United States Patent

Edgar

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[45] **Oct. 10, 1972**

[54] **STRUCTURAL CORE**

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[21] Appl. No.: **56,832**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 600,897, Dec. 12, 1966, abandoned.

[52] **U.S. Cl.** **264/45,** 156/78, 156/79, 156/245, 156/254, 156/264, 264/51, 264/158, 264/272

[51] **Int. Cl.**.....**B29d 27/04,** B29h 7/20, B32b 31/18

[58] **Field of Search**.....156/39, 43, 77, 78, 242, 245, 156/254, 264, 79; 264/41, 45, 58, 51, 158, 272

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[57] **ABSTRACT**

A structural core is formed by filling a rigid frame with an expanded synthetic polymer composition which may include fillers and which is adhesively secured to the frame. The resultant foam filled frame is then sliced to form panel cores. Finished panels are made by laminating panel faces to one or both sides of the core, or by painting, or otherwise treating the panel core. In one embodiment, the frame may be built up of a plurality of frame members with removable spacers to permit sawing of the foamed material without sawing the frame. The cores and panels thus constructed are useful in doors, walls, floors, roofs, etc. in buildings and in furniture and other structures outside the building industry. Reinforcing, electrical conductors, plumbing, etc. may also be built into the cores.

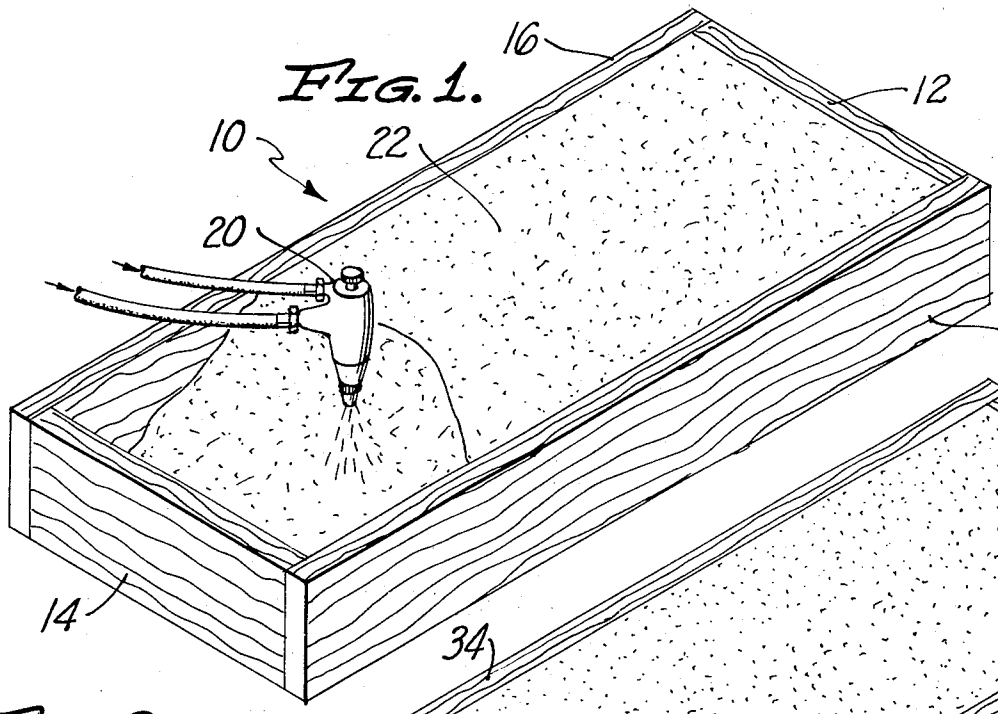
12 Claims, 14 Drawing Figures

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FIG. 1.



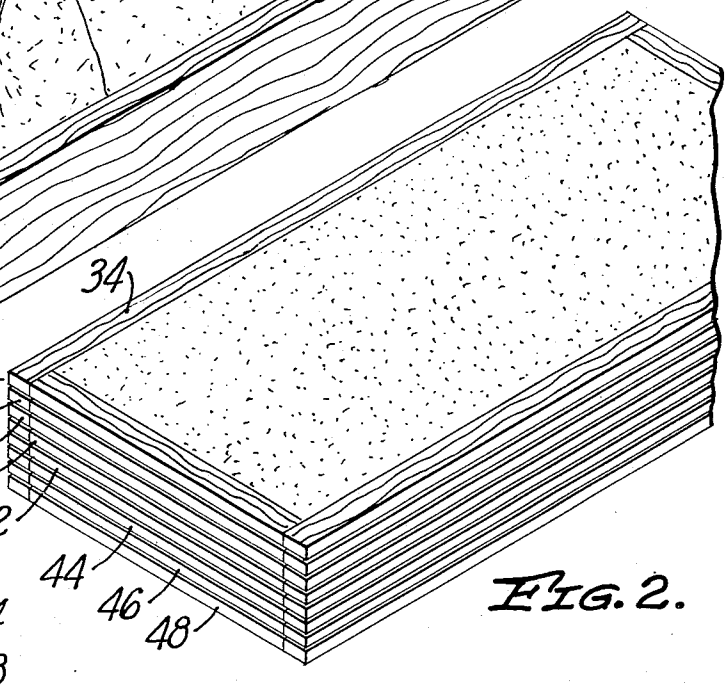


FIG. 2.

FIG. 3.

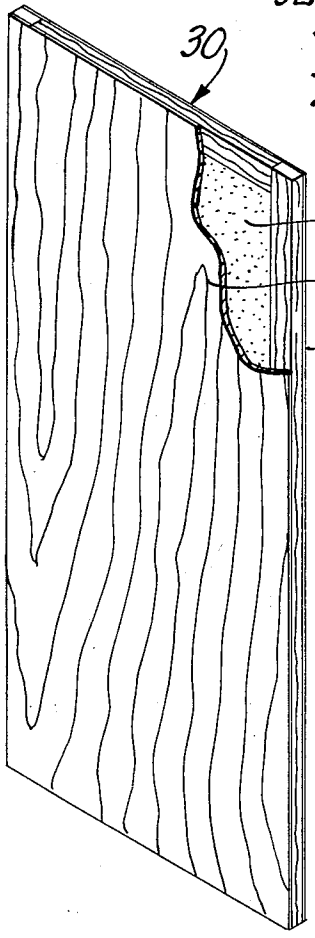


FIG. 4.

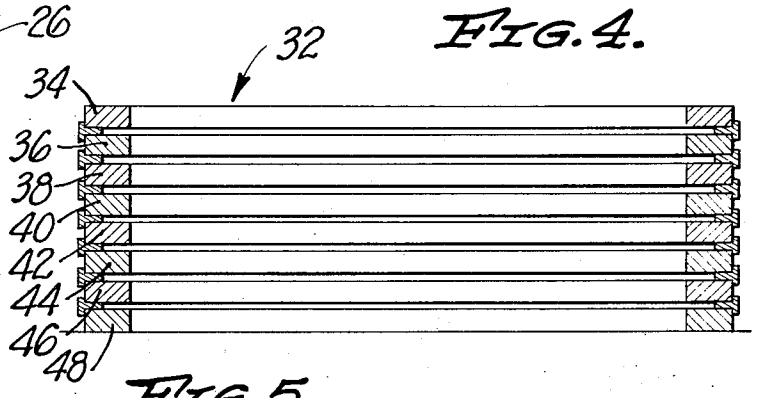
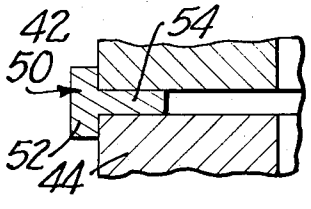


FIG. 5.



