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(54) **MODULAR BUILDING STRUCTURE**

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(57) **ABSTRACT**

Disclosed herein is a modular building structure. The structure includes a modular building roof structure comprising the roof structure which includes a plurality of truss structures each having a top and a bottom and a pair of deck layers attached to and for transversely spanning the tops of the truss structures. The roof structure also includes an acoustical ceiling suspended along the bottoms of the truss structures. The building structure also includes a modular building floor structure which comprises a deck structure including an upper deck pan and a lower deck pan disposed opposite and adjacent each other to create a plurality of spaced apart support channels. In a preferred embodiment, the deck structure is oriented transverse to the support beams. The floor structure further includes a plurality of support beams for supporting the deck structure. Significantly, the deck and the acoustical ceiling define a return air plenum that provides for proper venting, distribution and circulation of air, including introduction of fresh air, throughout the modular structure. Advantageously, no separate ductwork or duct system is required with the use of the air plenum. Preferably, the structure is substantially noncombustible and mold-resistant.

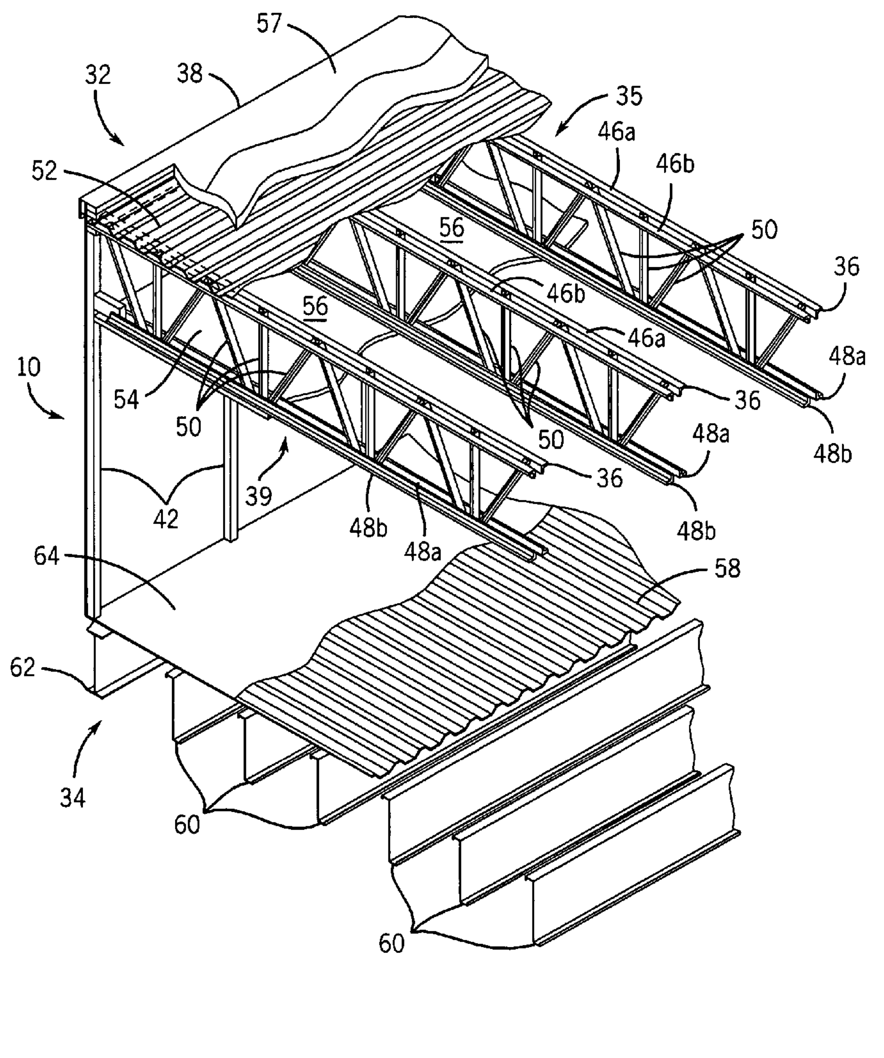


FIG. 1

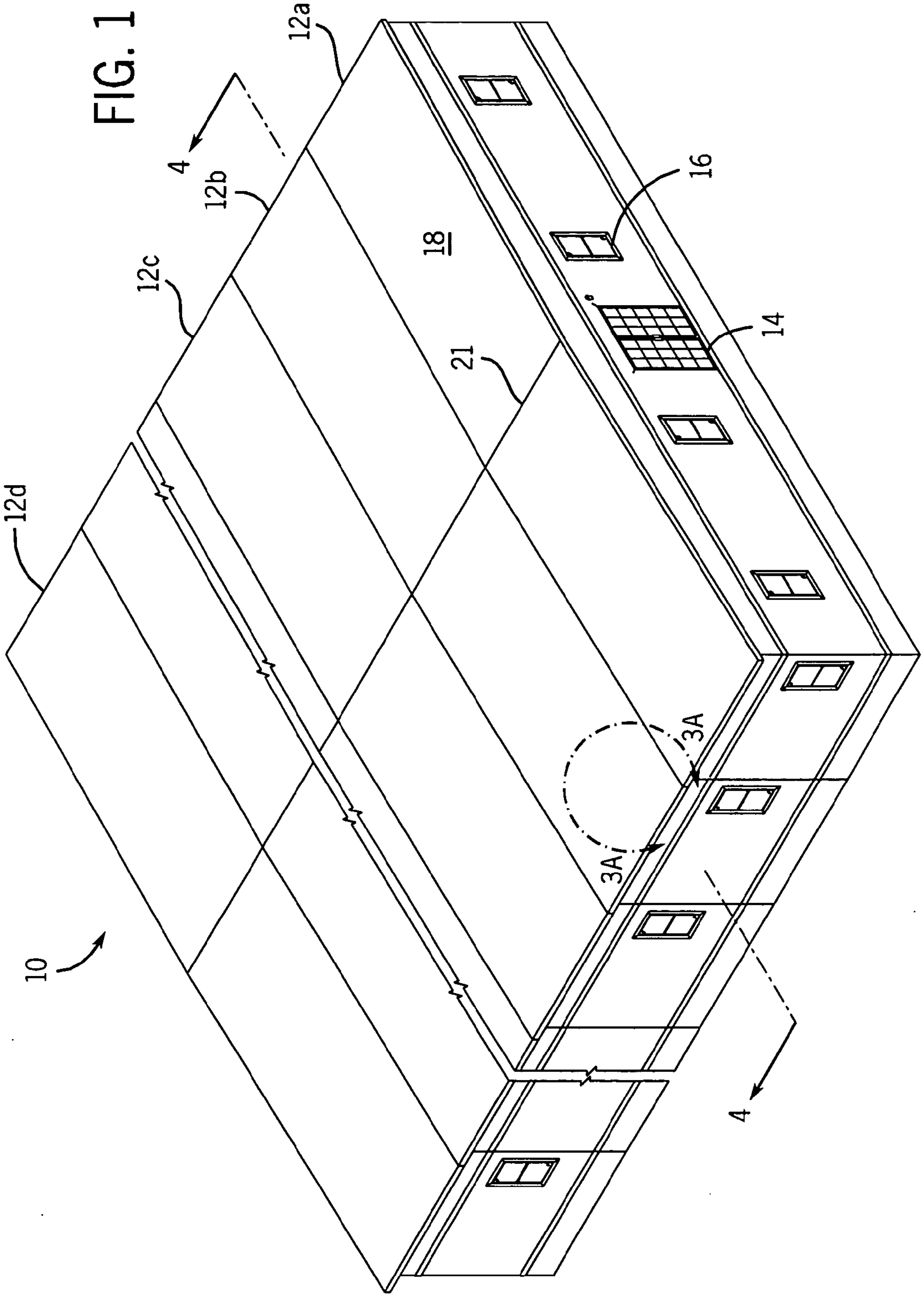
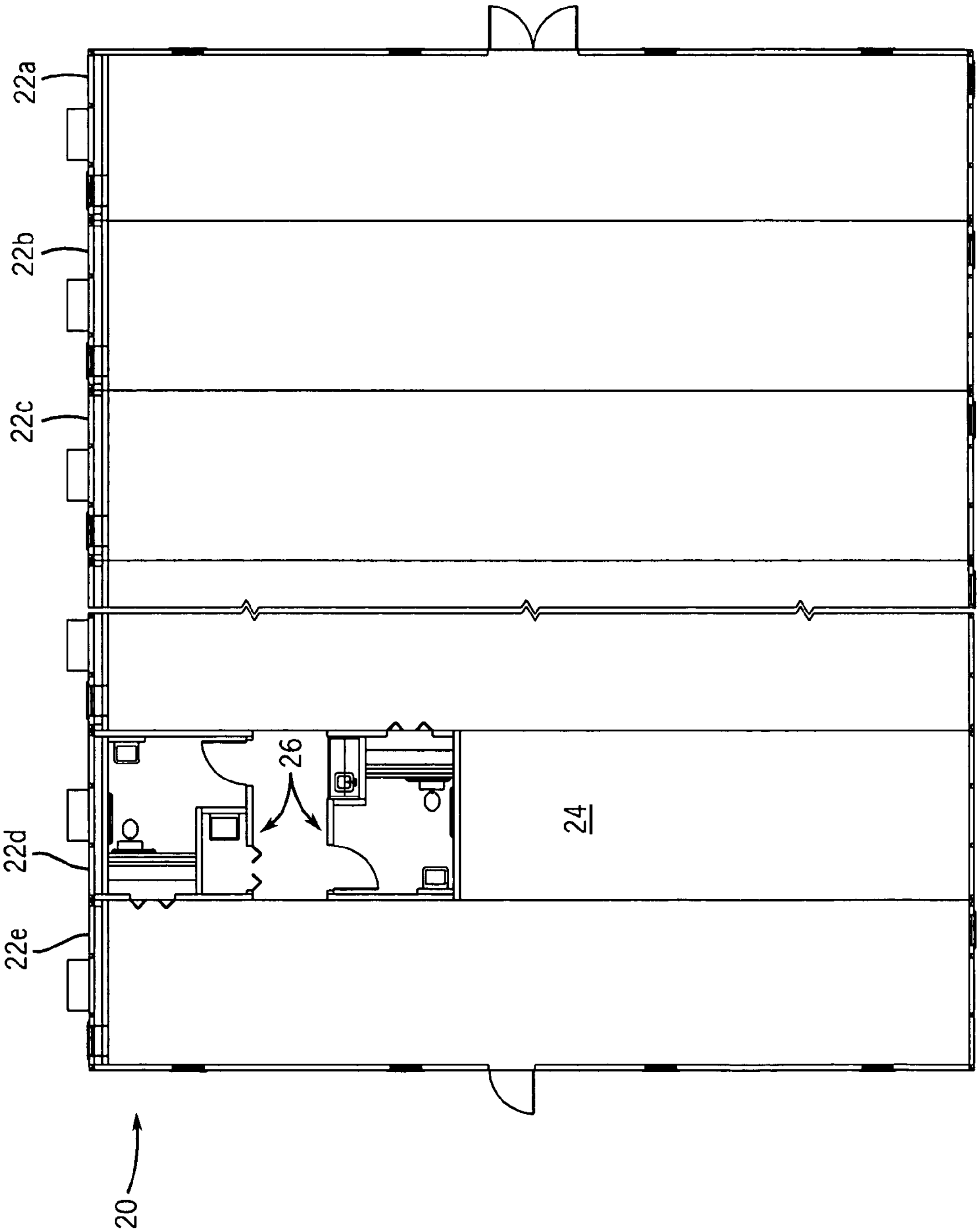
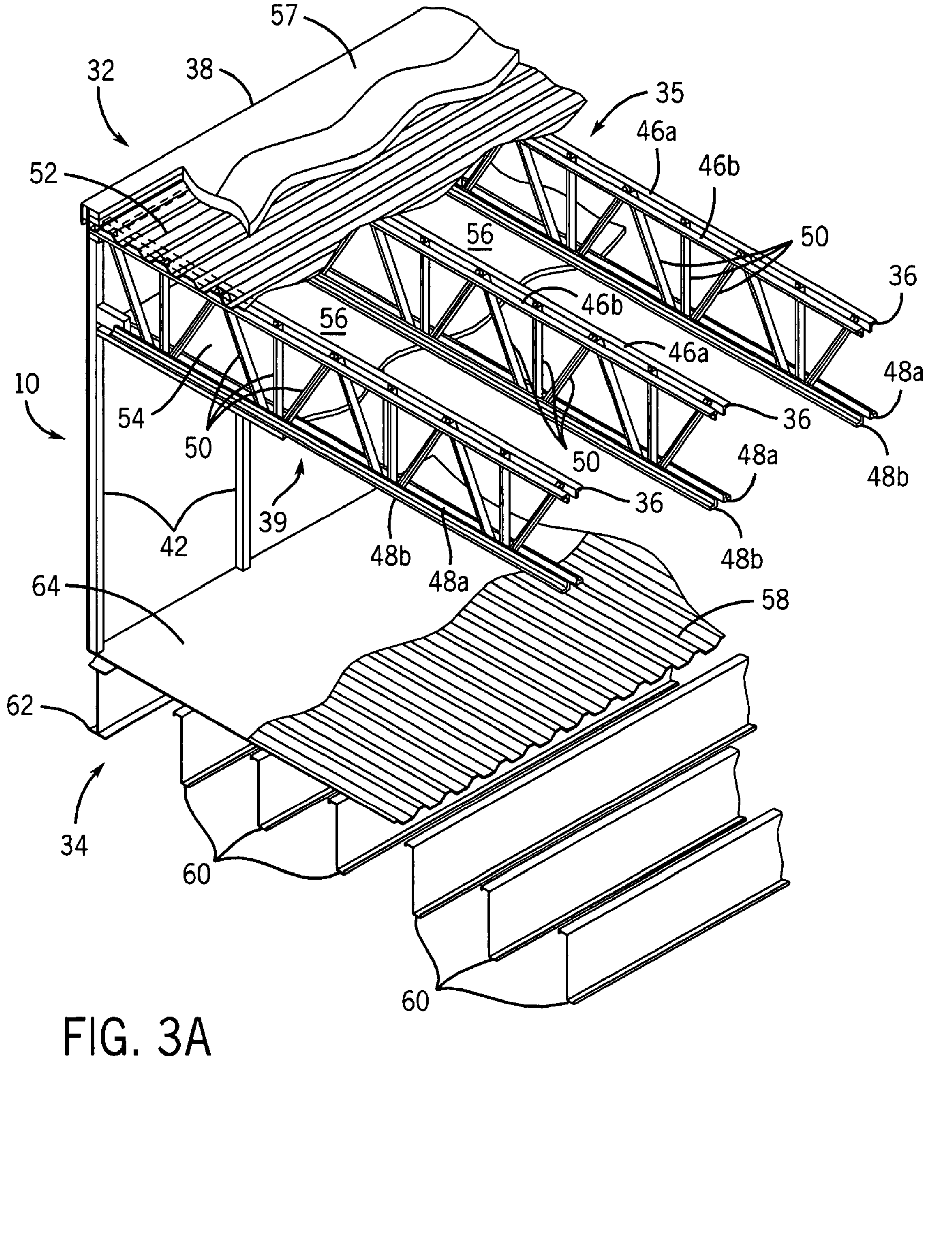


