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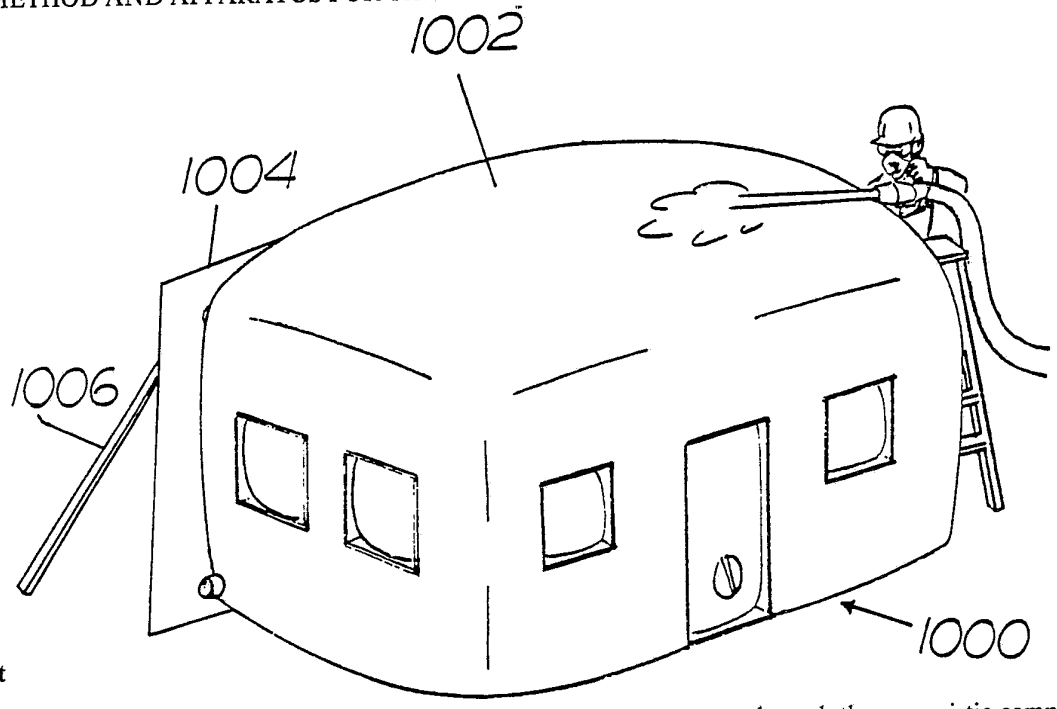

(57) Abstract

A method and apparatus for the construction of low-cost building structure through the synergistic composition of material, process, and structural design. In a first embodiment, a specially fashioned balloon (14), in the shape of a house, is used as a one-sided form, and is sprayed with a building material formulation. The building formulation may include: structural material, reinforcing material such as fibers (52) to eliminate or minimize separate structural reinforcement, a gaseous bubble material (to provide thermal insulation), and other ingredients such as fillers, strengtheners, bulk-formers, accelerators, coloring agents and dryers. The structure can be created rapidly, and the balloon (14) deflated and removed in minimum time, all by as few as two men. The low cost of the labor and materials and equipment used according to the present invention result in a more economical method of creating a building than any presently known method.

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METHOD AND APPARATUS FOR THE CONSTRUCTION OF A LOW COST STRUCTURE

BACKGROUND OF THE INVENTION

Food, clothing, & shelter are the three basic human needs. Tens of millions of people around the globe have no home. In mature civilizations, like the United States, housing costs and interest rates have put home ownership out of reach of many millions of people.

The criteria for the ideal housing structure to meet the above need include: utilization of materials that are low cost & easily available; a structure that is easily and quickly erected, substantial, & attractive; utilization of minimal amount of labor with minimal skill levels; low cost; minimal construction time; utilization of low-cost construction equipment which is easily used, easily maintained, easily transported, & easily repaired.

The prior art includes numerous examples of attempts to fulfill these objectives, all of which are subject to numerous deficiencies.

The following is a summary of the prior art related to methods and apparatus for the construction of low cost structures:

a. The International Basic Economy Corporation's system in Puerto Rico used a huge integral steel form to cast all the walls of the house integrally. First, the floor slab was poured. Then, reinforcing bars for the walls were assembled, and tied in place. After the slab cured, a huge crane set the steel form (consisting of an outside wall and an inside wall, between which the concrete was poured) in place on the slab. Then the concrete was poured, and vibrated to eliminate air pockets. Days later, the huge form was stripped away by the huge crane, cleaned, & set in place to pour the next house. The problems with this system include: long cycle time per house, the use of a very expensive steel form, a requirement for vibrating the concrete, a huge crane needed, many laborers needed - including highly - skilled & expensive crane operator, foreman, & engineer; a need to use reinforcing bars; and a need to assemble & tie the reinforcing bars all in place.

b. Another example of a building system utilizes re-usable steel or aluminum form panels, which are used to support the inner and outer surfaces of the concrete walls as they are poured. The problems with this system include: a relatively large amount of labor to assemble in place; a need for stripping and cleaning the panels after each use; the need for disassembling of the panels after each use, and the need for

vibrating of the concrete to prevent airpockets.

c. Another example of a building system uses tilt-up construction where the floor is used as the form for the casting of wall and roof slabs,which are then tilted up into position. The problems with this system include: long cycle time per house; corner posts have to be formed & cast to hold the walls together in the four corners of the house; and getting the roof slab on top of the walls takes substantial effort.

d. Another building system utilizes pre-cast concrete parts. The problems with this system include: major investment required to establish a casting plant; cracking & breaking of pre-cast parts between factory and final assembly; substantial effort is required to seal the pre-cast parts into an integral structure; cost of assembly & operating a truck to deliver the parts from the factory to the building sites.

e. Still another building utilizes a spray-on structure. Problems with this system result from the igloo shape of the structure. The igloo shape is not attractive to customers because the non-vertical walls create waste space immediately adjacent to them, as a result of their angle to the floor; people are generally uncomfortable in rooms that do not have vertical, flat, and parallel walls, because it seems to disturb their needs for a rectangular frame of reference, and land plots are generally rectangular(not round)so a round house does not fit its' land well.

SUMMARY OF INVENTION

The present invention provides a novel method and apparatus for the construction of low cost structures. The invention provides a novel, synergistic system, which includes a combination of two or more of the following elements, to provide a better, faster and cheaper structure, which overcomes the problems of prior art.

a. SPRAY MEANS - For purposes of illustration only, spray equipment as manufactured by Allentown Pneumatic Gun Company may be utilized.

b. SPRAY MATERIAL - For purposes of illustration, a standard shotcrete composition of cement, sand, and limited amount of water or sprayable plastics such as urethane foam or other composition material

having the necessary characteristics to form sections or structure may be used.

c. FOAMING AGENT - A foaming agent may be used to decrease the amount of sprayed material used, to provide a better thermal barrier, and lighten the weight of the structure. The use of a foaming agent reduces the weight of both the roof and the walls since a lighter roof requires thinner supporting walls beneath it. Also, the entire structure (floor&roof, too) needs less concrete.

d. HOLLOW BALLS - Hollow balls may be used to achieve the immediately above results, and also to constitute a cosmetic wall treatment.

e. COLORING AGENT - A coloring agent may be used to color the sprayed material.

f. ADDITIVES - Special purpose additives may be used optionally for purposes such as: insect-repelling, fire retardation, binders, low-cost bulk providers (such as clay, soil, etc.), dryers, accelerators, and super-plasticizers.

g. STRENGTHENERS - Strengtheners such as metal, plastic or glass fibers (which may be coated to resist alkali), or other material, such as welded wire mesh, whose presence eliminates or minimizes the need for adding reinforcements to the structure, may be utilized.

h. BALLOON - A custom-constructed balloon having the dimensions and shape of the inside, or outside, of the desired strucure, which is easily and quickly inflatable and deflatable, made of a lightweight and inexpensive material, may be utilized.