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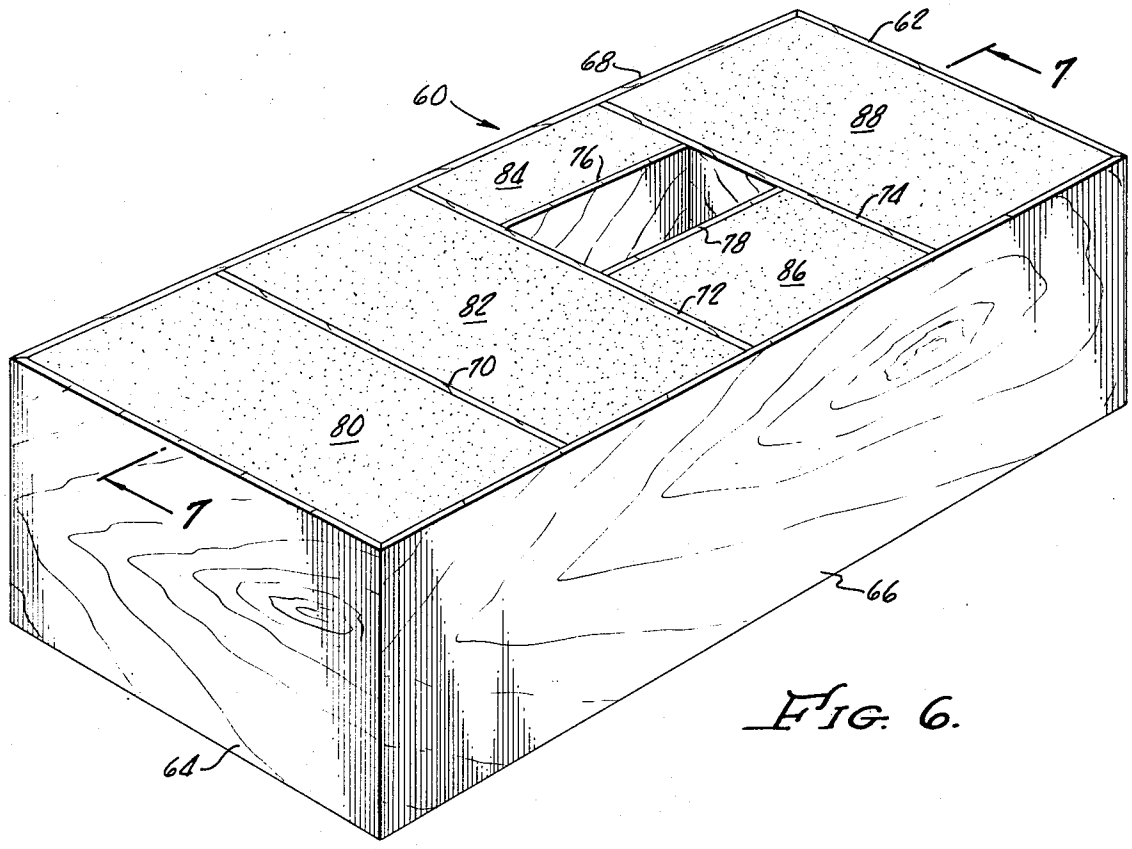


FIG. 6.

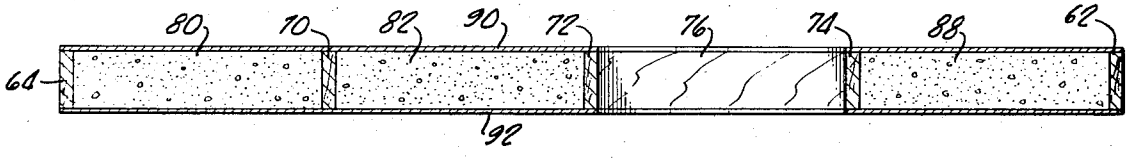


FIG. 7.

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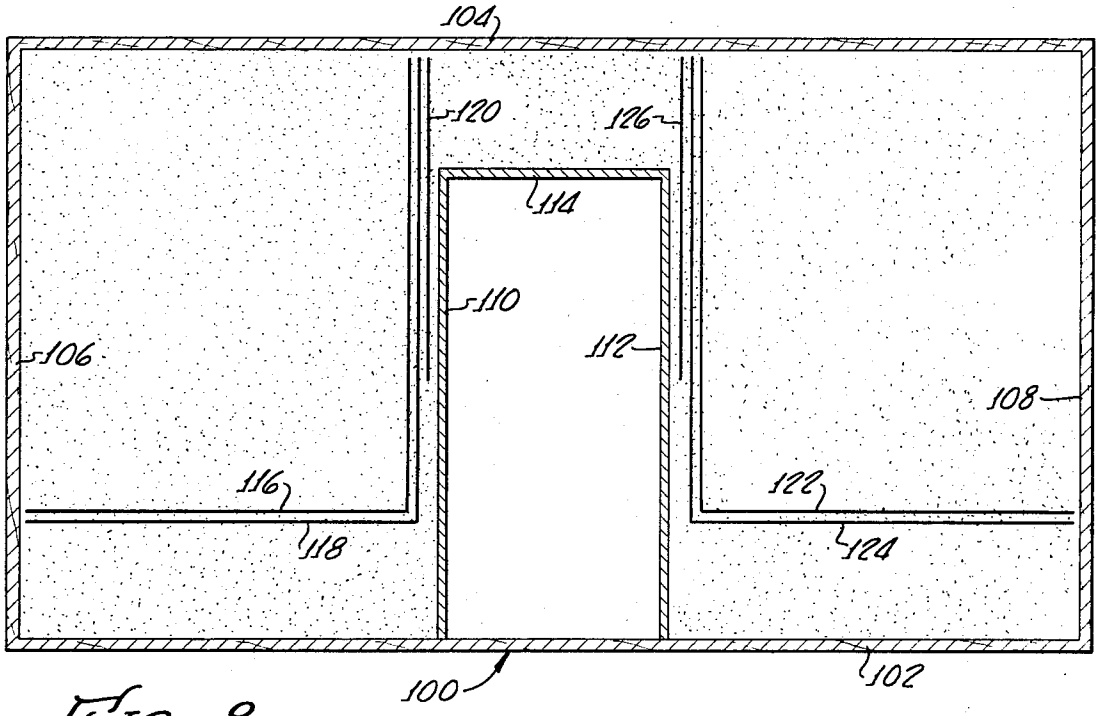


FIG. 8.

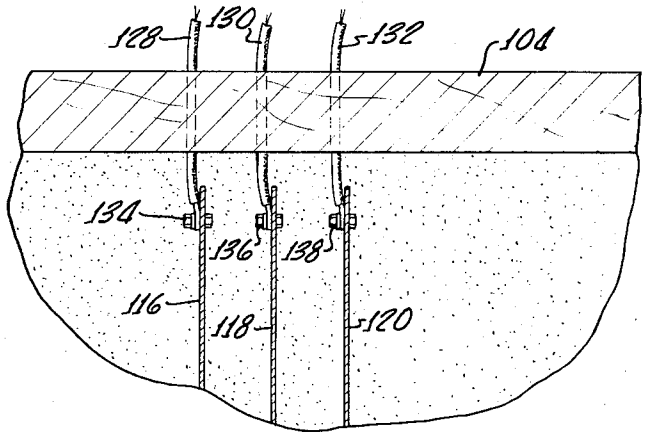


FIG. 9.