FIG. 2




57
32
38
35
46a
46b
52
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36
46b
56
46a
10
48a
54
36
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50
48a
48b
36
39
42
48b
48b
48a
64
58
62
34
60
60

FIG. 3A

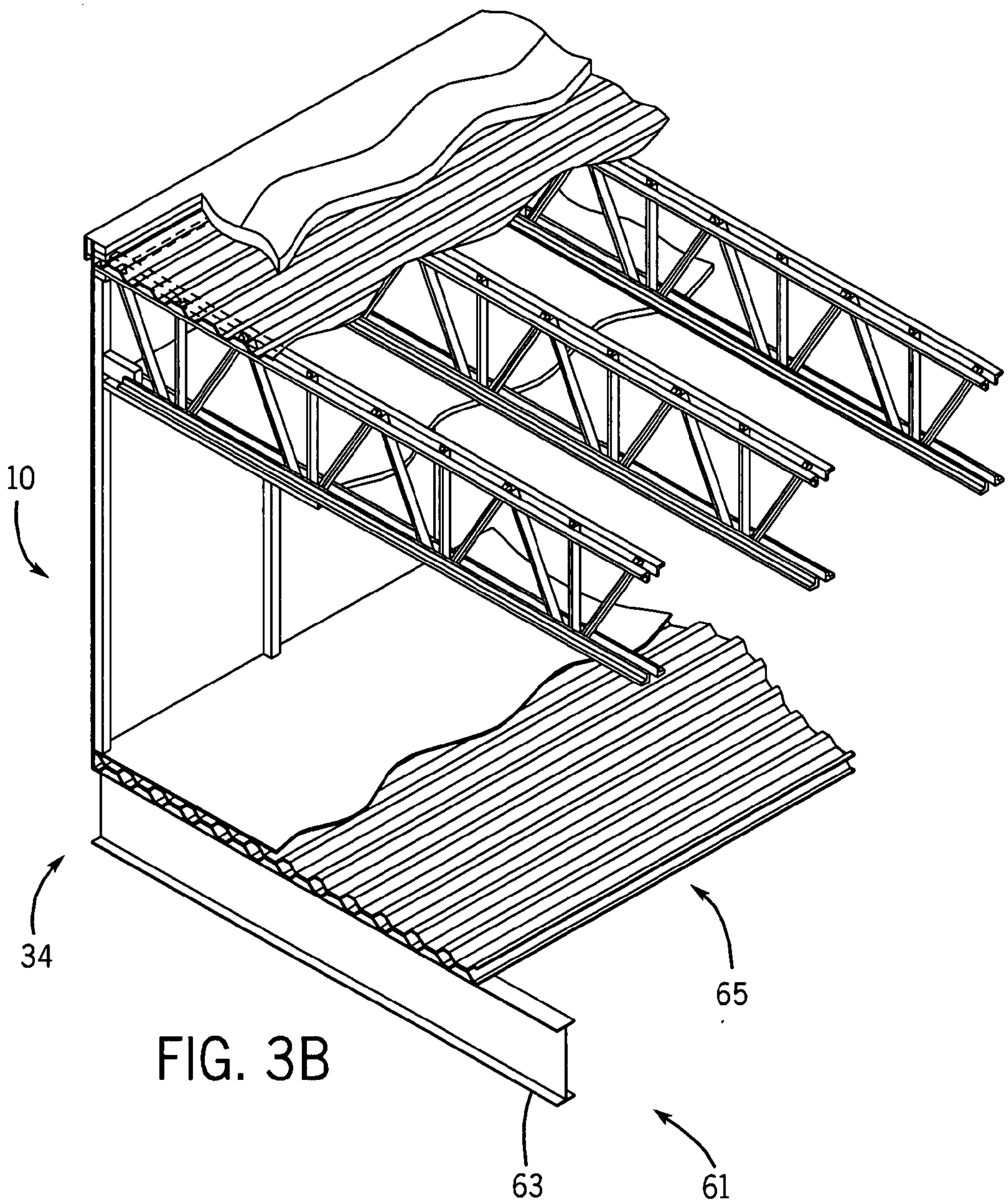


FIG. 3B

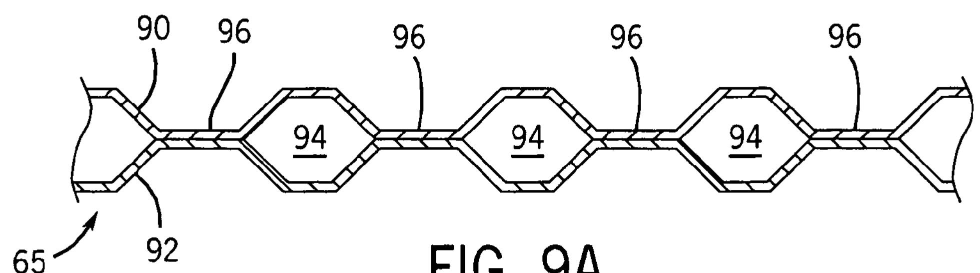


FIG. 9A

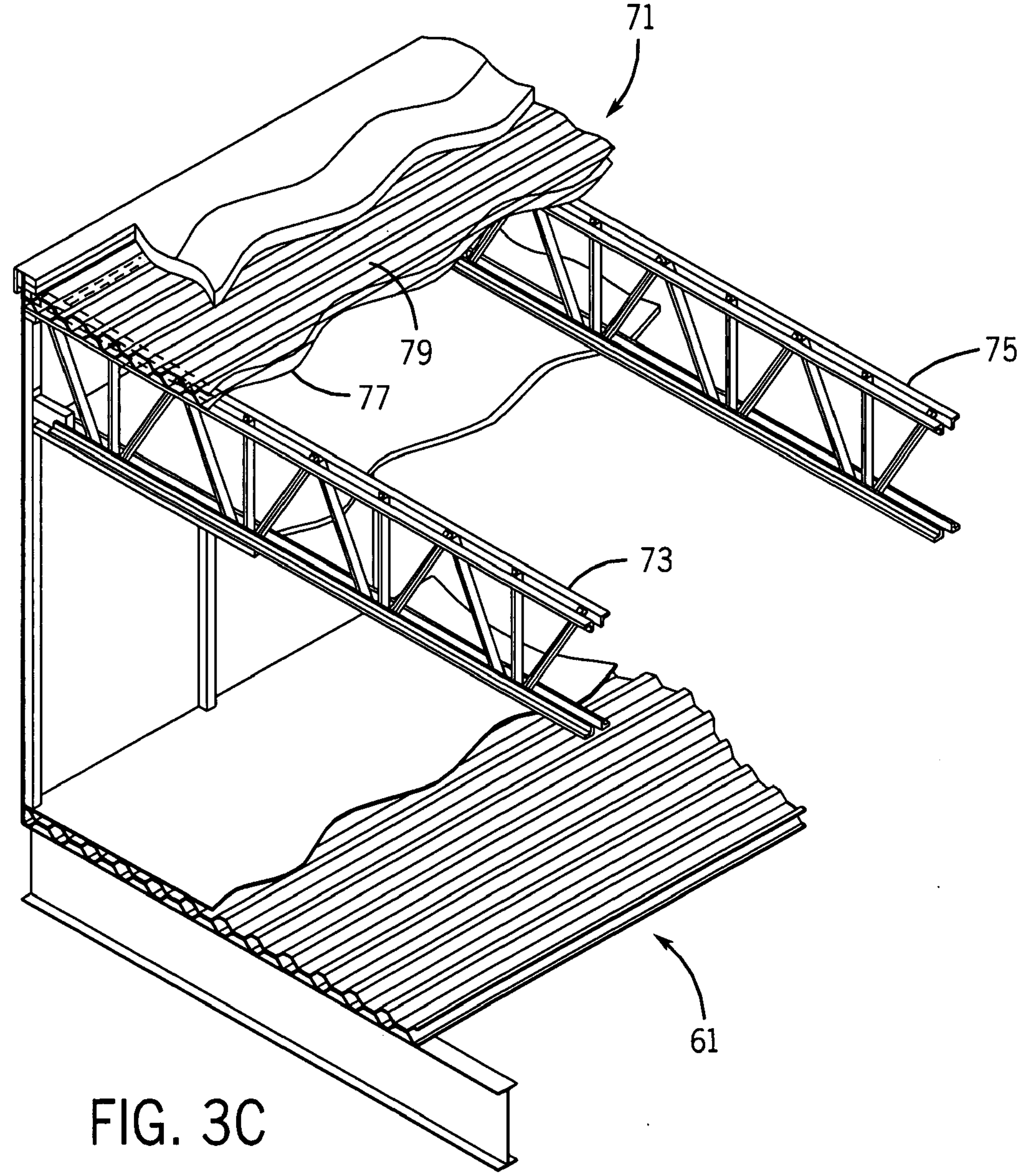


FIG. 3C

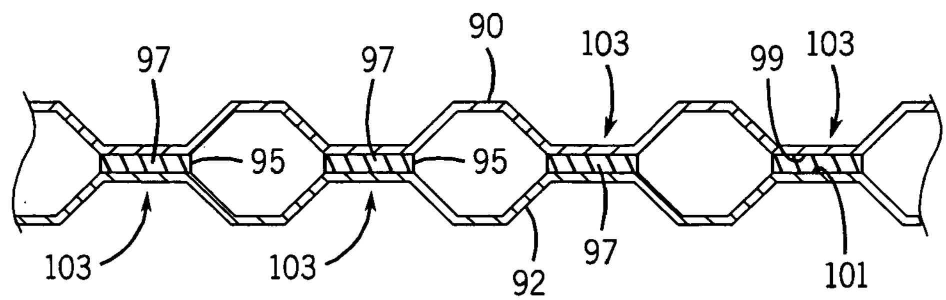