i. INTERNAL STRUCTURES - Some strictures inside the balloon, to conform the balloon to the desired shape (flat, straight, vertical walls) may be utilized.

j. EXTERNAL STRICTURES - Strictures outside the balloon, to conform the balloon to the desired shape (flat, straight, vertical walls) may be utilized.

k. APERTURE BUMPS - Aperture bumps may be provided on the balloon, which are then sprayed with material on the side of the bump perpendicular to the body of the balloon, but not on the large surface of the bump parallel to the balloon - to leave openings for doors and windows. The bumps can be integral with the balloon, or attachable at any chosen

location. The bumps can be inflated from the inside of the balloon, or independently inflated. The bumps can protrude sufficiently from the balloon surface to form an aperture all the way through the wall, or the bumps can be sufficiently shallow so that they merely form an indent on the inside of the wall of the strucure (with no opening from the inside to the outside of the wall of the structure) - for a closet, bookcase, or (with or without an external balloon) a bay window.

l. MULTI-LAYER SECTIONS - Multi-layer construction may be utilized for walls, roofs, floors, or ceilings. Plastic foam, because of all the air spaces therein, is a better thermal barrier than concrete. However, plastic foam has problems: while it is not feed for insects, they will burrow into it to make a home; sunlight deteriorates the plastic foam; plastic foam is combustible. So, to overcome these problems, plastic foam is used in a tri-layer configuration, with concrete on each side of it, or interspersed throughout the matrix.

m. HEIGHT GUIDES - Height guides in accordance with the invention are small, Eiffel Tower-shaped objects which are adhesively attached to the balloon. The spray hoseman sprays up to the tip of the height guides to get the proper material thickness. In the case of the sandwich construction, the thickness of each layer is marked on the height guide.

n. TEXTURED SURFACES - Textured surfaces are easily achieved on the surface of the sprayed structural material by texturing the surface of the balloon (or balloon cover) on which the material is sprayed. The exterior wall can be textured to a stucco pattern, a brick pattern, or whatever texture is desirable, by dealing with the exterior surface before it hardens, or by adding another layer, which latter layer is then textured, or by using an external textured balloon.

o. WINDOW FRAMES - Reusable frames may be provided, which are tapered for easy removal, and attached (adhesively) to the balloon. This option is especially useful in tropical climates where windows are not wanted, just apertures.

p. TIE DOWNS - Tie downs are provided, if needed, because of the tendency of the balloon to provide a wall that curves inward at the

floor level instead of making a vertical, right angle with the floor.

q. ROOF - The form of the roof has many options. The simplest is the dome, whose curvature is continuous with the vertical walls. Another option is to place supporting rods, protruding over the tops of the walls. A thin sheet of any membrane can be stretched across the supporting rods, and the building material can be sprayed over them, to form roof eaves of the desired thickness. Height guides can be employed on the eave-supporting rods.

r. SEPARATE ROOF - A separate roof can be employed.

s. "RUN-OFF" - Rainfall runoff may require that the floor slab extends beyond the eaves, so that heavy rain does not wash away the earth from under the structure.

t. FLOOR - Provision of a floor in the structure is optional. In some cultures an earthen floor is desired. Floors are sometimes more economically poured than sprayed. Pouring also makes it easier to screed a smooth surface.

u. REINFORCEMENT - The use of reinforcement is optional. Before a floor slab is poured, it is possible to insert vertically-oriented reinforcing rods at intervals into the earth, to tie the walls (when they are put in place, later) to the floor. A frame can be built of metal or wood or other material, placed outside of the balloon, and sprayed over when the structure is formed. This last system is applicable in the case of a separate roof, or a second floor.

v. WATER COLLECTION - Water collection can be achieved by adding a vertical rib around the periphery of the roof, to form a catch basin.

w. WATER TANK - A water tank may be provided in the form of an open, flower pot-shaped addition to the roof, and resting directly over a wall (because of the great weight of the water,) to furnish water under some pressure to the residents.

x. PLUMBING - Plumbing of the structure can be spaced from the side of the balloon, and sprayed within the wall, or attached later, to the room side of the completed wall.

y. ELECTRICAL WIRING - Electrical wiring can be put in place outside the balloon, and sprayed integrally into the wall, or added later to the inside of the structure. A horizontal baseboard strip, prefab-

ricated wiring panel, is usable.

z. FILLERS- Fillers such as soil, clay, refuse, broken glass, metal scrap, chopped auto tires, low-cost local material, bulk producers, etc. - all of which provide structural material at minimal cost, may be utilized.

aa. GAS BUBBLES - Gas bubbles may be beaten into (like a malted milk), blown into (as with compressed air, or other gas), or otherwise delivered into the structural material.

ab. FLATTENERS - A variety of flatteners to provide flat surfaces to the structure may be utilized such as: stretching the membrane over a frame; reinforcing with a stiff webbing; use of panels (of metal, plastic, glass, corrugated cardboard, honeycomb, or other sheet) that are extruded or rolled or cast or embossed with a pattern; mesh; placing panels or sheets on a supporting structure - such as an internal or external balloon with or without a supporting structure; or without a balloon; and using a material such as duct tape to smoothly hold flat surfaces and bumps and frames, etc.; and using collapsible-and-extensible apparatus, such as Archimedes scissors to support and flatten the balloon surfaces.

ac. PATTERNED SHEETS - Patterned sheets, which can be generated by embossed tooling (which can be rollers, molds, stamps, etc.) may be used, with or without self-ribbing (for stiffness); and, with or without a supporting balloon or other structure, can be used to give a pattern to the material sprayed on the surface.

ad. HARDENERS - Soil hardeners which permit the use of low, or no cost, indigenous materials such as soil or clay may be utilized to enable the soil or clay to form solid, durable building materials.

OBJECTS OF THE INVENTION

It is a principal object of the present invention to provide a low-cost building structure through the use of a single-sided form in combination with a sprayable building material.

Another object of the present invention is to provide a low-cost building structure through the use of an inflatable form.

Another object of the present invention is to provide a low-cost building structure incorporating a multi-layer construction.

Another object of the present invention is to provide a low-cost structure utilizing a single-sided form on which protuberances are provided to form door and window apertures.

Still another object of the present invention is to provide a method for producing a low-cost structure which uses a sprayable building material.

BRIEF DESCRIPTIONS OF THE DRAWINGS

Additional objects and advantages of the present invention will become apparent during the course of the following specification when taken in connection with the accompanying drawings in which;

Figs. 1A, 1B, 1C, 1D, 1E and 1F are perspective views showing the successive steps in the construction of a building structure in accordance with the present invention;

Fig. 1A shows the fabrication of a slab foundation;

Fig. 1B shows a portion of an inflated balloon which has a textured inner surface;

Fig. 1C shows the inside of the exterior half of the wall with electrical wiring and plumbing in place, prior to fabrication of the interior half of the wall;

Fig. 1D shows the balloon structure for the fabrication of a bay window;

Fig. 1E shows a truss for the support of the roof;

Fig. 1F shows an overall view of the completed structure;

Fig. 2 shows air bubbles formed in the wall structure for thermal insulation and light weight;

Fig. 3 shows fibers in the wall structure for reinforcement.

Fig. 4 is a fragmentary cross-sectional view which shows a

sandwich -type roof formed of a layer of foam material between two protective and supporting layers of concrete;

Fig. 5 shows a side view of a height-measuring device according to the present invention,which is used with the balloon,or other form.

Fig. 6 shows an alternative embodiment of the invention having an integrally-formed water trough incorporated at roof level in accordance with the invention to provide a fluid head for the water pressure, for the internal plumbing of the structure;

Fig. 7A is a perspective view of a truss structure which will be embedded in the structural material;

Fig. 7B is a perspective view of the truss structure of Fig.7A placed on the walls of the structure prior to the spraying of the structural material;

Fig. 8 is a perspective view of the structure fabricated according to the present invention,having a radially-patterned roof.