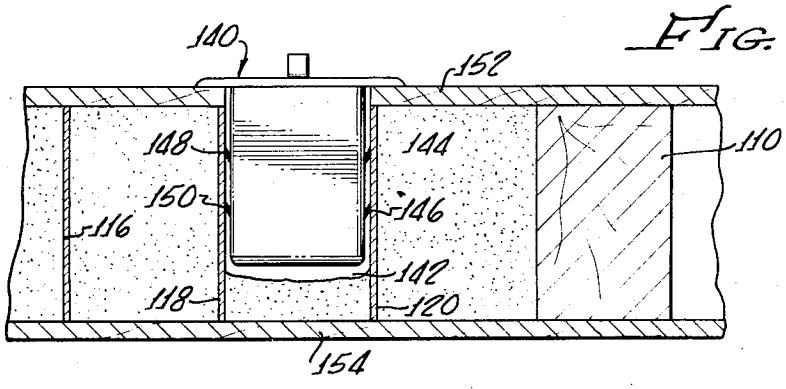
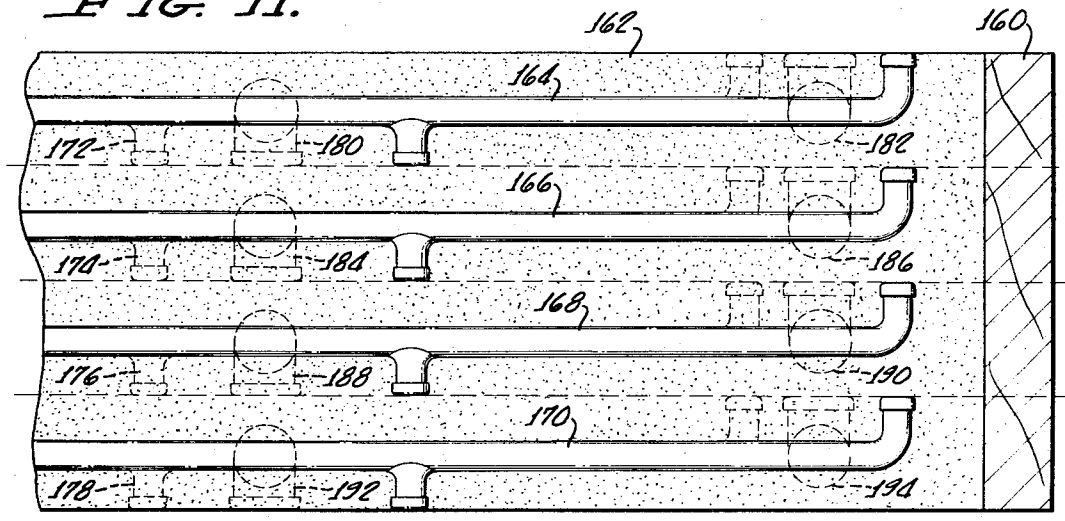
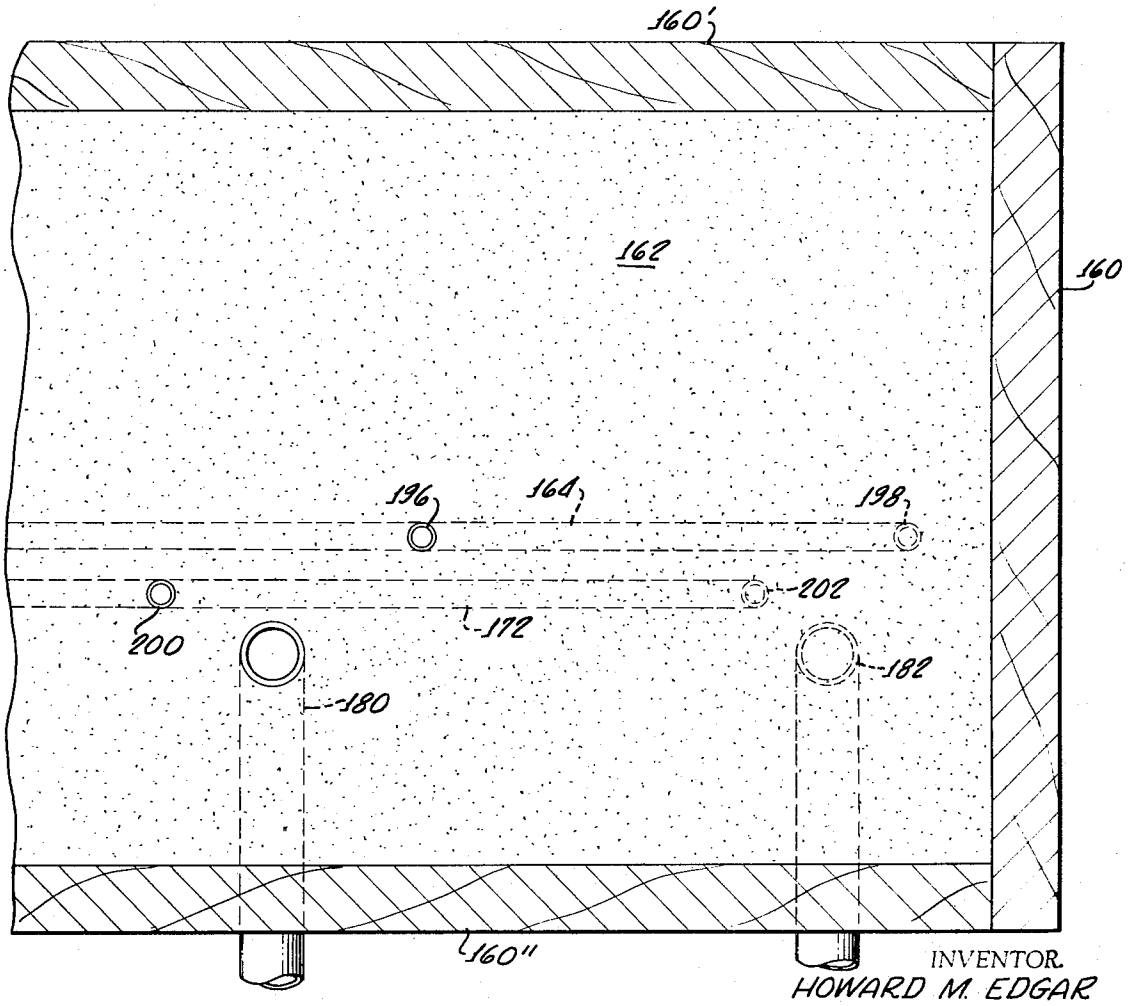


FIG. 10.

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FIG. 11.





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FIG. 12.

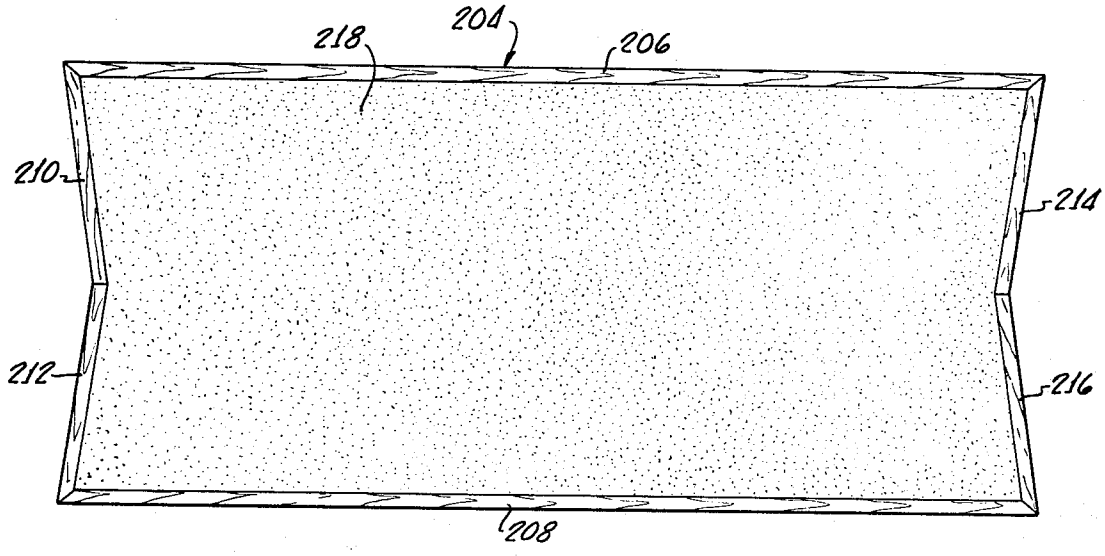


FIG. 13.