FIG. 9B

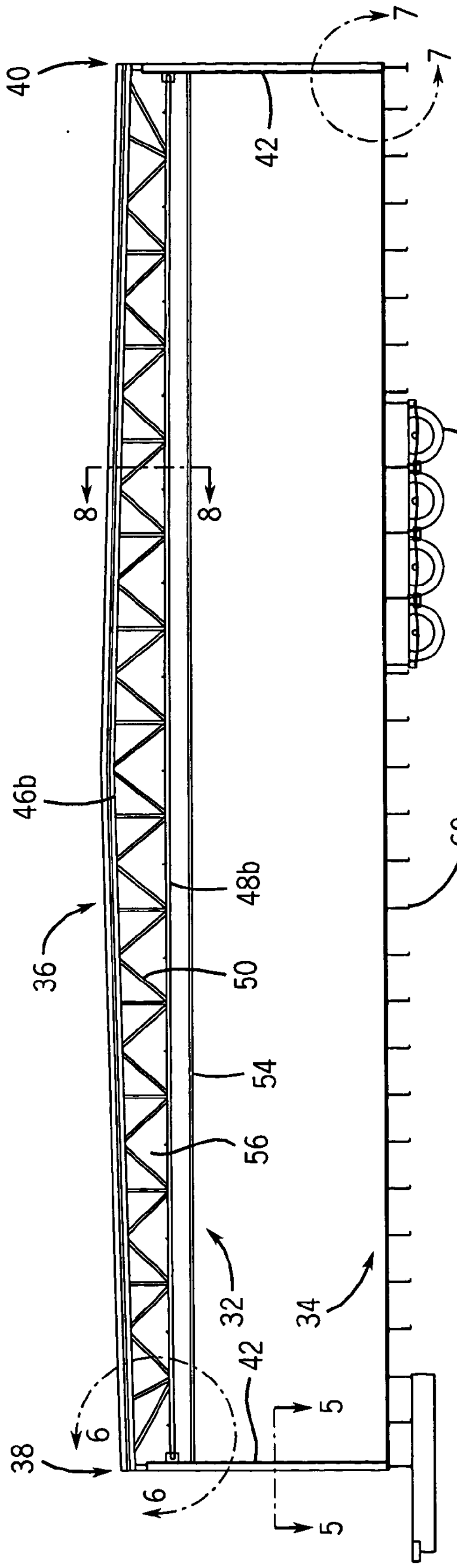
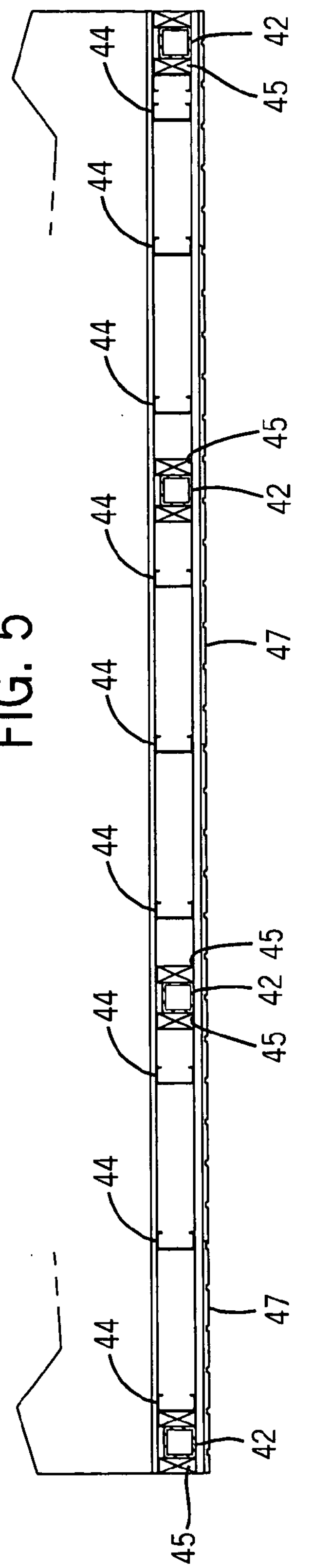

40
7
7
42
66
8
8
46b
60
48b
36
50
54
56
32
34
42
42
6
5
38
6
5

FIG. 4


44
42
45
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42
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47
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42
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42
45