Fig's 9A, 9B, 9C, 9D, 9E show the successive steps in the fabrication of a two-story structure,in accordance with another embodiment of the present invention;

Fig's 10A, 10B, 10C, 10D, 10E and 10F show the successive steps in the fabrication of the two-story structure, having textured walls in accordance with another embodiment of the present invention;

Fig. 11 is a perspective view of the balloon form used in the fabrication of the structure of Fig. 10;

Fig's 12A, 12B, 12C, 12D, 12E and 12F show six alternative methods for achieving patterned surfaces on the structure;

Fig's 13A, 13B, 13C, 13D, 13E, 13F, 13G, 13H and 13I show successive steps in forming a structure using a frame apparatus to stretch a membrane which is used as a one-sided form in accordance with another embodiment of the present invention.

Fig's 14A, 14B, 14C, and 14D show the use of a telescoping rectangular frame apparatus to stretch a membrane, in accordance with with another embodiment of the present invention.

Fig's 15A, 15B, 15C and 15D show the use of an apparatus according to another embodiment of the present invention which stretches a membrane around four vertical corner posts.

Fig's 16A, 16B and 16C show another embodiment of the present invention which features the use of a membrane type of one-sided form which utilizes guy cables, and

Fig's 17A, 17B, 17C, 17D and 17E show still another embodiment of the present invention which features the use of of a one-sided form using rigid panels in accordance with the present invention.

Fig's 18A, 18B, 18C, 18D, 18E, 18F and 18G show another embodiment of the present invention which features the use of a balloon form which includes internal webs,and pockets for the insertion of stiffeners.

Fig. 19 shows the repetitive use of a form to produce a structure which is larger than the form.

Fig. 20 shows the production of a seamless,unitary construction including an integral and self-supporting domed roof according to the present invention.

Fig. 21 shows another embodiment of the present invention which features the use of an automatic spray apparatus.

Fig. 22 shows another embodiment of the present invention which features the use of a structural re-inforcement in conjunction with a balloon form.

Fig's 23A, 23B, 23C, 23D, 23E and 23F show the sequence of operations in the construction of a structure in accordance with the present invention.

Fig. 24 shows the use of an external form in accordance with the present invention.

Fig. 25 shows the construction of structures having different appearances in accordance with the present invention.

Fig's 26A, 26B, 26C and 26D show the sequence of operations in creating a brick-appearing surface in accordance with the present invention.

Fig's 27A and 27B show the use of a collapsible form, which is erected by means of air pressure in accordance with the present invention.

Fig's 28A and 28B show a peaked roof structure which is constructed in accordance with the present invention, with domed roof panels.

Fig. 29 is an exploded view which shows the use of a flexible mold for roof construction in accordance with the present invention.

Fig's 30A, 30B, 30C and 30D show the incorporation of beams in the structure in accordance with the present invention.

Fig's 31A, 31B, 31C, 31D, 31E, 31F and 31G show the use of patterned panels in accordance with the present invention.

Fig. 32 shows the use of a crane to place and remove a flexible roof form.

Fig. 33 shows the details of construction of the intersection of roof and wall panels, beams, pins, and forms.

Fig. 34 shows the use of a formed welded wire mesh as a roof reinforcement, and the details of construction of the roof peak.

Fig. 35 shows an alternative construction of the welded wire mesh reinforcement and roof peak of Fig. 34.

Fig. 36 shows 2 perpendicular welded wire meshes.

Fig. 37 shows forming rolls in the process of forming the welded wire mesh re-inforcement.

Fig. 38 shows a variety of profiles which can be used to form the welded wire mesh re-inforcement of Fig. 35.

Fig's 39A and 39B show the use of a flexible form which is guided on or in a track.

Fig. 40 shows the high-speed construction system in accordance with the present invention, and illustrates the use of high-capacity mixing apparatus.

Fig's 41A, 41B, 41C, 41D and 41E show a unitary combination of sink, tub, shower and toilet which is heat-formed from a single sheet of material.

Fig. 42 shows a unitary construction similar to Fig. 41 and which includes a kitchen sink.

Fig. 43 shows the concrete mixing and application apparatus.

Fig. 44 shows the repetitive use of a large adjustable form which moves in the vertical direction.

Fig. 45 shows the dipping of a form into a container of liquid material in accordance with the present invention.

Fig. 46 shows a rotatable spray means for placing hardenable building material.

DETAILED DESCRIPTION OF THE INVENTIONS

With reference to the drawings, there is shown in Figs. 1A through 1F the successive steps in the construction of the building structure in accordance with the present invention. Fig. 1A shows the fabrication of a slab foundation 10 which includes reinforcing bars 12 in a conventional manner. Fig. 1B shows a portion of a balloon structure 14 which forms a major novel feature of the present invention. The balloon 14 is inflated and placed on top of the slab foundation 10. The inner surface 16 of the balloon is textured to generally simulate the appearance of, for example, a brick wall, and this inner surface is sprayed with hardenable spray material which will be presently described. The balloon 14 includes a protuberance 18 which forms a window aperture in the sprayed material. Fig. 1C shows the inside 20 of the exterior half of the wall, prior to fabrication of the interior half of the wall. The wiring 22 and plumbing 14 services are shown in place, and a protuberance 20 is shown, which is used to form the door aperture.

Fig. 1D shows a bay window 28 fabricated on the wall, and Fig. 1E shows a portion of the roof 30 broken away to show the use of a roof truss 32. Fig. 1F shows the completed structure 34.

Fig. 2 shows a portion of the wall 40 including a plurality of air bubbles 42 formed within the wall. The air bubbles 42 provide thermal insulation and reduce the weight of the wall, save material and cost.

Fig. 3 shows a portion of wall 50 including a plurality of reinforcement elements 52. The reinforcing elements 52 shown are in the nature of generally rod-like members which are randomly oriented within the wall 50. It is also within the scope of the present invention to utilize flat rectangular reinforcement members. A particularly effective configuration of the reinforcement members has been found to be ribbed or corrugated steel fibers manufactured under the trade name Xorex by the Ribbon Technology Corporation, Canal Winchester, Ohio. These fibers are made of steel and are approximately one-sixteenth to one-eight inch in width and one to three inches long. The surface of these members is corrugated or convoluted. The use of these fibers in concrete in amounts ranging from 0.5 to 2.0 in volume percent results in an increase in the concrete flexural strength value of over 100%.

The spray material, utilized in the present invention which is alternatively referred to as a building material, is a hardenable material which may be applied using conventional spray equipment, such as manufactured by the Allentown Pneumatic Gun Company. The building material may consist of a composition of cement, sand, & foam, or sprayable plastic orurethane foam. Foaming agents may be introduced to generate bubbles for the purpose of decreasing the weight of the material used and improving the thermal properties.

Accelerators of known types and compositions, such as flyash, may be used to speed the hardening of the cement, thereby enabling a first layer to be applied to a form to harden quickly and provide support for subsequent layers.

Other building materials which may be used in accordance with the present invention include soil mixed with a soil hardener material which transforms soil into a rigid building material.

Fig. 4 shows a portion of a roof structure 60 which is constructed by forming an inner concrete shell 62. Then forming a foam layer 64 on top of the inner concrete shell 62. An outer concrete shell 66 is then formed on top of the foam layer 64.

Fig. 5 shows a height-measuring device 70. The height-measuring device has a flat base 72 and a measuring member 74 which is generally perpendicular to the base. The measuring member 74 can be tapered and has a plurality of distinct zones 76, 78, 80, which are distinguished from each other by differences (diameter, color, texture, etc.). In use, a plurality of of height-measuring devices 70 are used to ensure the uniformity of the thickness of a sprayed structure. The base 72 is adhered to a balloon form or other single-sided form 90 and a first material layer is sprayed on to the form until the thickness of the layer reaches the first step 82. A second layer is sprayed until the thickness reaches the second step 84, and the third layer is sprayed until the thickness reaches the top 86 of the height measuring device.