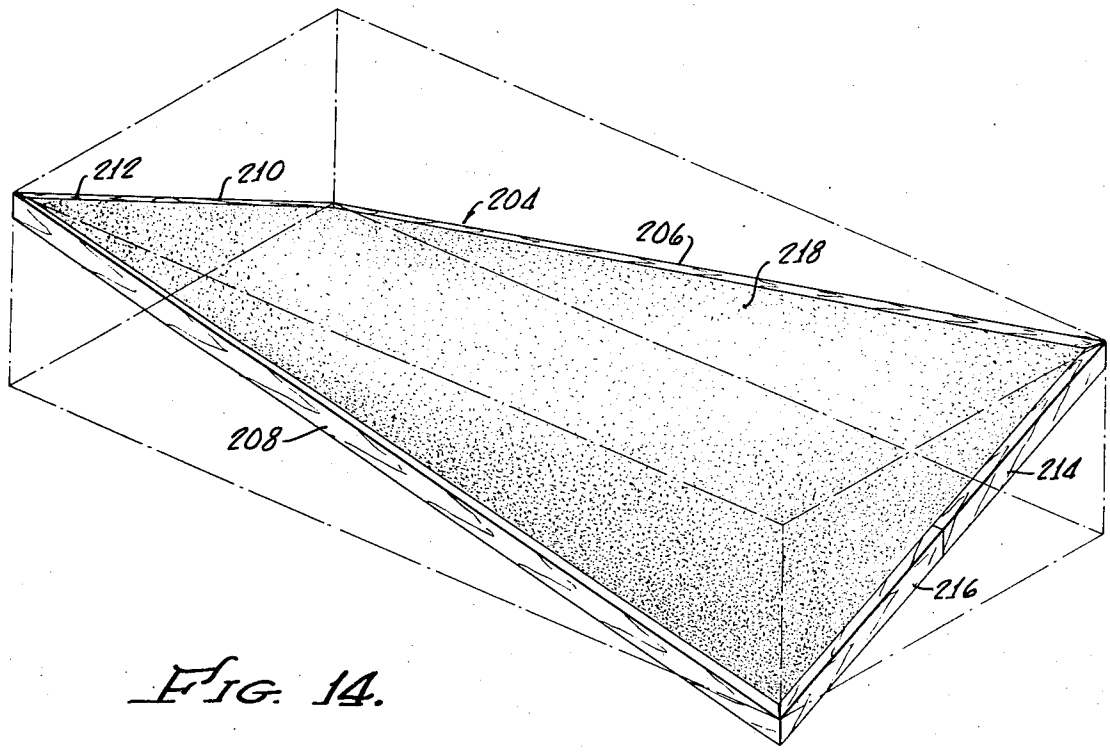


FIG. 14.

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STRUCTURAL CORE

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of my Pat. application Ser. No. 600,897, filed Dec. 12, 1966, entitled STRUCTURAL CORE AND METHOD OF MANUFACTURE, allowed Apr. 22, 1970, now abandoned.

The technology of foamed or expanded plastics is well developed. Most thermoplastic or thermosetting resins can be expanded in volume to create cellular structures which resemble fine honeycombs or masses of tiny hollow spheres fused together. Foaming is conventionally accomplished by mechanical frothing, dissolving a gas or low boiling point liquid in the resin, or by incorporating a foaming or blowing agent which will release an inert gas in the resin when the temperature is increased. Many adaptations and variations of these techniques are known.

The inclusion of a great variety of fillers, pigments, reinforcing materials, and other solid materials in foamed resins is also well developed. By the use of appropriate fillers, pigments, etc. a great variety of foamed plastics having many desirable structural, physical and aesthetic characteristics can be obtained.

Among the more common foamed plastics are the foamed urethanes. Urethane foams are cellular plastics formed by an isocyanate and a polyol reacted in the presence of catalysts and usually in the presence of several control agents and boiling agents. By varying the ratio of raw materials for the foaming conditions, a broad spectrum of end properties may be produced. Polyols useful in urethane foam production are polyethers such as the propylene oxide adducts of sorbitol, sucrose, diamines, pentaerythritol and methyl glucoside. Blowing agents such as carbon dioxide produced by the reaction of water with isocyanate, fluorocarbon-11, and methylene chloride are commonly used. Widely used catalysts include tertiary amines in combination with stannous salts. Additives such as fire retardant agents, extenders, dyes, colorants, nucleating agents such as talc or carbon black and special purpose additives are commonly used.

Polystyrene foams and foamed vinyl resins, foamed polyethylene and polypropylene, phenolic foams, epoxy foams, foamed silicones and cellular cellulose materials are also well known.

There are many patents and publications available which discuss foamed systems of this type. The following publications are incorporated by reference as exemplary of sources of additional information regarding the above and other foam systems: MODERN PLASTICS ENCYCLOPEDIA, 1967, published September 1966, Volume 44, No. 1A, McGraw Hill, New York; "A New Look in Plastics in Building," MODERN PLASTICS, 42, 108, March, 1965; "Chemistry and Flame Retardancy of Rigid Urethane Foam," MODERN PLASTICS, 42, 197, January, 1965; "Formation of Cellular Plastics," BRITISH PLASTICS, 38, 552 (September, 1965); and Flory, PRINCIPLES OF POLYMER CHEMISTRY, George Banta Company, Menasha, Wisconsin, 1953 (5th printing, 1966).

The filling of interior voids with foam synthetic polymer compositions is also well known in the prior art. This technique provides a very satisfactory structural member. Relatively thin walled structures can be made firm and rigid while maintaining lightness and thermal insulating qualities. However, the previously taught individual foaming of structural members has many disadvantages. In relatively thin structural cores, a large unsupported side area is provided. Foaming produces large pressures and very rigid support must be provided if the sides are to be undistorted.

Furthermore, if foaming is completed after the sides are in place, as is conventional in the prior art, each of the structural members must be individually handled. Also, one end must be closed after foaming is complete.

Among the more serious problems of the prior art are those problems resulting from the incomplete or improper filling of a form or mold in which the surface area of the form is very high compared with the volume of foam produced. There is a distinct tendency for the foam either to leave large voids adjacent the surfaces of the form or to adhere to portions of the surface thus causing distortion of the foam and unequal filling of the foam or mold.

These and other serious problems are overcome by the present invention.

According to this invention, structural cores are produced by filling a rigid frame made up of members forming sides positioned in a pattern corresponding to the outline of the desired completed structural core. The frame has a height substantially greater than the thickness of the structural core or cores to be formed and has an open interior. The interior of the frame is filled with a lightweight expanded polymer composition material, which may include fillers, coloring materials, additives, etc., as previously alluded to, which adhesively attaches to the interior of the frame. The polymer composition or foam material is allowed to set or cure to a rigid condition.

The entire foam filled frame structure is then sliced into a plurality of cores. This usually is done by cutting the foam filled frame bun along relatively parallel planes so that each core includes a border of the frame and a quantity of foam filament material adhesively bonded to the frame. Of course, asymmetrical panels may be formed by cutting the foam filled frame bun along relatively nonparallel planes but in a manner in which the core thus formed includes a border of the frame to which the foam is adhesively bonded.

In this process, the expansion of the foam is toward the upper side of the structural frame, which is usually open. The frame is so constructed that the surface area in contact with the resin in any core formed from the frame is small compared with the surface area of the foam core when cut.

The edges of the frame which form the borders of the core are normally of a relatively heavy material such as wood, metal, high density resin, etc., so as to provide a degree of structural strength along the borders of the core. The faces of the core are preferably then covered by laminating a thin side panel to one or both sides of the core to form a finished structural member. Lamination is not always required since the core may be used as a structural member without further treatment or with only painting, varnishing, dying, or other treatment.

One of the significant advantages and very important commercial advantage of the present invention is that the foaming can be accomplished in a very large frame which, when sliced, results in a multiplicity of finished structural cores. The time and labor in handling the materials is very greatly reduced as compared with the construction of similar cores using the techniques of the prior art.

One of the features of this invention is that a plurality of structural cores can be produced according to the method of this invention more rapidly and more economically than is possible using conventional techniques. These cores may be used for a large variety of applications. Among the more obvious applications and uses of the structural cores of the invention are the use of such cores in doors, movable partitions and panels, furniture tops, sides, etc., and in other applications where structurally strong but lightweight panels are desirable.

According to one of the important features of the invention, the frame is so constructed and arranged that when the foam filled frame bun is sliced each slice constitutes the core of a major element of a building. Such major elements include walls, ceilings, roofs, floors, permanent and temporary partitions, or portions thereof. These structural units may be preformed with interior reinforcing elements, doors, windows, plumbing, electrical conduits, etc. so as to permit the production of finished or semi-finished structural units from an appropriately constructed foam filled frame simply by slicing the frame. The substantial savings in time, material and labor costs which may be accomplished through the inventive process are apparent.