FIG. 5

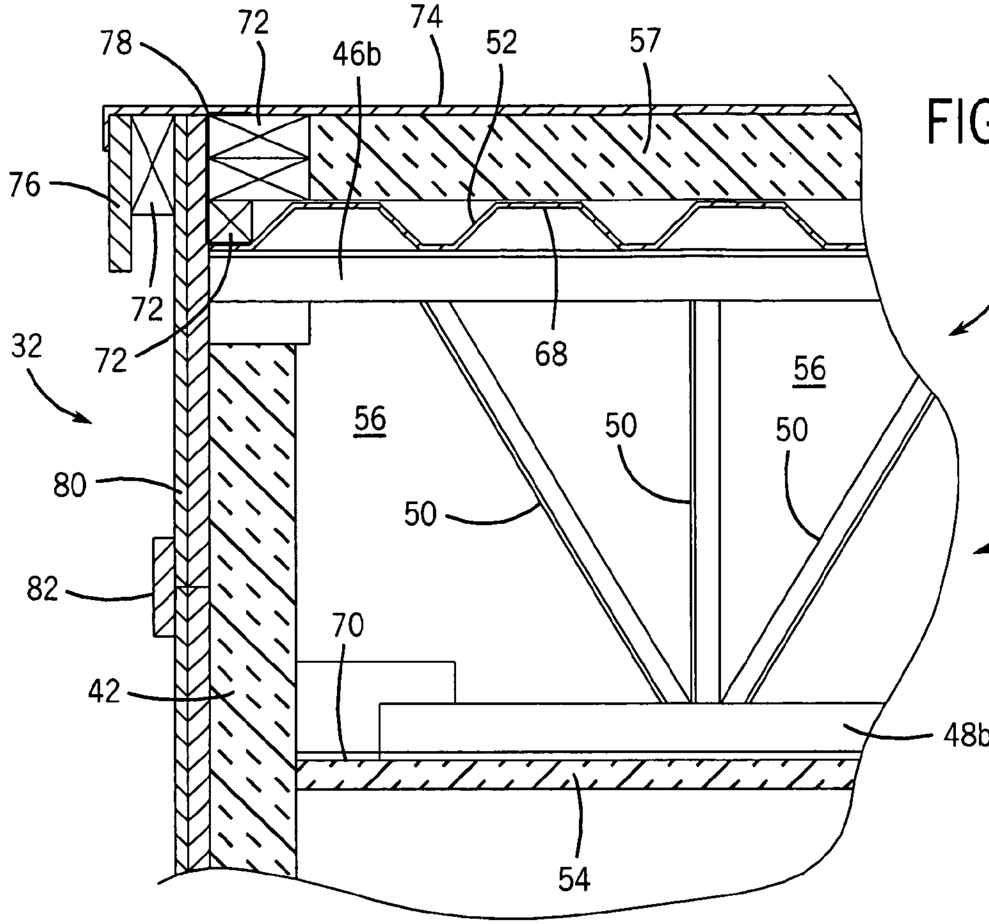
78
72
74
46b
52
57
76
72
72
36
68
32
56
56
50
50
37
80
50
82
70
42
48b
54

FIG. 6

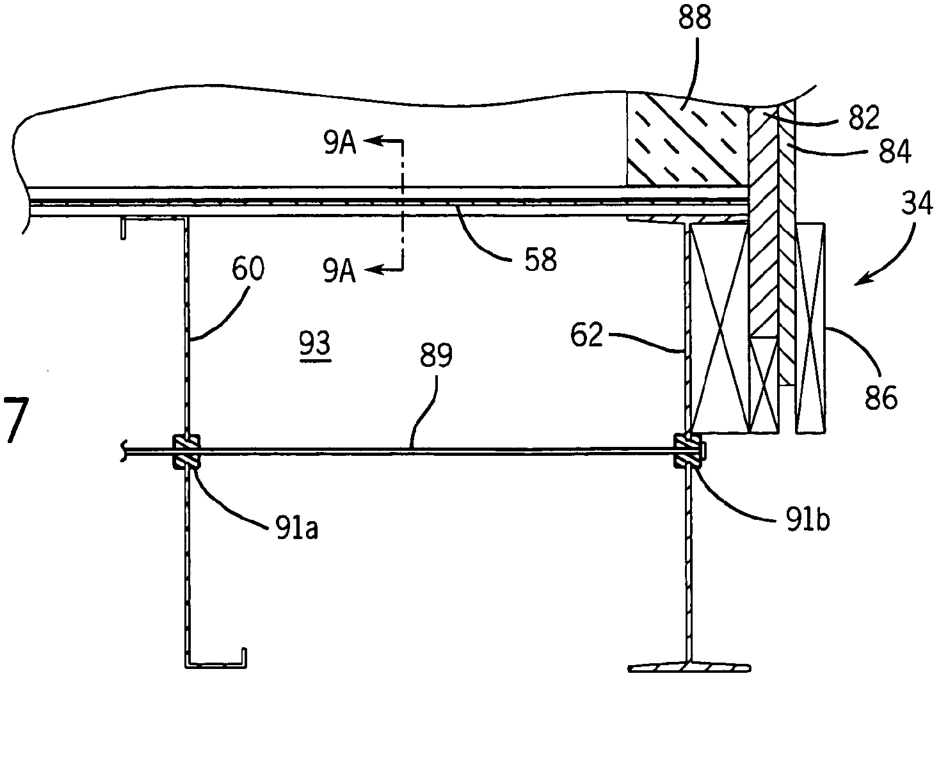
88
82
9A
84
34
9A
58
60
93
62
89
86
91a
91b

FIG. 7

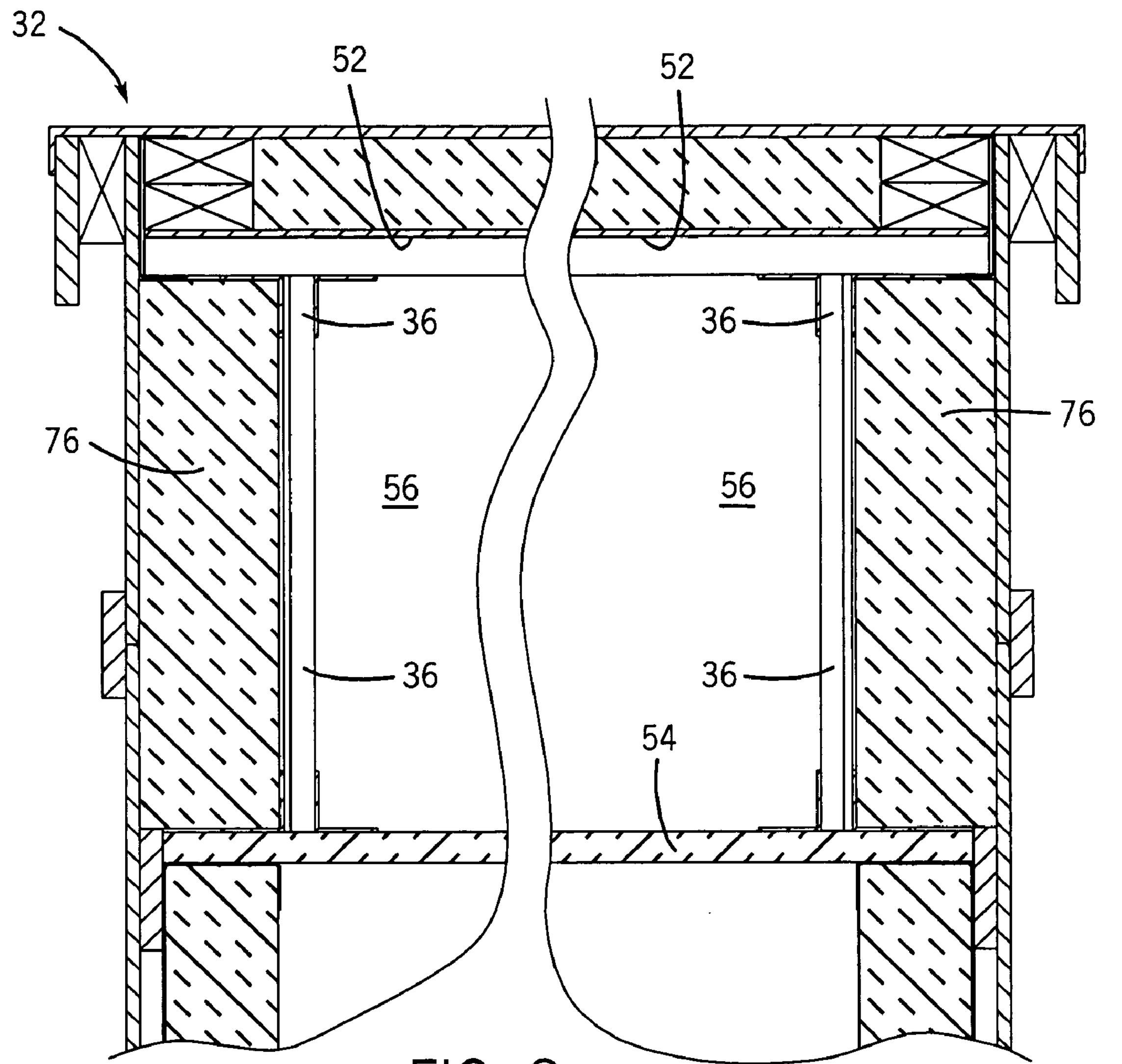

FIG. 8

MODULAR BUILDING STRUCTURE

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to modular building systems, and more particularly to modular building roof and floor structures.