Fig. 6 shows another embodiment of the invention including a water trough 91 which is integrally formed on the upper portion of the wall 92 of the structure 94. The water trough 91 catches the run-off of rain falling on the roof 96 and provides a reservoir for water storage and also a fluid head for water pressure for the internal plumbing of the structure 94.

Fig's 7A and 7B show another embodiment 100 of the invention, which utilizes a truss structure 102. The truss structure 102 shown in Fig. 7A is placed on top of the previously formed walls 104,106, and the spaces between the trusses are filled with triangular-shaped balloon members 108, 110, 112 and the truss & balloon are sprayed with a structural material ,and the truss structure 102 is embedded within the structure which is formed by the structural material.

Fig. 8 shows another embodiment 120 of the invention in which the roof 122 has a generally conical form which includes a plurality of flutes which is typically indicated by the flute 124. The roof is formed by spraying a building material from above or below against a tent-like form which is supported by a central pole(s).

Fig's 9A through 9E show another embodiment of the invention in which a 2-story structure 130 is formed using an inflated balloon form 132 which is sprayed with a building material to form the walls 134 of the first story 136 of the structure 130. A table-like form 138 shown in Fig. 9B is placed within the previously formed walls 134. A building material 140 is applied to the top surface of the form thereby forming a floor as shown in Fig. 9C. An inflated balloon form 42 is placed on top of the floor, Fig. 9D, and a building material is applied to the balloon form 142 in a manner similar to that applied to the first floor shown in Fig.9A, thereby forming the 2-story structure 130 shown in Fig. 9E.The balloon forms 132, 142 include projecting portions144, 146 which form the window and door apertures, and the form 138 includes a projecting portion 148 which forms an aperture connecting the upper and lower floors of the structure 130.

Fig's 10A through 10F show another embodiment of the invention in which a 2-story structure 160 is formed with the structure having textured walls 162 which simulate the appearance of conventional siding.

In Fig. 10A a building material 164 is applied to the inside surface of an inflated balloon form 166. The inside surface of the balloon form is textured with a plurality of inclined surfaces 168 which simulate the appearance of conventional siding. The balloon form 166 also includes protuberances 170 which form window apertures. A table-like form 172 shown in Fig. 10B is placed inside the walls 174,176 formed in Fig.10A, as is shown in Fig. 10C and a building material 178 is applied to the top surface of the form 172 to form a floor 180. When the floor 180 is completed, a second inflated balloon form 182 is placed on top of the floor 180 and a building material 184 is applied to the inside surface thereby forming the walls 186,188 of the second story of the structure 160 as is shown in Fig. 10D. When the walls of the second story are complete, a roof 190 is added as shown in Fig. 10E. The completed structure is shown in Fig. 10F. The second balloon form 182 may be different in configuration from the first balloon form 166, or alternatively, the first balloon form can be re-used to form the second story.

Fig's 11A and 11B are a perspective view and a cross-sectional view respectively of the balloon forms used in Fig's 10A through 10D showing the outer balloon form having a grid-like structure which forms a plurality of cells 192. The grid-like structure contributes toward the overall rigidity of the balloon form.

Fig's 12A through 12F show six alternative methods for forming a patterned surface on a structure using a balloon form. In Fig. 12A a building material 200 is applied to the outside surface of the balloon 202, and the outer surface of the balloon form is configured to provide the desired pattern, which is shown by way of example, as a simulation of a brick wall, and the building material 210 is applied to the inner surface.

In Fig. 12C a plurality of individual panels 212 are attached to the outer surface of the balloon 214 and the outer surface of the panels 212 includes the desired pattern. The building material 214 is applied to the outer surface of the panels 212. Fig. 12D is similar to Fig. 12C with the exception that the panels 216 are applied to the inner surface of the balloon 218. In Fig. 12E the individual panels are replaced by a large sheet 220, which may be rigid, or semi-rigid, and which

incorporates the desired pattern. Fig. 12E shows the sheet 222 applied to the outside of the balloon form 226, and Fig. 12F shows the sheet 222 applied to the inside of the balloon form 226.

Fig's 13A through 13I show the successive steps in forming a structure using another embodiment 300 of the invention in which a frame 302 apparatus is used to stretch a membrane, thereby providing a one-sided form. Fig. 13A shows the frame apparatus 302 as having four leg members 306,each of which is pivotally connected at its lower end to a base member 308. An enlarged view of the pivotal connection 310 is shown in Fig. 13B. Fig. 13C shows an overall view of the membrane member 304 placed around the partially erected legs 306. Fig. 13E shows the legs 306 being swung into a vertical orientation and locked in place by means of a pin member 312, which is shown in Fig. 13F. Fig. 13G shows the membrane 304 being tightened by means of an adjustable strut 314 placed between the diagonally opposite legs. Fig. 13H shows individual members being attached to the taut membrane in order to form protuberances 316, 318, 320. The protuberances may be attached by any one of a number of known attachment means such as tape, glue, or hook and loop fasteners. Fig. 13I shows building material 322 being applied to the outside of the membrane 104, and the protuberances 316, 318, 320 forming a door and windows.

Fig's 14A through 14 D show the successive steps in using another embodiment 400 of the present invention in which a frame apparatus 402 is used to stretch a membrane 404 in order to form a one-sided form. The apparatus of Fig. 14A shows the apparatus 400 comprising a rectangular frame 402 formed by telescoping members 410, 412. Fig. 14A shows the frame 402 in the retracted position identified by reference number, 420 and in the extended position identified by reference number 422. Fig. 14B shows the membrane 404 placed over the frame 402. The frame includes projecting portions 406 which pass through holes in the membrane 404 in the extended position for ease in stretching the membrane 404 with the frame members 402 shown symbolically in broken lines. The periphery of the membrane includes a pocket portion 408 into which the frame member fits.

Fig's 15A through 15B show another embodiment of the invention 500 in which an elongated membrane 502 is placed around a set of four vertically-disposed members 504, 506, 508, 510 to form a rectangular one-sided form. The membrane 502 includes a first end portion 512, which includes, for instance, a plurality of holes 514 which are disposed to fit, one each, over a series of, for instance, rectangular clips or staple-like projecting members 516 which are mounted on one of the vertically-disposed members 506. The membrane 502 is retained by a plurality of wedges 518 which are inserted, one each, into the clip members 516 as is shown in Fig's 15C and 15D. The opposite end 520 of the membrane 502 has a plurality of clip members 522 which are similar to the clip members 516 and which pass through a series of holes 524 in the membrane. The end 520 of the membrane is secured by a plurality of wedges 526 which are inserted, one each, into the clip members 522.

Fig's 16A through 16C show another embodiment 600 of the invention which utilizes a flexible inflated envelope 602. The envelope 602 is retained in position by a series of guy cables 612, 614 which maintain the surfaces of the envelope in a generally flat configuration. The inside surface of the envelope 602 can be coated first with a building material layer, then (if desired) with an insulating material such as urethane, thereby forming planes 604,606 in or on which tube or conduit members 608, 610 are installed. The tube or conduit members may be used for electrical wiring or plumbing services. Fig. 16C shows a portion of the construction drawn to an enlarged scale. The construction may only include the envelope 616, the urethane layer 618, the conduit 610,and the building material 620 which may be sprayed concrete. Inflation of the envelope 602 is accomplished by means of an air compressor 622 which introduces air into the envelope via the door assembly 624, for instance.

Fig's 17A through 17D show still another embodiment of the invention in which a one-sided mold is formed by a rigid panel. Fig. 17A shows a plurality of panels 702 being brought to the job site on a trailer truck 704. Fig. 17B shows a rigid panel being supported in a vertical orientation by support members 708, 710. The panel 706

includes protuberances which aid in forming door and window apertures. Fig. 17C shows the panels 716,718 being joined on the outside surface by tape 720,while a building material is applied to the inside surface. Fig. 17D shows the panels 722,724 being joined by tape 726,and additionally protuberances 728,738 for forming window and door apertures being attached to the panels 730, 732 by means of tape. The use of tape facilitates the re-configuration of the panels,and the rearrangement of the window and door apertures to suit a variety of building configurations. Fig. 17E shows the rigid panels 734,736 being assembled over an inflated balloon 740.