Pressures resulting from the expansion of the foam in the frame are largely released through the expansion of the foam upwardly from a relatively large interior portion of the frame. This eliminates or reduces the need for heavy bracing to overcome foaming pressure. Where very large and deep foam filled frame buns are formed, some bracing is usually required but the cost of the bracing is substantially less expensive than is required in prior art techniques.

Several other features and advantages of the structural cores of the invention and the inventive process will be apparent from the specification and claims which follow and from the drawings to which reference is made.

FIG. **1** is an isometric view showing a step in the process of forming a structural core according to this invention; the step illustrated being the filling of the frame with a foaming synthetic polymer composition.

FIG. **2** is an isometric view, with certain portions broken away, showing an alternative embodiment of the invention wherein a plurality of individual frame or border members are built up into a frame into which the polymer composition is foamed.

FIG. **3** is an isometric view, with certain surface parts broken away, of a finished panel structural member which is made up by laminating sides on a core made according to the processes illustrated in FIG. **1** or FIG. **2**.

FIG. **4** is an enlarged transverse section of a plurality of frame or border members, such as are shown in FIG. **2**, showing the manner in which they are stacked and spaced prior to being filled with foamed polymer composition as, for example, illustrated in FIG. **1**.

FIG. **5** is an enlarged partial vertical section showing two adjacent frame members and a spacer of the type illustrated in FIG. **4**.

FIG. **6** is an isometric view of a foam filled frame bun showing interior reinforcing elements and an opening which forms a window opening in a finished wall; the frame bun being particularly adapted to being sliced into walls or wall units.

FIG. **7** is a cross sectional view of a panel formed from the foam filled frame bun of FIG. **6**, including laminated skins on both sides of the core.

FIG. **8** is a plan view of a wall unit formed according to this invention and the process described herein including an opening for a door and door framing and electrical conduit suitable for forming a portion of a building electrical circuitry system.

FIG. **9** is a cross section in enlarged scale of a portion of the panel shown in FIG. **8** illustrating a simplified method for attaching electric wiring to the conduitry built into the core.

FIG. **10** is a cross sectional view of a portion of a core of the type shown in FIG. **8** illustrating one method for connecting a switch box to the conduitry formed into the core.

FIG. **11** is a partial vertical section of a foam filled frame bun according to this invention including built in plumbing elements, the dashed lines indicating the planes along which the bun is to be sliced.

FIG. **12** is a partial elevational view of a core cut from the foam filled frame bun shown in FIG. **11** illustrating the relative placement of the plumbing elements therein.

FIG. **13** is a plan view of a structural core member cut from a foam filled bun for use in the manufacture of a curved roof panel.

FIG. **14** is a perspective view of the panel illustrated in FIG. **13** shown formed in a hyperperabolic configuration, the dashed lines indicating a rectangular space partially occupied by the curved structural core.

The structure and process of the invention is most easily described with reference to the drawings. In the embodiment of FIG. **1**, a frame **10** comprising a top **12**, bottom **14**, left side **16**, and right side **18**, is provided. The rectangular configuration of the frame **10** is illustrative and, of course, results in the desired configuration of structural core which is rectangular in external configuration. Should a different shape of core be desired, the frame **10** is arranged in such a manner as to define the lateral limits of the finished structural core. Furthermore, while butt corner joints are shown, it is equally clear that any conventional type of structural corner joint can be applied.

In an exemplary process, flush door cores are preferably produced from the structural frame **10**, and thus the interrelationship of the rails is that which is conventional for flush doors.

The frame **10** is open at the top and is closed at the bottom. The bottom closure may comprise merely the placing of the frame **10** upon a flat surface, or may comprise securing, temporarily or permanently, a bottom to the frame. The bottom may be a rigid sheet or panel member or it may simply be a paper or fabric for temporary use. The bottom may be formed of any convenient, inexpensive material and may desirably be of a nature as to prevent the sticking of the foamed or expanded polymer composition to the supporting base.

The height of the frame **10**, as illustrated in FIG. **1**, is at least as thick as a plurality of thicknesses of the structural cores which will be produced therefrom by slicing the foam filled frame bun formed according to the process. After the frame **10** is produced and closed, if desired, and placed on a supporting surface, the interior of the frame is filled. The step of filling comprises inserting by spraying, injecting, pouring, or by other means, any convenient foamable or expandable synthetic polymer composition which is suitable in physical characteristics for the purpose to which the structural core will be put.

In an illustrative embodiment, a conventional foam depositing nozzle **20** is illustrated as depositing lightweight material **22** through the open top of the frame **10** to fill the entire interior of the frame.

The synthetic polymer composition can be an expandable thermosetting or thermoplastic synthetic polymer composition such as, for example, urethane, polyester, polystyrene (which may be in the form of expandable beads) or any other expandable resinous material. Foamed plastics as described hereinbefore and those equivalent to such materials are generally suitable for use in this invention.

The expanded polymer composition, when cured, preferably has a density of from about one lb. per cubic foot to about 20 lbs. per cubic foot for most structures. If extremely high strength and/or high density cores are required, the density of the expanded polymer composition may be as high as 40 or 50 lbs. per cubic foot but for most structural purposes a density of 1.25 to 5 lbs. per cubic foot gives adequate strength, rigidity, and desirable structural characteristics.

Expansion of the polymer material may be induced by catalysts, heat probes, steam, or other techniques, some of which have been described hereinbefore.

Suitable lightweight materials, fillers, binders, reinforcing materials, dyes, pigments, and special additives may also be included in the expanded polymer composition. Lightweight aggregates mixed with binders, such as polyester, epoxy and other binders, may also be included in the polymer composition to give the desired physical and aesthetic characteristics. The particular material used is not critical, provided that it has a reasonable amount of rigidity and preferably that it adhesively attaches to the interior of the frame.

Adhesive attachment is particularly important in terms of high strength, rigidity, and economy in manufacture. Core structures of the prior art have been made using the "cut-and-fit" technique in which one of a plurality of pieces of foam are carefully cut to very precise dimensions and fitted into a carefully dimensioned frame. Resins and bonding materials are provided to secure the expanded polymer pieces together and to the frame. This technique obviously requires a great deal of time, is expensive in terms of labor, and the results are not entirely satisfactory because of the high criticality required in cutting and positioning.

The necessary bonding between the expanded polymer in the interior of the frame, in the present invention, is usually and is most conveniently accomplished simply by using a polymer composition which forms a structurally sound bond with the frame. The same result can be accomplished, less conveniently however, by coating the interior of the frame with an adhesive or other bonding material or a material which when in contact with or reacted with the expanded polymer forms an adhesive bond between the expanded polymer and the frame. For example, the interior of the frame may be coated with an epoxy, which forms an excellent bond with the expanded polymer. When the expanded polymer is curing, a comparatively high quantity of exothermic heat is generated which, in a properly designed system, is sufficient not only to result in the final curing of the expanded polymer but to cure the epoxy and thus form a high strength structurally sound adhesive bond between the expanded polymer and the frame. In most instances, however, it is unnecessary to provide special adhesive agents on the frame surface although preparation of the frame in the conventional manner to form a strong bond may be recommended.

After the frame is filled with lightweight material, such as filled or unfilled expanded polymer, the polymer is then cured. The cured foam filled frame is then sliced into individual structural cores. Preferably, this slicing comprises the slicing of a plurality of relatively thin structural cores from the frame and foam material structure. These slices are preferably planar, and are preferably of uniform thickness for most uses. In certain wall constructions and where particular aesthetic effects are desired, however, the planes may be of nonuniform thickness and the slices may be cut along relatively nonparallel planes. Thus, the cores may be wall panel cores and may, if desired, be thicker at the bottom than at the top. In any event, each slice forms a structural core which contains a portion of the frame which encloses the expanded polymer to form an edge border of the desired configuration.

The individual structural cores may be, of course, cut in any desired thickness. Moreover, a plurality of structural cores may be cut from a single foam filled frame bun in differing thicknesses and in differing configurations. In most instances, the structural cores would be cut in planes perpendicular to the axis of the frame but this is not required and pleasing aesthetic effect and, in certain instances, desired structural elements may be obtained by slicing the frame at an angle with respect to the axis thereof. Many thicknesses and styles of structural cores may be cut from a single expanded polymer composition filled frame.