[0002] Modularly constructed building structures are advantageous in that they provide shelter from the elements in which a variety of activities can be housed, and are relatively easily transported from one locale to another. Moreover, such structures can typically be assembled in stackable sections, or sections placed side-by-side (i.e., the sections are positioned adjacent each other), right on site after being transported. Modular building structures can be used for production of single and multi-unit or multi-family homes, as well as apartments, condominiums, classrooms, general offices, medical facilities, commercial buildings and the like.

[0003] Many modular building structures are custom designed. However, building structures can also be designed according to standard or pre-fabricated building templates as well. Today's modular building structures are computer-engineered to meet national building codes. They can be precisely engineered for increased structural durability. High quality can be maintained by inspection during construction process. In one construction example, a modular building structure is delivered to a desired site, after which individual modular structures or "modules" are assembled into an overall modular building structure.

[0004] In general, the metrics of building construction costs break out on a per square foot basis. It is a continuous goal to reduce the construction costs of the modular structures. To this end, it would be desirable to provide a modular building structure that, while meeting all applicable building codes and other standards, is simpler to construct than known modular building structures. For example, a building structure comprising fewer pieces, parts or other components in its construction is desirable. Similarly, material selection for such modular building structures is key, in that the material type and placement can result in a building structure of having a greater useful life and durability.

[0005] It would also be desirable to use stronger and more durable modules or substructures in making the overall modular building structure. This can lead to a decrease in the number of supports or braces in a given area, thereby reducing modular building structure costs on a square foot basis. Advantageously, the mating of various components can provide increased strength, which, in conjunction with the reduction in the number of support structures, reduces overall modular weight, in addition to construction and transportation costs.

[0006] Further, in the modular building structure industry, there are increasing requirements aimed at improving the structure resistance to mold and combustion. Accordingly, it would be desirable to provide a modular building structure that increases the used of stainless steel materials in order to achieve these desired ends.

BRIEF SUMMARY OF THE INVENTION

[0007] An inventive modular building structure is disclosed herein. In one embodiment, a modular building roof structure in combination with an acoustical ceiling is disclosed, the combination comprising a modular building roof structure comprising a plurality of truss structures each having a top and a bottom; a pair of deck layers attached to and for transversely spanning the tops of the truss structures; and an acoustical ceiling suspended along the bottoms of the truss structures; wherein the deck and the acoustical ceiling define a return air plenum.

[0008] In another embodiment, a modular building floor structure is disclosed comprising a deck structure including an upper deck pan and a lower deck pan disposed opposite and adjacent each other to create a plurality of spaced apart support channels; and a plurality of support beams for supporting the deck structure. In a preferred embodiment, the deck structure is oriented transverse to the support beams.

[0009] And in another embodiment, a modular building structure is disclosed comprising a modular building roof structure in combination with a suspended acoustical ceiling system, the combination comprising a modular building roof structure comprising a plurality of truss structures each having a top and a bottom; a pair of deck layers attached to and for transversely. spanning the tops of the truss structures; and an acoustical ceiling suspended along the bottoms of the truss structures; and a modular building floor structure comprising a deck structure including an upper deck pan and a lower deck pan disposed opposite and adjacent each other to create a plurality of spaced apart support channels; and a plurality of support beams for supporting the deck structure; wherein the deck and the acoustical ceiling define a return air plenum. In a preferred embodiment, the deck structure is oriented transverse to the support beams.

[0010] Other objects, aspects, and advantages of the invention will be apparent upon a thorough reading of the detailed description below along with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Embodiments of the invention are disclosed with reference to the accompanying drawings and are for illustrative purposes only. The invention is not limited in its application to the details of construction or the arrangement of the components illustrated in the drawings. The invention is capable of other embodiments or of being practiced or carried out in other various ways. Like reference numerals are used to indicate like components.

[0012] **FIG. 1** is a perspective view of a group of modular building structures according to one aspect of the present invention;

[0013] **FIG. 2** is a top plan view of a plurality of modular building structures;

[0014] **FIG. 3A** is a cut-away partial perspective view of the modular building structure taken along line **3A-3A** of **FIG. 1**;

[0015] **FIG. 3B** is an alternative embodiment of the perspective view of the modular building structure of **FIG. 3A** showing the use of an I-beam dual deck pan floor construction;

[0016] **FIG. 3C** is a is an alternative embodiment of the perspective view of the modular building structure of **FIG.**

3A showing the use of an I-beam dual deck pan floor construction in addition to a dual deck pan roof construction;

[**0017**] **FIG. 4** is a cross-sectional view of the modular building structure taken along line **4-4** of **FIG. 1**;

[**0018**] **FIG. 5** is a cross-sectional view taken along line **5-5** of **FIG. 4**;

[**0019**] **FIG. 6** is an enlarged sectional view taken along line **6-6** of **FIG. 4** showing a portion of the modular building roof structure;

[**0020**] **FIG. 7** is an enlarged sectional view taken along line **7-7** of **FIG. 4** showing a portion of the modular building floor structure;

[**0021**] **FIG. 8** is an enlarged cross-sectional view taken along line **8-8** of **FIG. 4** showing a portion of the modular building roof structure with a return air plenum according to one aspect of the present invention;

[**0022**] **FIG. 9A** is an enlarged cross-sectional view taken along line **9A-9A** of **FIG. 7** showing the pair of deck pans according to one aspect of the present invention;

[**0023**] **FIG. 9B** is an alternative embodiment of the pair of deck pans shown in a spaced apart arrangement; and

DETAILED DESCRIPTION OF THE INVENTION

[**0024**] Referring to **FIG. 1**, a perspective view of a group of modular building structures **10** are shown. The group includes any number (as indicated by the hashed lines) of individual structures **12***a-d*, such as modular structure **12***b*, which can be aligned or positioned in a repeatable fashion as shown according to the space requirements for the particular application. In the embodiment shown, the modular units include roof structures **18** having a pitch with an apex along centerline **21**. In select applications, the roof structures **18** can be constructed in a flattened manner to the extent that modular units can be stacked to facilitate transportation of multiple units to specific locations. In general, if stacking of the modular structures is desired, as is contemplated in multi-story applications of the present invention, the roof structure pitch is typically reduced or eliminated altogether. Applications for modular building structures such as that shown in **FIG. 1** include office, educational, health or medical, laboratory space, residential, and light manufacturing, among others. In a typical construction, each modular building unit can include such features as doors **14** and windows **16**, replicating features found in permanent building structures. Each individual structure or module **12***a-d* has in and of itself the requisite elements to resist the lateral loads due to winds and earthquake conditions. Advantageously, the lateral loads resistance or lateral load bearing characteristics are also additive. That is, when the structures are placed next to one another side to side, the lateral load resistance is additive. Therefore, providing one structure with x lateral load resistance level next to another structure with y lateral load resistance, an additive effect of x+y total lateral load resistance will be achieved. The combined structure will be able to withstand the combined individual additive lateral loads. When a plurality of the modular buildings are placed laterally together to create a modular building group having a total lateral load bearing characteristic, the total lateral load bearing characteristic is additive from the individual modular building lateral load bearing characteristics.