Fig's 18A through 18G show another embodiment 800 of the invention in which a balloon form 802 includes internally-disposed web members 804, 806, 808, 810 which aid in defining the shape of the balloon form 802. The balloon form 802 also includes pockets which are best shown in Fig's 18E and 18G and into which a stiffener 816 may be inserted in order to maintain a flat configuration.

Fig. 19 shows the repetitive use of a form 900 to produce a structure 902 which is larger than the form 900. The form 900 was used to produce modules 904 and 906,and is in the process of being used to produce module 908. An additional module which will be fabricated is shown in broken lines 910.

Fig. 20 shows the production of a seamless,unitary structure 1000 including an integral and self-supporting domed roof 1002 according to the present invention. Optional outer form 1004 makes a two-sided form for pouring the hardenable building material, instead of spraying it.

Fig.21 shows another embodiment of the present invention which features the use of an automatic spray apparatus 1102 riding on a track 1104 disposed on the floor 1106 of the balloon form 1108. Hardenable building material 1110 is sprayed onto a form by

a plurality of jets 1112,which are mounted on a vertical member 1114. The apparatus 1102 is driven along the track 1104 by a motor 1116 & the apparatus 1102 is hand-operated,or programmed to selectively cause the jets 1112 to operate, so that the jets 1118 do not spray out the window 1120, conserving building materials. The balloon form 1108 shown by way of example is only one of many forms that may be employed therewith, such as rigid panel forms. The automatic spray apparatus 1102 may take a number of specific structures, such as a central, stationary, revolving spray apparatus 1102 with either a single, directionally-controllable nozzle or a multiplicity of jets, located either within or without the structure.

Figure 22 shows another embodiment 1200 of the present invention which features the use of a structural reinforcement assembly 1202 in conjunction with a balloon form 1204. This embodiment 1200 may be used to fabricate multi-story structures.

Figures 23A through 23F show the sequence of operations in the fabrication of a structure 1300 in accordance with the present invention.

Figure 23F is a sequence summary of the operation which utilizes an alternative construction of the balloon form 1306 which does not include the roof peaks 1308, 1310.

The embodiment of Figures 23A through 23F features the use of a conventionally structured peaked roof 1302 in conjunction with a structure 1300 which has been constructed using a balloon form 1304. In figure 23A through 23F the roof 1302 is prefabricated and lifted onto the structure 1300.

Figure 24 shows another embodiment 1400 of the invention which features the use of a conventionally-structured peaked roof 1402 in conjunction with an external balloon form 1404. The internal surface of the balloon form 1406 has a surface texture which simulates bricks. Plumbing and electrical wiring for electrical services 1408 are installed spaced from the balloon form surface 1406 and are incorporated into the wall 1410 of the structure 1412. When construction is finished ,the structure 1412 has the outer appearance of a conventional brick building. Instead of spraying, optional inner

form 1414 can be used to create a 2-sided form, to pour hardenable material.

Figure 25 shows a plurality of structures 1414, 1416, 1418, each having a different outer wall surface appearance,and each constructed using the techniques of Figures 23 and 24.

Figures 26A through 26D show the sequence of operations in creating the appearance of a brick wall in accordance with another embodiment of the present invention. In Figure 26A a form release agent is sprayed onto the flexible form 1502 by means of the spray apparatus 1504. A white pigment is applied to the raised edge 1506 of the flexible form 1502 by the roller 1508. The building material 1510 is sprayed onto the flexible form 1502 by the spray nozzle 1512 in Figure 26B. The flexible form 1502 is pulled from the finished wall 1514 in Figure 26C. Figure 26D shows the finished wall 1514, with the interstices1516 colored with the white pigment, thereby simulating the appearance of mortar vs. the red-colored concrete.

Figures 27A & 27B show another embodiment 1600 of the present invention which features a collapsible form 1602 which is erected by means of pressurized air,which is delivered via a hose 1604. The form includes hose 1604,a collapsible frame 1606, a plurality of air-pressure-made-rigid textured panels, 1608, 1610, 1612, 1614, and a flexible balloon 1616.

Figure 27B shows the inflated balloon 1616 holding the form 1602 in an erect configuration.

Fig's 28A and 28B show a building 1200 having a peaked roof which is constructed in accordance with the present invention. The building 1200 includes curved roof panels 1702, 1704 in order to provide additional arched structural stiffness.

Figure 29 is an exploded view of another embodiment 1800 of the invention which features the use of a flexible mold 1802 for the construction of a roof 1804 in accordance with the present invention. A portion 1806 of the form is shown in a rolled configuration, to handle easily & conserve space. The surface 1808 of the mold has a textured surface simulating the appearance of roof shingles 1810.

Figure 30A through 30D show another embodiment 1900 of the

present invention which features the use of a variety of beam members 1902, 1904, 1906, 1908 which are utilized to form a roof 1910. The beams are first assembled as is shown in Figures 30A and 30B. Figures 30C and 30D show the form 1912, a layer of sprayed building material 1914, an insulation layer 1916,and a second layer of sprayed building material 1918.

Figures 31A through 31G show another embodiment 2000 of the present invention which features the use of patterned rigid panels 2002 in accordance with the present invention. The panels 2002 feature a front surface 2004 which has a desired pattern. The rear surface 2006 of the panel 2002 has a multiplicity of pins 2008, or fingers. In Figures 31C and 31D the panel 2002is applied to the form 2010 using a removable, pressure-sensitive adhesive 2010,and the rear surface 2006 of the panel 2002 and the pins 2008 are covered by sprayable building material 2014. In Figures 31E and 31F,the panel 2002 is applied to a recently-sprayed surface 2016,and the pins 2008 are embedded in the soft building material. The panels may themselves be used as the form against which the hardenable building material is sprayed, or otherwise applied.

Figure 32 shows another embodiment 2100 of the invention in which a crane 2102 is used to place and remove a flexible roof form 2104. A plurality of pins 2106 are provided on the roof peak 2108, and on the wall plates 2110, 2112, which fit into holes 2114 which are formed in the flexible roof form 2104. This flexible roof form 2104 is corrugated to provide rigidity in the transverse direction while retaining flexibility in the longitudinal direction, enabling it to be rolled.

Figure 34 shows another embodiment 2200 of the invention which features the use of a layer of welded wire mesh 2202 as reinforcement. The formed welded wire mesh 2202 is held in tension between a plurality of pins (reinforcing bar ends) 2203 which project from the roof peak 2204 and a plurality of pins (reinforcing bar ends) 2206 which project from the wall plates 2208 in the manner shown in Figure 33. The formed welded wire mesh 2202 is covered by a flexible roof-forming layer 2212, which is held in tension by guy wires 2222 in the manner of a tent.

Figure 35 shows another embodiment 2300 of the invention, similar to the embodiment shown in Figure 34. The welded wire mesh 2302 is formed with sharper angles than the previous embodiment and the stiff axis 2304 of the welded wire mesh convolutions run from the roof peak 2306 to the wall plates 2308,to supportively span the gap. The roof 2210 includes a layer of foam concrete 2212 which is sprayed against the flexible form 2214 (which is later removed), a layer of *insulating urethane or polyethylene foam (sprayed or cast) 2216, the welded wire mesh 2202,and a second layer of foam concrete 2020. The plurality of pins (reinforcing bar ends) 2202 support a ridge cap member 2240. [*Insulation required by Building Codes, not the invention.] As is shown in Figure 34 the general configuration of the formed welded wire mesh is that of a truncated "V". Other configurations may be utilized,including those shown in Figure 38. The wire mesh 2202 may be formed by forming rollers 2242, 2246 as is shown in Figure 37.

Figure 36 shows an alternate embodiment 2400 of the invention which utilizes two layers of formed welded wire mesh reinforcement 2402, 2404 installed with their stiff axes perpendicular to each other.