It will be also be recognized that the foam filled frame buns also constitute an article of commerce. Thus, the expanded polymer composition filled frame bun may be prepared at one location and sold commercially to fabricators, manufacturers, and others for subsequent slicing into structural cores.

One structural core of uniform thickness formed by slicing the foam filled frame bun along parallel planes is illustrated in FIG. **3** at **24**. A plurality of the structural cores **24** are produced from a single foam filled frame bun comprising the frame **10** and the foam material **22**. Slicing is accomplished by means of a conventional band saw, when the frame is made of wood or by using hardened tooth band saws adapted to cut the particular material of which the frame is constructed.

After the individual structural cores, such as illustrated at **24**, are produced, they may be covered with a suitable cover sheet or panel. In the case of the structural core **24**, FIG. **3**, door skins **26** and **28** are laminated on the surfaces of the core. Depending on

the configuration and thickness, the structural cores can be used for the mass manufacture of lightweight panels for many uses. The panels may be used as table tops, counter tops, furniture panels, and any other items which have laminations of expanded polymer composition with veneers, metal plates, sheets, or other coverings including shaped or flat panels. The structural member **30**, which is specifically a door, falls within this class of structures. The door skins or other structural core coverings can be secured by any convenient means. Adhesive bonding is preferred, however. In the example of the structural member **30**, since it is flat rather than contoured, a plurality of such structural members can be placed together and the door skin secured thereto in stacked multiple relationship, to further save labor and press time. It will be understood that the structural member **30** merely exemplifies the invention and that the core need not be of uniform thickness, or rectangular configuration. Curved sawing and a curved frame will, of course, produce a core having at least one curved exterior surface. Curved or flexible panels can be laminated to such surfaces using conventional techniques.

FIGS. **2, 4** and **5** illustrate an alternative embodiment of the invention. In this embodiment a frame, generally indicated at **32** and corresponding to the frame **10** of FIG. **1**, is made up of a plurality of frame or border members. The border members making up the frame **32** are indicated at **34, 36, 38, 40, 42, 44, 46** and **48**. Each of the border member **34–48** has an appropriate external structure configuration defining edge or means.

In the structure shown, top, bottom and side border elements are provided so as to create a structural core of suitable nature and of desired configuration so as to be usable as the core of a flush door. Other outlines and configurations than the rectangular configuration illustrated can be provided, depending upon the needs and requirements of the finished panel or core.

In the frame **32** the structural cores are necessarily planar, as compared to the curves or otherwise nonplanar structural cores which can be cut from the frame **10**. An appropriate number of border members are used in accordance with the process requirements, the size of the equipment available, the number of units required, and other economic and technical considerations. By appropriate technique, any reasonable number can be used.

In order to maintain the frame or border members **34–38** in properly aligned stacked relationship, combined guide and spacer means **50** are provided. The combined guide and spacer means comprise a structure of T-shaped cross section with head **52** arranged to embrace the exterior of adjacent frame members. For example, in FIG. **5** the head **52** embraces frame members **42** and **44** so as to maintain them in vertical alignment. Guide and spacer means **50** extend all the way around the frame **32**. The combined guide and spacer means are preferably of unitary structure so as to maintain the frame members in appropriate stacked position. However, individual strips can be used so long as the frame assembled from the frame members and combined guide and spacer means is properly and evenly stacked or held in stacked relationship. The upright **54** of the T's, one of which is shown at **50**, extends inwardly between the rails of the adjacent frame members. In FIG. **5** it extends inwardly between the rails of frame members **42** and **44**. The amount of spacing produced by the uprights **54** is preferably equal to the kerf produced by the slicing means when the frame is sliced into individual structural cores.

As is illustrated in FIG. **4**, a combined guide and spacer means **50** is positioned between each adjacent pair of frame members. The resultant structure, as shown in FIGS. **2** and **4**, is quite similar to the frame **10**. After this frame is assembled, it is filled with foamed polymer composition in the same manner as previously described. After the foam material is set or cured so as to be relatively rigid, although complete curing is not always required, the combined guide and spacer means **50** is removed. In the case of individual strips, they are simply pulled out of place. In the case of a complete rigid structure, the structure is disconnected so that the combined guide and spacer means can be removed.

The foam filled frame bun, in which the frame is made up of a plurality of border elements forming the frame member **32** is then sliced into individual structural cores. Slicing is accomplished by sawing between the frame members so that each frame member defines the border or outline of the desired core member. After slicing, each of the frame members comprises an individual structural core identical in all essential elements to the structural core **24** and may be employed in the same way.

Through the use of the frame **32**, as compared with the frame **10**, smaller pieces of material can be used, rather than employing the large side, top and bottom structures used in the frame **10**. Furthermore, materials which are difficult to cut can be used. For example, metal rails can be used as the border elements to form the outline of the structural core. Since slicing occurs only between the individual frame or border members, it is not necessary to provide a saw capable of cutting the metal. This latter technique has the disadvantage in that more handling is required but in certain instances this handling may economically and technically be justified or required. This additional handling is in the assembling of the frame **32** and the removal of the combined guide and spacer means **50** and, by the use of appropriate jigs and assembling devices, can be accomplished rather efficiently, although more time and expense is usually involved than is involved in the preparation of structural cores using frames of the type illustrated in FIG. **1**.

FIGS. **6** and **7** illustrate the application of the process and techniques of this invention to the construction of whole or partial walls or wall units. According to this embodiment of the invention, a frame generally indicated at **60** is constructed of ends **62** and **64**, a bottom **66** and a top **68**. The frame may be constructed of several unitary pieces of wood, as shown, of high strength laminated board, of metal, or of a plurality of border pieces, as illustrated in FIG. **2**. Interiorly of the frame, a plurality of reinforcing members **70, 72** and **74** are provided to give added strength to the core structures when finally finished. Between reinforcing elements **72** and **74** lateral interior structural elements **76** and **78** define the top and bottom of an opening which, in the finished core, will comprise a window opening. The structural elements **76** and **78** along with the ap-

propriate portions of the reinforcing members **72** and **74** comprise means for defining an opening in the interior of the frame which is not filled with the expanded polymer composition.

While only one opening is illustrated in FIG. **6**, it will be understood that a plurality of such openings may be constructed. The openings may be constructed in conjunction with the reinforcing members **72** and **74**, or other types of reinforcing members. The openings may, however, also be constructed using simply structural elements, in the form of boards or panels, or metal sheets or plastic sheets, etc., analogous to elements **76** and **78** of FIG. **6** which provide no reinforcing for the overall core structure. Likewise, the openings may be useful as windows, doors, or for other passageways useful or necessary in residential, commercial or industrial buildings, or for other purposes.

FIG. **7** illustrates in cross section a panel completed using a core cut, as described previously, from the foam filled frame bun illustrated in FIG. **6**. The panel comprises a core having portions formed from the synthetic polymer composition filled areas **80**, **82**, **84**, **86** and **88** of the foam filled frame bun of FIG. **6**. The faces of the core are covered with skins **90** and **92**. These skins may be of a decorative panel, a structural material, or an unfinished material suitable for being finished in a building. In certain instances, it may be desirable to leave one or both faces of the core unsheathed by skins and in certain instances it may be only necessary or desirable to paint or otherwise decorate the surfaces of the core. In the ordinary instance, however, substantially greater structural strength is accomplished by adhesively laminating, or otherwise securing, skins to the surfaces of the core and the skins can be selected greatly to enhance the aesthetic value of the finished panel.

FIGS. **8**, **9** and **10** illustrate a panel and portions thereof equipped with electrical conductors and fixtures. According to this embodiment of the invention, cores are formed using the methods and techniques and materials as previously described. In addition, however, conductive strips are formed into the foam filled frame bun and appear in the finished core. These conductive strips or conductive elements are then suitable for use in distributing electricity throughout a building constructed from cores and panels so formed.

FIG. **8**, which is an elevational view of such a panel, designated generally at **100**, includes a bottom **102**, a top **104**, and ends **106** and **108**. A doorway is defined by structural members, which in the panel constitute a door frame **110** and **112** at the respective sides and **114** as a header.