[**0025**] **FIG. 2** is a top plan view of a plurality **20** of modular building structures **22***a-e*. In structure **22***d*, a portion of the modular building structure interior **24** is shown along with several interior elements **26** (e.g., a sink, a toilet, a door, etc.). In the embodiment shown, the modular structures are shown positioned in side-by-side or adjacent fashion, however, it is contemplated that the modular units can be arranged or positioned in ways that can vary to convenience. In addition, the modular units are scaleable, both in size and number, depending on the application at hand.

[**0026**] **FIG. 3A** is a cut-away partial perspective view of modular building structure **10** taken along line 3A-3A of **FIG. 1**. In **FIG. 3A**, various components and layers are illustrated in cutaway fashion to facilitate understanding of the invention. **FIG. 4** is a cross-sectional view of the modular building structure **10** taken along line **4-4** of **FIG. 1**.

[**0027**] Referring to **FIGS. 3A and 4**, modular building structure **10** includes a modular building roof structure **32** and a modular building floor structure **34**. The modular building roof structure **32** includes a plurality of longitudinal, open web trusses **36**. Each of the plurality of trusses **36** has a first end **38 (FIG. 3A)** and a second end **40** opposite the first end. Tubular columns **42** may be positioned at the first and second ends **38**, **40** of the trusses **36** for supporting the trusses. The ends **38**,**40** of the trusses **36** may also be supported by a two-dimensional frame in order to reduce the number of columns required Each truss or truss structure **36** includes longitudinally disposed supporting beams **46** and **48** connected in overlapping or "sandwiched" fashion using tension and compression members **50**. The beams **46** and **48** are, in the embodiment shown, comprised of individual support beam members **46***a,b* and **48***a,b*. A deck **52** is attached to and spans the tops **35** of the truss structures **36**. In one embodiment, the deck is roll-formed and can be made of steel. A suspended acoustical ceiling **54**, which may be of a ceiling tile variety, can be suspended along the bottoms **39** of the trusses and in this fashion be combined with the modular roof structure **32**.

[**0028**] Significantly, the deck **52** and the suspended acoustical ceiling define a return air plenum space **56**. The return air plenum space **56**, in combination with any physical vents, provides for proper venting, distribution and circulation of air, including introduction of fresh air, throughout the modular structure. As a result of the present structural arrangement, no separate ductwork or duct system is required, which provides savings in the manufacture, both in terms of material and labor costs, of the modular building structure of the present invention. Preferably, at least one of the plurality of longitudinal, open web trusses, the plurality of tubular columns, and the roll-formed deck can be constructed of steel, and in a preferred embodiment, the deck **52** is substantially covered with a mold-resistant foam insulation material **57**. Accordingly, the modular building roof structure **32** can be described as substantially non-combustible and substantially mold-resistant.

[**0029**] The modular building structure **10** further includes a modular building floor structure **34** which is joined or connected to the roof structure **32** as shown via columns **42**.

The floor structure **34** includes a single layer deck structure **58**. A plurality of longitudinal main support beams **60**, also called "Z purlins", are connected to the deck pans and are oriented transverse to the length of the floor structure. Advantageously, the present invention provides for the ability of the support beams to be positioned in spaced apart fashion, typically about 12 to 14 feet apart over the entire length of the modular building unit. End support beams or "I-beams"**62** are utilized at the outer region of the floor structure. In one embodiment, a decking surface **64**, typically of a plywood, cement board, poured concrete or combination type, can be connected to, positioned or laid over, or otherwise formed over, the pair of deck pans. As an additional feature, wheels **66** can be provided to improve the mobility of the modular unit.

[0030] **FIG. 3B** is an embodiment of the perspective view of the modular building structure **10** of **FIG. 3A** showing an improvement through the use of an I-beam dual deck pan floor construction **61** for use in the overall floor structure **34**. The z purlins of **FIG. 3A** are replaced here on each edge with an I beam **63** that runs the length of the building **10**. Although not shown, the opposite edge would mirror the edge shown to complete the floor structure. Advantageously, the result is the use of fewer heavy metal construction components. Specifically, the plurality of transverse z-purlins are replaced by only two I beams that run the length of module **10**. The benefits conferred by I-beams **63** include: reduction of construction costs of module **10**, reduced overall weight, and reduced material (which reduced material transportation costs), among others. A pair of deck pans **65** is utilized in order increase strength. The pair are oriented to be transverse to the length of the I-beams such that the ribs of the pair run the width of module **10**. It is the increased strength of the transverse deck pan pair **65** that helps permit the use of the longitudinal I beams **63**, and at longer intervals between beams, to reduce the number of support beams required overall. The traverse dual decking **65** and the lengthwise I-beams **63** together make up the I-beam dual deck pan floor construction **61** for use in the overall floor structure **34**.

[0031] **FIG. 3C** is a is an alternative embodiment of the perspective view of the modular building structure of **FIG. 3B** showing the use of an I-beam dual deck pan floor construction **61** in addition to a dual deck pan roof construction **71**. By "dual deck pan roof construction" it is meant that the roof construction comprises two main trusses **73**, **75** along with a pair of deck pans **77**, **79**. Again, the dual pans provide additional structural support when compared to a single deck pan arrangement. The increased strength permits the weight of the roof to be supported by few trusses, as shown, trusses **73**, **75**, without deleterious effects such as buckling or significant bending. The benefits conferred by the roof structure shown include: reduction of construction costs, reduced overall weight, and reduced material (which reduce material transportation costs), among others.

[0032] **FIG. 6** is an enlarged sectional view taken along line **6-6** of **FIG. 4** showing a portion of the modular building roof structure **32**. Support member **46***b* and **48***b* are connected via tension and compression members **50**. Decking **52** is attached at its lower surface **68** to the top of truss **36**, and specifically as shown to member **46***b*. 1.5" deck is one material that is suitable for use in the present invention. Acoustical ceiling **54**, which is typically made of an insulation material, is attached at its upper surface **70** to decking **52** through the use of suspension wires. The roof structure and ceiling create combination **37**. Decking **52** and ceiling **54** create return air plenum **56**. Again, as a result of the present structural arrangement, no separate return air ductwork or duct system is required, the modular building structure of the present invention can be constructed for less money with fewer materials and with a less complicated air distribution system. Truss **36** is supported at its end by column **42**. Various supports **72** include, as shown, 2×2 or 2×4 wood supports members. A roofing material **74** (e.g., 0.060 in. EPDM) can be laid or applied to the upper surface of the foam insulation **57**. The roofing material can be secured, for example, to trim **76**. Supports **72** are connected and secured to the truss **36** via a track **78**, such as a "C" track, and covered by the roofing material **74**. Other paneling **80** and trim elements **82** can be added to complete the exterior of the roofing structure as desired.

[0033] **FIG. 8** is an enlarged cross-sectional view taken along line **8-8** of **FIG. 4** showing a portion of modular building roof structure **32** with plenum **56**. Space or plenum **56** runs, in a preferred embodiment, substantially the entire length of the modular building roof structure. Again, in a known fashion, the plenum is defined by the deck **52** at its upper boundary and the ceiling insulation material **54** on its lower boundary, as well as, by thermal insulation material **76** on its ends. The deck and ceiling are connected by truss **36**.