Figure 39A and 39B show another alternative embodiment 2500 of the invention which utilizes a mountable, de-mountable, removable and reusable flexible form 2502 vertically. Hardenable building material is sprayed against the flexible form 2502. The flexible form 2502 is assembled against a framework structure 2504 which not only supports flexible form 2502, but also keeps it taut and flat. The flexible form 2502 is bolted to the framework structure 2504 using, for example, a bolt 2406 and a nut 2408.

Figure 40 shows another embodiment 2600 of the invention which features a high-speed construction system utilizing a high-capacity (optionally computer-controlled) mixing apparatus 2602. The high-capacity mixing apparatus 2602 is shown delivering sprayable or pourable hardenable building material 2938 via a plurality of hoses 2604, 2606, 2608, 2610, 2612, to mass-produce structures by a division of function: 1 man produces only slabs, 1 man only interior walls, 1 man only exterior walls, 1 man only roof-ceilings, and 1 man only walkways, curbs and driveways - all at the same time. Because of

the fast-curing, hardenable building material, the whole crew and the mixer move to the next site down the road, where each encores his specialty on the next structure. With concrete that can be walked on in about ½ hour after spraying or pouring, forms can be rapidly stripped, cleaned and reused.

Figures 41A through 41E show another embodiment 2700 of the invention which features a unitary combination bathroon sink 2702, tub 2704, shower 2706 and toilet 2708, which is heat-formed from a single sheet of material. The combination 'wet unit' does for the plumbing what the rapidly-placed-and-hardened foam concrete does for the structure=brings up the quality and brings down the cost, by minimizing the transporation cost (for a sheet, instead of a multiplicity of 3-dimensional plumbing units) and radically lowering:the weight , the installation cost (just 1 unit, instead of many), and the hook-up cost (because each of the hot water, cold water & drains are all hooked together for quick and ready supply hook up).

Figure 42 shows another alternative embodiment 2800 of the present invention, which features a unitary construction similar to Figure 41, which utilizes a different arrangement of the component parts, adding a kitchen sink and cabinet to the unitary construction = providing plumbing for the two wet rooms = bathroom and kitchen, all-in-one.

Figure 43 shows another embodiment of the present invention, which features a concrete mixing-and-application apparatus 2900, which includes a water tank 2902, air compressor 2904, bags of sand 2906, cement 2908, additives 2910, mixer 2912, foamer 2914, tank of diluted foaming agent 2916, drive motor 2918, feed hopper 2920, pump 2922, surge arrestor 2924, and concrete feed line 2926, accelerator tank 2928, air valve 2930, accelerator line 2932, airline 2934 and nozzle 2936. The apparatus 2900 is shown in use, spraying building material 2938 against a wall 2940. The nozzle 2936 is of special design,to use air-pressure (turbulently injected) to propel the slurry to great distances (horizontally and vertically),and introduce and turbulently mix into the slurry the rapid-acting accelerator at the last possible moment (to prevent the slurry from hardening inside its own hose).

The controls for: the slurry pump 2942, the air pressure 2944, and the accelerator 2946, are all at the nozzleman's fingertips.

Figure 44 shows another embodiment 3000 of the invention which features the use of a large adjustable form 3002 which may be repetitively moved upwardly in the vertical direction. The form 3002 may be adjusted by means of selectively placed removable inserts 3004,3006, 3008,3010, to form window 3012 and door 3014 apertures.

Figure 45 is another alternative embodiment 3100 of the invention which features the dipping of a form 3102 into a container 3104 of heated liquid material 3106 in order to form a structure of the dipped liquid, which solidifies as it cools on the form 3102. The hollow building structure is removed from the form 3102 while it is sufficiently flexible to strip from the form 3102, and hardens into its final shape apart from the form 3102. The hollow structure can be used as is, or its walls and roof can be filled with any material (including insulating material); or alternatively, a hollow form can be used, creating a solid structure inside the walls of the form, and used as is, or coated with one or more layers of materials.-

Figure 46 shows a rotatable spray means 3200, comprising a support means 3202, a rotational means (pancake [but need not be] motor shown) 3204, inclinable means 3206, hardenable construction material supply 3208, and manual or automatic function by a program that controls: nozzle tilt moter 3210, rotational motor 3204, and material supply 3208. Alternatively, the rotatable means 3200 could be equipped with a multiplicity of nozzles, as seen in Figure 21.

While preferred embodiments of the invention have been shown and described herein, it is obvious that numerous additions, changes and omissions may be made in such embodiments without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1 An apparatus for the rapid construction of structures comprising an inflatable member having a plurality of outwardly projecting protuberances, means for inflating said inflatable member, and means for applying a hardenable material to said inflatable member in areas between said protuberances thereby forming a shell structure with said protuberances forming apertures in said shell structure for the purpose of defining door and window openings.

2 An apparatus according to claim 1 in which said means for applying a hardenable material comprise spray means.

3 An apparatus according to claim 1 in which said hardenable material comprises a concrete material.

4 An apparatus according to claim 1 in which said hardenable material contains a multiplicity of reinforcing fibers.

5 An apparatus according to claim 4 in which said reinforcing fibers have a convoluted surface.

6 An apparatus according to claim 1 in which said hardenable material includes an agent for forming a multiplicity of bubbles in the hardenable material.

7 An apparatus according to claim 1 in which said protuberances comprise inflatable members.

8 An apparatus according to claim 1 in which said protuberances comprise rigid members.

9 An apparatus according to claim 8 in which said protuberances are removably attached to said inflatable member and further comprising attachment means for attaching them to said inflatable member.

10 An apparatus according to claim 9 in which said attachment means comprise flexible adhesive tape means.

11 An apparatus according to claim 1 in which said inflatable member further comprises means for maintaining portions of said inflatable member substantially flat.

12 A method for construction of a low-cost structure comprising the steps of erecting a one-sided form with said form having a configuration defining a desired structure and having protuberances defining desired window and door apertures. in said struc-

ture,
- spraying said form with a layer of hardenable material, with said material having defined characteristics.
- allowing said hardenable material to solidify,thereby forming a shell having the configuration of said structure, and
- removing said one-sided form.

13 A method for construction of a low-cost structure according to claim 12 further comprising the step of spraying a second layer of hardenable material on to said layer of hardenable material prior to said step of removing said one-sided form, with the characteristics of said second layer of hardenable material different from the charateristics of said first layer of hardenable material.

14 A method for construction of a low-cost structure according to claim 13 further comprising the step of spraying a third layer of hardenable material on to said second layer of hardenable material, prior to said step of removing said one-sided form, with the characteristics of said third layer of hardenable material different from the characteristics of said second layer of hardenable material.

15 A method for construction of a low-cost structure according to claim 12 in which said step of erecting a one-sided form comprises inflating an inflatable member.

16 A method for construction of a low-cost structure according to claim 12 in which said step of erecting a one-sided form comprises stretching a membrane to form a desired structural configuration.

17 A method for construction of a low-cost structure according to claim 12 further comprising the steps of
- erecting a second one-sided form disposed above said shell.
- spraying said second form with a layer of hardenable material to solidify, thereby forming a second shell.
- removing said one-sided form ,thereby forming a second story on said structure.

18 An apparatus for the rapid construction of structures according to Claim 12 further comprising thickness-measuring means for measuring the thickness of said hardenable material with said thickness measuring means mountable on said inflatable member and projecting outwardly from the surface of said inflatable member.

19 An apparatus for the rapid construction of structures according to Claim 1 with said inflatable member further including means forming a concave portion for the purpose of forming a trough in said shell structure.

20 An apparatus according to Claim 12 in which said one-sided form comprises textured surface means for the purpose of forming a corresponding textured surface in said contacting building material

21 A method for construction of a low-cost structure according to claim 12, further comprising the steps of repositioning said one-sided form adjacent said structure and repeating said steps of erecting said form, spraying said form, allowing said hardenable material to solidify, and removing said form.