In addition, two sets of electrical conductors are formed into the panel for use in distributing electricity to outlets, switches, etc. in the panel. One set of conductors **116** and **118** is so arranged as to provide a convenient source of electricity for electrical outlets. One conductor **120** is so arranged as to provide a convenient means for switching. In the other set, conduits **122** and **124** are conveniently positioned to permit the mounting of electrical outlets in the panel while the conductor **124** is conveniently located to permit switching.

These electrical conductors may be in the form of sheets of conducting material, such as copper, vertically positioned in the frame and about which the foam flows so as entirely to encompass the conductors. In this case, it is desirable to perforate the sheets with numerous openings of suitable size to permit the expanded polymer material to flow freely through and about the conductors. In this embodiment of the invention, the expanded polymer composition should be electrically insulating. This will result, of course, in the requirement that certain classes of fillers, which are highly electrically conductive, be omitted. The electrical conductors may, however, constitute simply wires, insulated or uninsulated, appropriately positioned and spaced in the frame around which the expanded polymer composition flows. If insulated wires or other conductors are used, the expanded polymer composition need not be electrically insulating, although this may be a desirable characteristic. Simply for purposes of illustration, the conductors are shown as sheets of conductive material.

These sheets of conductive material may be connected to the remainder of the building or house circuitry as illustrated in FIG. **9** in which a plurality of wires **128**, **130** and **132** extend through a border element, such as top **104**, and are secured to the conductors, for example conductors **116**, **118** and **120**, respectively. The connection between the wires and the conductors may be made by any conventional or desired means, bolts **134**, **136** and **138** being illustrated simply for convenience. The connection can be made by simply augering or cutting out the polymer material from around the ends of the respective conductors. The connections may be potted using conventional polymeric resins following completion of the connections, if desired. Foamed or expanded polymer potting compositions may likewise be utilized.

Fixtures, such as switch **140**, may be connected in any desired manner, the embodiment of FIG. **10** being merely illustrative of one simple method of connecting such fixtures. In this embodiment, a portion of the expanded polymer composition is dug or augered out of the core, as illustrated at **142**. The switch box is provided with sharp teeth **144** and **146** on one side and **148** and **150** on the other side which extend outwardly and engage the conductors **118** and **120** to form electrical connections therewith. These teeth are then connected to the switch elements and provide for making and breaking an electrical circuit between the conductor **118** and the conductor **120**, for example. The core may desirably be sheathed with skins **152** and **154** in the conventional manner.

Of course, many conventional methods of making electrical connection and many methods especially designed to make electrical connection with the conductors may be used without departing from the scope of this particular facet of the invention. What is significant in this invention is that the conductors are factory built into walls or wall units. Since this can be done on a mass production basis and using highly specialized jigs and other machinery, there is an enormous saving of time and effort, as compared with field installation of wiring. Moreover, by appropriate design, all essential electrical wiring can be built into cores and panels formed from the cores so that only nominal hookup is required in the field. Where the panels and cores are used for floors, ceilings, roofs, and for exterior walls,

for example, outlets for lights, appliances, heating, and other electrical using devices may be built into the panel, depending upon the particular needs, simply by positioning electrical conductors in the frame at desired intervals and in desired configurations prior to the filling of the frame with the expanded polymer composition.

FIGS. **11** and **12** illustrate another advantageous feature of this invention which may be used alone or in conjunction with the feature illustrated in FIGS. **8, 9** and **10**. In this embodiment of the invention, roughed in plumbing elements are built into panel cores and panels. FIG. **11** illustrates a foam filled frame bun prepared for slicing along the dashed lines. When so sliced, four cores are formed from this particular frame. As illustrated, each of the cores will include hot and cold water piping and drain piping. As illustrated in FIG. **11**, for example, one portion of a frame **160** is shown. The frame is filled with a foam of the type described illustrated at **162**. Positioned in the frame, with or without positioning brackets not shown, are four sets of cold water pipes illustrated at **164, 166, 168** and **170**. Also shown, in dashed line, are four sets of hot water pipes **172, 174, 176** and **178** and eight sets of drain pipes identified as **180** and **182** in the top core portion, **184** and **186** in the second core portion, **188** and **190** in the next core portion, and **192** and **194** in the bottom core portion. A portion of a core corresponding to the top core portion is illustrated in FIG. **12**. Such a core would result from the slicing of the foam filled frame **160** along the top dashed line.

As illustrated, this core has a border **160** including a top **160'** and a bottom **160''** and is filled with an expanded polymer material **162** as in FIG. **11**. The cold water pipe **164** has a capped outlet **196** facing outwardly from the sheet and another capped outlet **198** which would open to the other side of the core. In like manner, the hot water pipe **172** has a capped outlet **200** on the side of the core shown with another capped outlet **202** opening to the other side of the core. Drain pipe **180** opens to the front side of the core while a similar drain **182** has an outlet opening to the other side of the core. The core may, of course, be sheathed with a skin or otherwise coated or treated as previously described. In the illustrated embodiment, the water pipes are offset vertically with respect to each other. By incorporating somewhat more complex plumbing into the frame and using appropriate positioning supports, etc., any desired arrangement of plumbing outlet can be achieved. When the desired plumbing arrangement is achieved in the frame, then the foam filled frame bun is sliced along predetermined planes. Where necessary, the foam is augered out to expose the plumbing, the caps are removed, and connections are made in the usual manner or by using special fittings.

By careful design and placement, all or a substantial portion of the electrical conductors and plumbing may be prebuilt into wall panels at the factory. This, of course, results in very substantial savings in cost as well as in higher quality walls, greater precision in placement of fixtures and plumbing outlets, higher dependability in production and the avoidance of expensive and inefficient field labor. Another advantage will be apparent with respect to the inclusion of plumbing in the expanded polymer. Water hammer is reduced, since the plumbing is secured at all points in the wall and, even where water hammering is not avoided, the sound and vibration commonly resulting from this undesirable phenomena are greatly reduced and attenuated.

It will be apparent from the preceding discussion that the structural core members formed according to the process of this invention may be manufactured in an enormous variety of sizes, shapes and configurations and that the expanded polymer composition may be of any of a great variety of densities, textures, colors, etc. and may have physical properties of many types, according to individual desires or requirements. For walls intended to bear very heavy loads, it may be desirable to slice frames filled with high density, high crush strength reinforced polymer composition to form structural cores. These cores may then be used alone or with one or both surfaces covered with skins. The structural cores may be stressed or covered with skins to provide additional strength, covered with high density building board for high acoustical attenuation, with high quality paneling for specialized construction needs, or with low cost paneling for construction where economy is the dominating factor. The skins may be fastened to the structural cores in any desired manner but preferably are adhesively secured thereto.

In addition, structural cores cut from frames filled with selected expanded polymer compositions may be curved, twisted or otherwise formed after the slicing operation. One exemplary embodiment of such a technique is illustrated in FIGS. **13** and **14**. The structural core, identified at **204**, is manufactured in the usual way and includes border elements **206** and **208** on opposing sides and end elements **210** and **212** on one end and **214** and **216** on the other end. The end border elements **214** and **216** are joined at one end with the respective sides **206** and **208** and converge inwardly toward the center of the structural core and are joined end to end on the longitudinal center line of the structural core. End elements **210** and **212** are likewise joined end to end along the longitudinal center line of the structural core and at the opposite ends to the respective sides **206** and **208**.

As illustrated in FIG. **14**, diagonally opposite corners, formed by the junction of border elements **206** and **214** and by border elements **208** and **212**, respectively, are raised or supported and when the remaining opposite diagonal corners are permitted to sag or are depressed so that the structural core occupies a portion of a rectangle indicated in dashed lines in FIG. **14**, four corners of which are defined by the corners of the panel. The panel is then curved in a generally hyperbolic fashion. Thus, while the structural core forms a polygon with two parallel sides but with nonparallel end elements, the hyperbolically curved structural core, in outline, defines a rectangle. The structural core may be fixed in the hyperbolically curved configuration by covering it with appropriately curved skins or by covering it with skins which are flexible but which set to a rigid condition. For example, a structural core was constructed according to the techniques described, formed into the hyperbolic configuration illustrated in FIG. **14**, and both sides of the structural core were skinned with a glass fiber reinforced polyester.