[0034] Referring to **FIG. 5**, a cross-sectional view taken along line **5-5** of **FIG. 4** is shown. As can be seen, a portion of the modular building structure is shown, illustrating several basic structural members. These members include tubular members **42**, "C" beams **44**, which, in conjunction with stud members **45** serve to provide the requisite support for the trusses and connects the roof structure with the floor structure of the modular building unit. Also, these members eliminate the need for intermediate support or support members within the overall modular building structure. Exterior panels **47** are also included to protect the exterior surface of the modular building structure.

[0035] **FIG. 7** is an enlarged sectional view taken along line **7-7** of **FIG. 4** showing a portion of the modular building floor structure **34**. Support beams, such as I-beam **62** and Z-purlins **60** which are shown in exemplary fashion, are used to support the deck pan **58** (with I-beams being used in transverse fashion when supporting dual layer deck pans). Again, foam insulation **82**, paneling **84** and trim **86** are used to provide protection and buttress the support beams. Stud **88**, preferably made of steel, provides the support necessary for the dual pans **58** to withstand the stresses imposed thereon. A steel strap **89** is shown for use in supporting insulation (not shown) which can be inserted or placed in space **93** located above the strap. The strap runs through center punches **91***a-b* (also called eyelits) in I-beam **62** and Z-beam **60**.

[0036] **FIG. 9A** is an enlarged cross-sectional view taken along line **9A-9A** of **FIG. 7** showing deck structure pair **65** of deck pans. In one embodiment, 1.5" deck is one material that is suitable for use in the present invention, although other materials are possible and contemplated. More specifically, an upper deck pan **90** and a lower deck pan **92** are positioned in opposing adjacent fashion to create the deck support. The positioning of the pans **90**, **92** create support channels **94**, spaced apart by regions **96** in which the pans contact or substantially contact each other. One manner of accomplishing this arrangement is to take a first rolled, corrugated deck pan, and position it in opposing fashion with a similar, if not identical, second deck pan. The arrangement illustrated promotes maximum strength and rigidity for the modular floor structure, while minimizing the need for additional or unnecessary floor structure support members. Additionally, bending or other deflection of the floor structure is also minimized. As a result, the deck structure is capable of supporting a greater load than each of one of the pair of deck pans individually. Also, the deck structure has a combined deflection level that is less than an individual deflection level for each of the deck pans individually for a given load. Advantageously, the strengthening can be accomplished using materials, such as those described herein, that are common in the modular building industry. Moreover, it is contemplated to add or insert materials into channels **94**, with the insertion of said additional materials adding to the strength of deck structure pair **58**.

[0037] **FIG. 9B** is an alternative embodiment of the pair of deck pans **90**, **92** shown in a adjacent and opposed relationship with a spaced apart arrangement to create gaps **95**. This arrangement can be used on the roof structure in addition to the floor structure of the present invention. In the embodiment shown, spacers **97** are inserted into gaps **95** to provide a separation between deck pan **90** and pan **92**, and more specifically, to separate deck pan interior surfaces **99**, **101**. Here, in regions **103**, the deck pans contact spacers rather than the opposing deck pans directly. Significantly, spacers **97** provide for enhanced load distribution for a given load. Resultantly, when compared to a single layer deck pan, and even some dual deck pan arrangmenets, for steel deck pans of a given gauge, a greater load can be distributed, and alternatively, for a given load, the embodiment of **FIG. 9B** permits the use of a lighter gauge steel.

[0038] While the present invention has been described in terms of the preferred embodiment, it is recognized that equivalents, alternatives, and modifications, aside from those expressly stated, are possible and within the scope of the appending claims.

What is claimed is:

1. A modular building roof structure in combination with an acoustical ceiling, the combination comprising:

a modular building roof structure comprising:

a plurality of truss structures each having a top and a bottom;

a pair of deck layers attached to and for transversely spanning the tops of the truss structures; and

an acoustical ceiling suspended along the bottoms of the truss structures;

wherein the deck and the acoustical ceiling define a return air plenum.

2. The combination of claim 1 wherein the trusses further comprise a plurality of longitudinally disposed supporting beams connected in overlapping relationship to a plurality of tension and compression members such that the trusses form a longitudinal, open web truss structure.

3. The combination of claim 1 wherein the pair of deck layers is roll-formed.

4. The combination of claim 1 wherein the pair of deck layers is corrugated.

5. The combination of claim 1 wherein the pair of deck layers is constructed of steel.

6. The combination of claim 1 wherein the modular building roof structure is at least one of substantially non-combustible and substantially mold-resistant.

7. The combination of claim 1 further wherein at least one of the plurality of longitudinal, open web trusses, the plurality of tubular columns, and the roll-formed deck comprise steel.

8. A modular building floor structure comprising:

a deck structure including an upper deck pan and a lower deck pan disposed opposite and adjacent to each other to create a plurality of spaced apart support channels; and

a plurality of support beams for supporting the deck structure;

wherein the deck structure is oriented transverse to the support beams.

9. The modular building floor structure of claim 8 further comprising a decking surface laid over the pair of deck pans.

10. The modular building floor structure of claim 9 wherein the decking surface includes plywood and wherein the plywood is supported at least in part by the support channels.

11. The modular building floor structure of claim 8 wherein the decking surface includes cement board and wherein the cement board is supported at least in part by the spaced apart support channels.

12. The modular building floor structure of claim 8 wherein the decking surface includes poured concrete and wherein the concrete is supported at least in part by the support channels.

13. The modular building floor structure of claim 8 wherein at least one of the upper and lower deck pans is corrugated.

14. The modular building floor structure of claim 8 wherein the deck structure is capable of supporting a greater load than each of one of the pair of deck pans individually.

15. The modular building floor structure of claim 8 wherein the deck structure has a combined deflection level that is less than an individual deflection level for each of the deck pans individually for a given load.

16. The modular building floor structure of claim 8 wherein the support members comprise at least one I-beam.

17. The modular building floor structure of claim 16 wherein the support members comprise two I-beams.

18. The modular building floor structure of claim 8 wherein the plurality of main support beams are spaced apart in intervals that are in a range of about 12 to about 14 feet.

19. A modular building structure comprising:

a modular building roof structure in combination with a suspended acoustical ceiling system, the combination comprising:

a modular building roof structure comprising:

a plurality of truss structures each having a top and a bottom;

a pair of deck layers attached to and for transversely spanning the tops of the truss structures; and

an acoustical ceiling suspended along the bottoms of the truss structures; and

a modular building floor structure comprising:

a deck structure including an upper deck pan and a lower deck pan disposed opposite and adjacent each other to create a plurality of spaced apart support channels; and

a plurality of support beams for supporting the deck structure;

wherein the deck and the acoustical ceiling define a return air plenum; and

wherein the deck structure is oriented transverse to the support beams.

20. The modular building structure of claim 19 wherein the upper deck pan and the lower deck pan are separated to create a plurality of deck gaps, and further including a plurality of spacers inserted into the plurality of deck gaps.

21. The modular building structure of claim 19 further including inserting support materials into the plurality of spaced apart support channels for increasing the support strength of the deck structure.

22. The modular building structure of claim 19 wherein each modular building has a lateral load bearing characteristic, and that when a plurality of the modular buildings are placed laterally together to create a modular building group having a total lateral load bearing characteristic, the total lateral load bearing characteristic is additive from the individual modular building lateral load bearing characteristics.

23. The modular building structure of claim 19 wherein the pair of deck layers are separated to create a plurality of deck gaps, and further including a plurality of spacers inserted into the plurality of deck gaps.

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