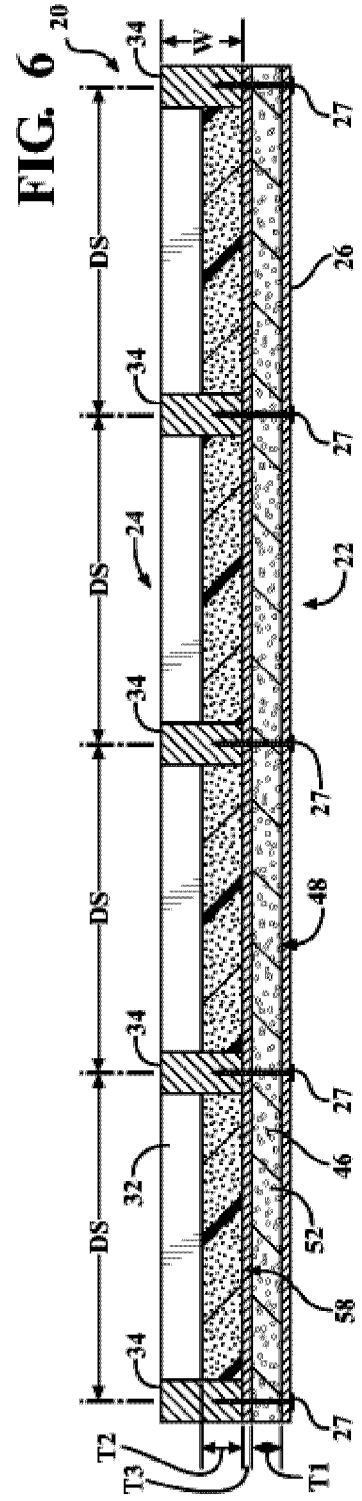
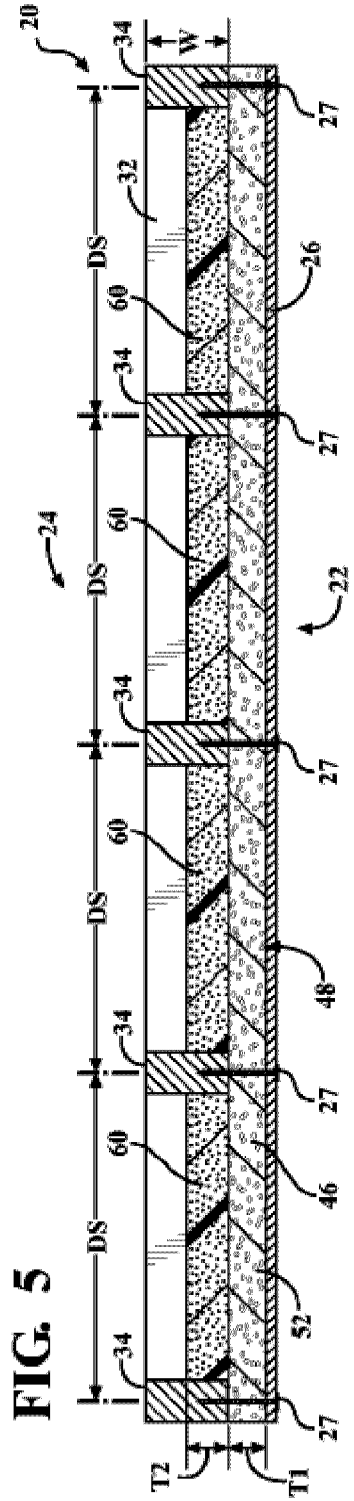


FIG. 4A





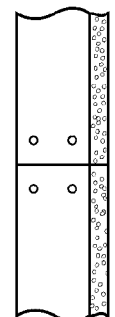
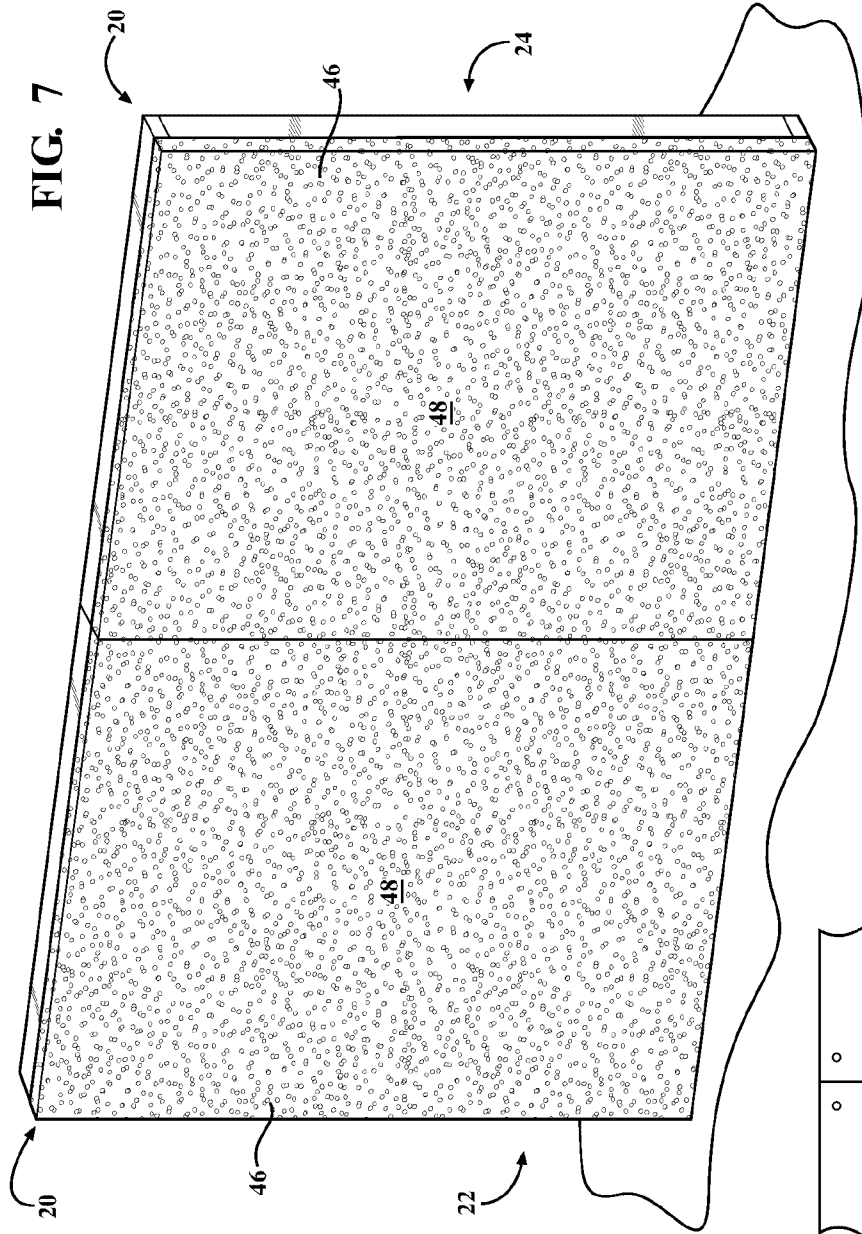


FIG. 8

FIG. 7