22 An apparatus according to claim 2 in which said spray means further comprise a guide track means, for guiding said spray means.

23 An apparatus according to claim 2 in which said spray means further comprise a programmable rotatable means for guiding said spray means.

24 An apparatus according to claim 22 further comprising motor means for driving said spray means along said guide track means.

25 An apparatus according to claim 21 in which said spray means comprises a plurality of spray jets.

26 An apparatus according to claim 24 in which said spray means further comprises control means for selectively controlling flow through said plurality of spray jets.

27 An apparatus according to claim 1 further comprising reinforcement structure means disposed outside said inflatable member.

28 An apparatus according to claim 1 further comprising rigid roof panels, adapted for mounting on said structure.

29 A method for construction of a low cost structure comprising the steps of coating a mold having raised patterned surface with a pigment,
spraying said mold with a layer of hardenable material having a color different from said pigment, allowing said hardenable material to solidify, and removing said mold.

30 An apparatus according to claim 1 in which said inflatable member further comprises a collapsible framework and a plurality of rigid panels mounted on said framework.

31 An apparatus for the rapid construction of structures comprising a plurality of rigid panels with each panel having a first and a second surface and a multiplicity of projecting members disposed on said first surface of said panel for the purpose of embedding said projecting members in a hardenable building material permanently.

32 An apparatus for the rapid construction of structures comprising a rollable form member.

33 An apparatus according to claim 32 in which said structure includes a plurality of projecting pins and in which said rollable form member includes a plurality of apertures, disposed to receive said plurality of pins.

34 An apparatus according to claim 32 in which said rollable form member comprises a tent member.

35 A low cost structure comprising a formed welded wire mesh layer having a plurality of substantially parallel bends and means for covering said wire mesh layer with a hardenable building material.

36 An apparatus according to claim 34 further comprising a pair of formed welded wire mesh layers.

37 An apparatus according to claim 36 in which said bends in each of said pair of wire mesh layers are mutually perpendicular.

38 An apparatus according to claim34 further comprising a framework structure and means for attaching said rollable form member to said framework structure.

39 An apparatus for the rapid construction of structures, comprising a combination sink, toilet and tub molded as a single unitary structure.

40 An apparatus according to claim 39 further including a second sink in the unitary structure.

41 An apparatus according to claim 39 further including a shower in the unitary structure.

42 An apparatus for the rapid construction of structures, comprising a rigid movable form and means for moving said form in a vertical direction in order to segmentally form portions of a structure.

43 An apparatus according to claim 42 further comprising removable insert means disposed on said form for the purpose of forming apertures in said structure.

44 A method for the rapid construction of structures comprising the step of dipping a form into a liquid hardenable material, allowing said liquid hardenable material to solidify,and removing said form.

45 An apparatus according to claim 2 in which said spray means comprises a water tank means,air compressor means, mixer means for hardenable building material added to the storage tank means, hopper means, pump means, surge arrestor means, accelerator tank means, nozzle means and conduit means connecting said water tank means, air compressor means, air compressor means added to storage tank means, accelerator tank means and said nozzle; and controller means mounted on said nozzle means for controlling the flow of sand, additive means, hardenable building material means and said accelerator means through said nozzle.

46 A method for construction of low-cost structures comprising the steps of spraying a mold with a release compound ,coating on a raised portion of said mold with a pigment, spraying said mold with a hardenable material having a color different from said pigment, & allowing said hardenable material to solidify, and removing said mold.

47 An apparatus for the construction of a low-cost structure comprising a plurality of rigid form panels, aperture-defining members & attachment means for removing said aperture-defining members from said rigid panels.

48 An apparatus according to claim 47 in which said attachment means for removably attaching said aperture-defining members to said rigid panels is capable of disengaging said aperture-defining members from said rigid panels after said structure has been completed and said panels are removed from such structure.

49 A method for construction of a low-cost structure according to claim 47 in which said attachment means for removably attaching said aperture-defining members to rigid panels are capable of disengaging said aperture-defining members from said rigid panels prior to removing said rigid panels from said structure, thereby leaving said aperture-defining members as part of that structure.

50 An apparatus for the construction of a low-cost structure comprising a plurality of support members, with said support members further comprising a plurality of projecting pins and a plurality of transverse members including a plurality of apertures to receive said pins.

51 A method for the construction of a low-cost structure comprising the steps of erecting a one-sided form, spraying a layer of hardenable building material on the underside of said one-sided form, applying a layer of reinforcing material to said layer of hardenable building material, allowing said hardenable material to solidify, and removing said one sided form.

52 A method for the construction of of a low-cost structure according to claim 51 further comprising after the step of applying a hardenable building material layer, applying a layer of reinforcing material and placing a layer of insulating material.

53 A method of constructing a low-cost structure comprising an integrally uniform wall portion and a roof portion, with said roof portion comprising a pair of curved panels joined to form a peak.

54 An apparatus according to claim 1 in which said inflatable member comprises externally-disposed web means with said web means connecting selected portions of said inflatable member for the purpose of defining the configuration of the inflatable member.

55 An apparatus according to claim 1 in which said inflatable member comprises an internally disposed cable means which connects selected portions of said inflatable member for the purpose of defining the configuration of said inflatable member.

56 An apparatus according to claim 1 in which said inflatable member further includes pocket means,with stiffener means removably inserted in said pocket means.

57 An apparatus according to claim 1 in which said inflatable member includes rigid panel means.

58. An apparatus for the construction of a low-cost structure comprising form means, with said form means capable of accepting pourable hardenable building material, with said form means further comprising an inflatable member and a rigid member, with said rigid member spaced apart from said inflatable member thereby creating a cavity for said building material.