Since the structural cores of this invention may be made in almost any size, it is possible and convenient to

form the roof of an entire building or a portion of a building by constructing a frame of appropriate size, slicing the foam filled frame to form the structural cores and configuring the structural cores in the from illustrated in FIG. 14. The hyperbolically configured roof panel may be preformed and transported to the building site or the structural core, in the flat configuration illustrated in FIG. 13, may be transported to the building site and then formed into the hyperbolically curved panel as illustrated in FIG. 14.

Many other configurations are also possible, the illustrated configuration being merely exemplary of the flexibility allowed to a designer or architect through the use of the structural cores and panels formed therefrom.

While the principles and procedures used in the process of this invention and the advantages of the structures and the process of the invention are clearly described in the preceding discussion, the following example indicates the specific application of these principles to the formation of particular structures.

A two pound per cubic foot density cured expanded polymer composition filled frame bun was prepared according to the following technique and using the materials indicated. A commercially available polyol, produced by Reichhold Chemicals, Inc., consisting essentially of a propylene oxide-water adduct having a molecular weight of about 400–500 and containing a fluorinated hydrocarbon as a foaming agent and a tertiary aliphatic amine as the catalyst was mixed with a commercially available isocyanate also produced by Reichhold Chemicals, Inc. in a ratio of 45 parts of polyol to 55 parts of isocyanate. The mixing time was 40 seconds, the cream time was 1 minute, 40 seconds, the string gel time was 5 to 6 minutes, the full rise time was eleven minutes and the tack free time was eleven to twelve minutes.

This composition filled a frame which had been constructed of ¾ inch thick plywood. The expanded resin composition formed an adhesive bond with the plywood which was of equal or greater strength than the body of the expanded polymer. A large number of expanded polymer filled buns in a great variety of shapes and sizes were made in this general manner.

After the polymer had cured, usually by setting at least overnight, the expanded polymer composition filled frame was sliced on a band saw to form structural cores in which a portion of the frame formed a border extending around the polymer filled interior. These structural cores were, in most cases, sheathed on both sides with ¼ to ¾ inch thick plywood.

The structural cores varied in thickness from less than one inch to five or six inches, or more. Structural cores four to six feet in width and up to twelve feet in length were formed from foam filled frames of like dimension. Where desired, a plurality of structural cores were adhesively bonded together using conventional techniques. A skin of plywood was then adhesively bonded on both sides of the combined structural core assembly to form panels of any desired shape and configuration.

Where the quantity of production contemplated justifies, the buns may be formed with any exterior configuration and in virtually any size so as to avoid the necessity for handling and adhesively bonding the individual structural cores. The only contraint on the size in which the structural cores can be constructed appears to be the constraint imposed by the size of the saw available. In the foregoing examples, a band saw was used for slicing the buns. The band saw available was a pilot plant type saw and foam filled frame buns having a width of greater than about six feet could not be sliced. Using a larger band saw, however, the slicing of expanded polymer composition filled frame buns of 12 feet in width and 60 feet or more in width is planned.

Panels constructed by sheathing both sides of the structural cores or both sides of assemblies containing a plurality of structural cores formed as described have been used in the construction of buildings. It is thus possible to slice an entire building wall out of a single expanded polymer composition filled frame bun. The wall, moreover, may include not only windows and doors where required but reinforcing and, if desired, electrical and plumbing elements. The advantages of the inventive process and the structures of the invention in the mass production of buildings will be apparent. Of course, smaller panels, such as for doors, movable partitions, etc., are very easily fabricated using the inventive techniques.

Where high strength is required, higher density expanded polymer is used to fill the frame. Conversely, where only low strength is required, low density expanded polymer compositions are quite suitable. In general practice, it has been found that expanded polymer compositions which, when cured, have densities from 1.25 to about 5 lbs. per cubic feet are quite suitable for most building structural uses. Where screws, nails or other frictional fasteners are used, rather than epoxy, polyester, or other conventional adhesives, densities of 5 to 10 lbs. per cubic foot may be desired, although it is doubtful that the advantages resulting from these higher densities justify the added weight and cost.

It will be clearly apparent from the foregoing discussion that there are a great many variations and adaptations of the process of the invention and of the structures of the invention which can be made and which would obviously be made by one skilled in the art without departing from the spirit and the scope of the invention as defined in the claims which follow.

I claim:

1. The process of producing a structural core, said process comprising the steps of:

providing a rigid frame having connected sides located in a pattern corresponding to the outline of the completed structural core, said frame having a height substantially greater than the thickness of a to-be-completed structural core and an open interior;

filling the interior of the frame with a lightweight expanded polymer composition material capable of adhesively attaching to the interior of said frame by injecting an expandable polymer composition into said frame and

allowing said composition to expand and set to a final, rigid condition; and

slicing the resultant unitary structure into a plurality of structural cores by cutting it in parallel planes so that each core includes a border of part of said

frame and a quantity of material adhesively bonded to said part of said frame;

said rigid frame being so constructed that the surface area of the frame in contact with the resin in a structural core is small compared with the surface area of the foam when the filled frame is so cut.

2. The process of claim 1 further including the preliminary step of assembling the frame from a plurality of frame members, each of which frame members defines the exterior configuration of the desired resultant structural core.

3. The process of claim 2 further including the placement of spacers between the frame members so that the frame members are spaced from each other during the filling step and including the removal of the spacers after the filling step and prior to the slicing step.

4. The process of claim 1 wherein said frame is composed of unitary panels, each of which defines a side of said frame and said panels are cut during said slicing.

5. A process for manufacturing structural cores comprising the steps of:

providing a rigid frame having an external configuration corresponding to the external configuration of the desired structural cores, a height equal to at least a plurality of thicknesses of the desired structural cores and a substantially open interior;

filling the open interior of the frame with a lightweight expanded polymer composition by injecting an expandable polymer composition into said frame which when set will be adhesive bonded to the interior surface of the frame and

allowing the polymer composition to expand and set to a rigid condition; and

slicing the expanded polymer filled frame into a plurality of structural cores by cutting the expanded polymer filled frame into a plurality of panel-like units having a rigid border which is that part of the frame cut from the frame surrounding the expanded, set polymer composition in the interior;

said polymer composition being adhesively bonded to the interior of said rigid borders and said rigid frame being so constructed that the surface area of the frame in contact with the resin in a structural core is small compared with the surface area of the foam when the filled frame is so cut.

6. The process as defined in claim 5 wherein the expanded polymer composition contains at least one material selected from the group consisting of dye, pigment, filler, fire retardent material, reinforcing fibers and nucleating particles.

7. The process as defined in claim 5 wherein the frame includes means defining at least one opening which is not filled with expanded polymer for forming passageways through the structural cores sliced from an expanded polymer composition.

8. The process as defined in claim 7 further comprising the step of positioning electrical conductors in said frame, said conductors being so constructed and arranged as to be substantially surrounded by the expanded polymer composition and to form at least a pair of individual electrical conductors in the structural cores sliced from the expanded polymer filled frame.

9. The process as defined in claim 7 further comprising the step of positioning a plurality of plumbing elements in said frame such that when the expanded polymer filled frame is sliced the structural cores formed thereby include at least one plumbing element adapted for use in connection with a plumbing fixture.

10. The process as defined in claim 5 further comprising the step of positioning electrical conductors in said frame, said conductors being so constructed and arranged as to be substantially surrounded by the expanded polymer composition and to form at least a pair of individual electrical conductors in the structural cores sliced from the expanded polymer filled frame.

11. The process as defined in claim 5 further comprising the step of positioning a plurality of plumbing elements in said frame such that when the expanded polymer filled frame is sliced the structural cores formed thereby include at least one plumbing element adapted for use in connection with a plumbing fixture.

12. The process as defined in claim 5 further comprising the step of positioning at least one reinforcing member in said frame, said member being so constructed and arranged as to be substantially surrounded by said expanded polymer composition and to form a reinforcing member in the structural cores sliced from the expanded polymer filled frame.

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