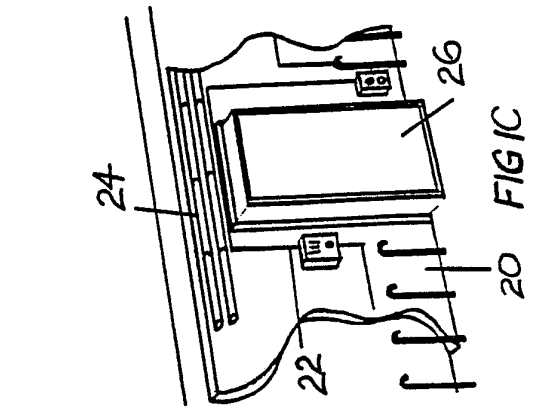

FIG IC

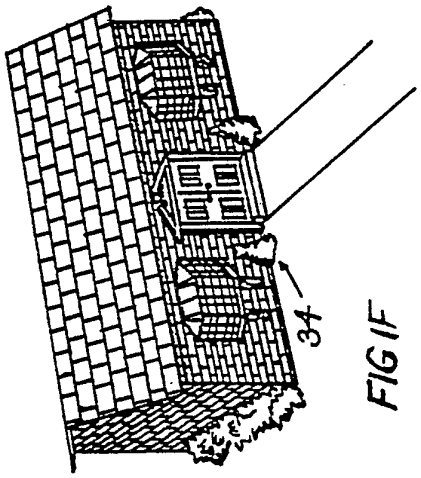

FIG IF

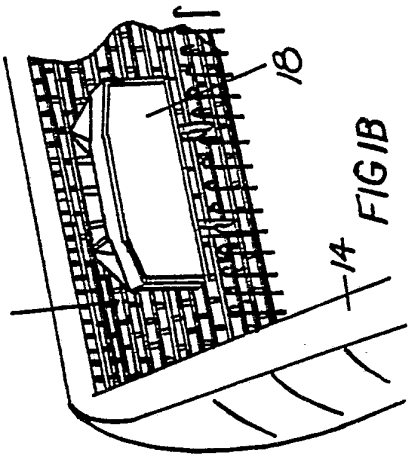

FIG IB

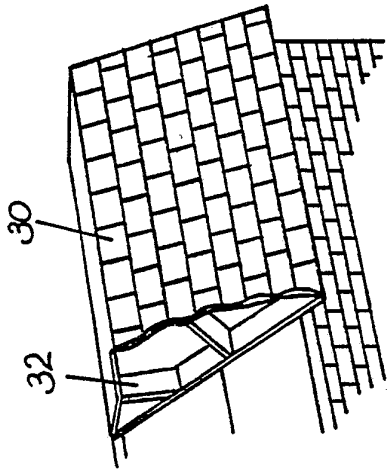

FIG IE

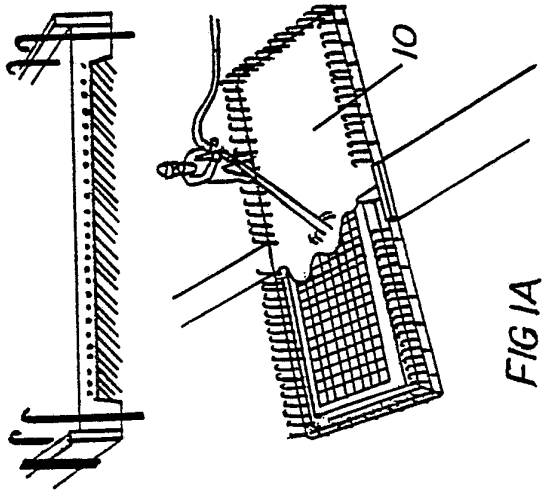

FIG IA

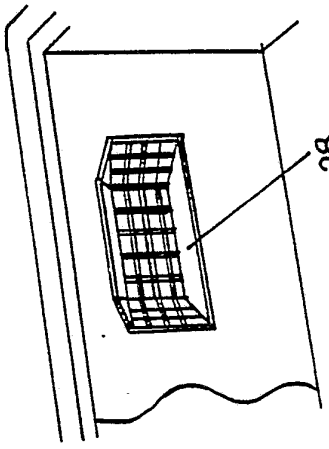

FIG ID

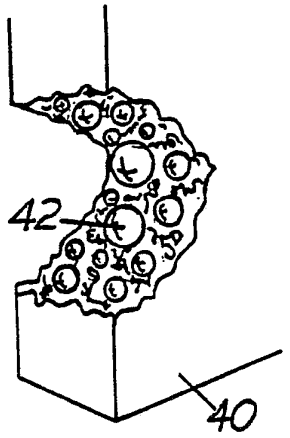

FIG 2

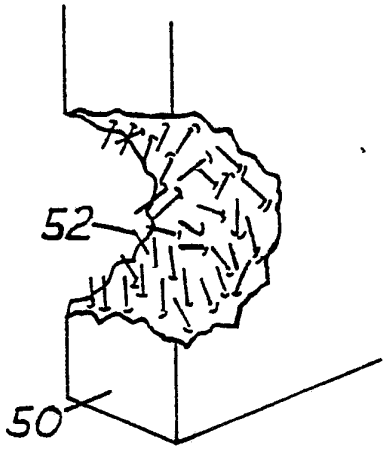

FIG 3

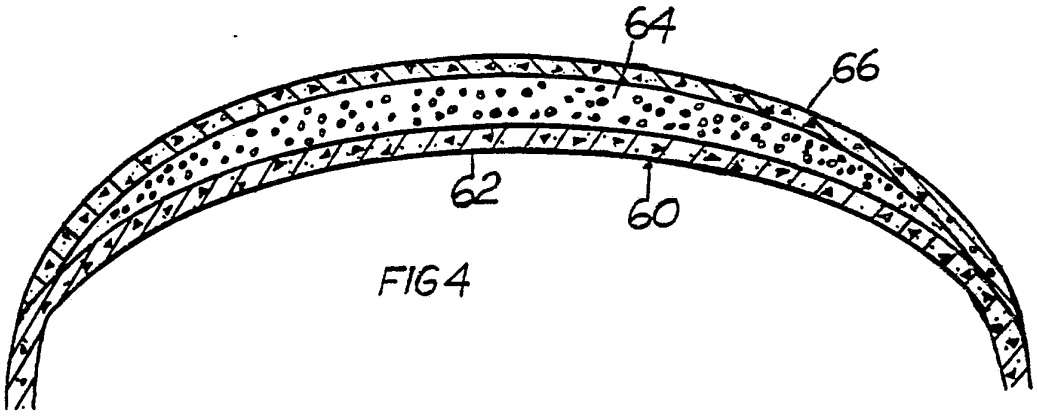

FIG 4

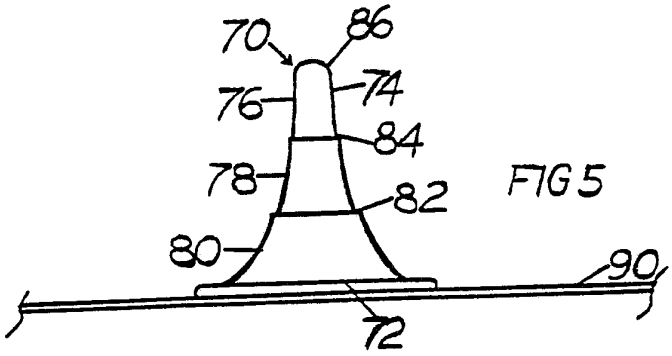

FIG 5

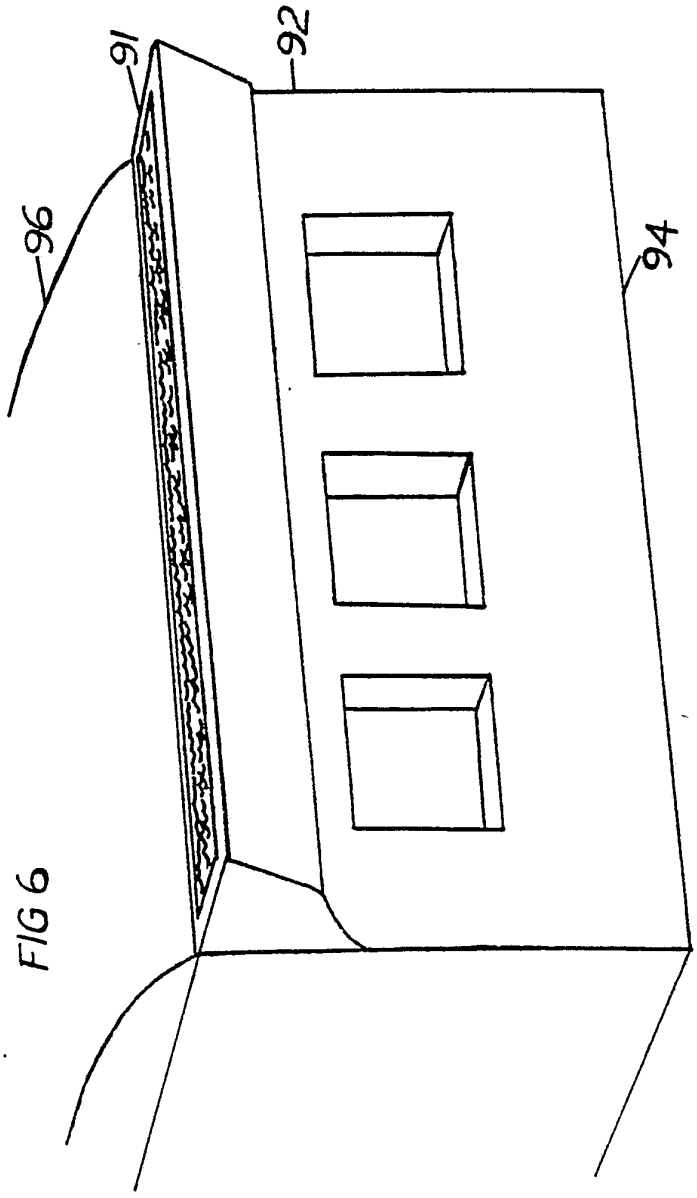

FIG 6

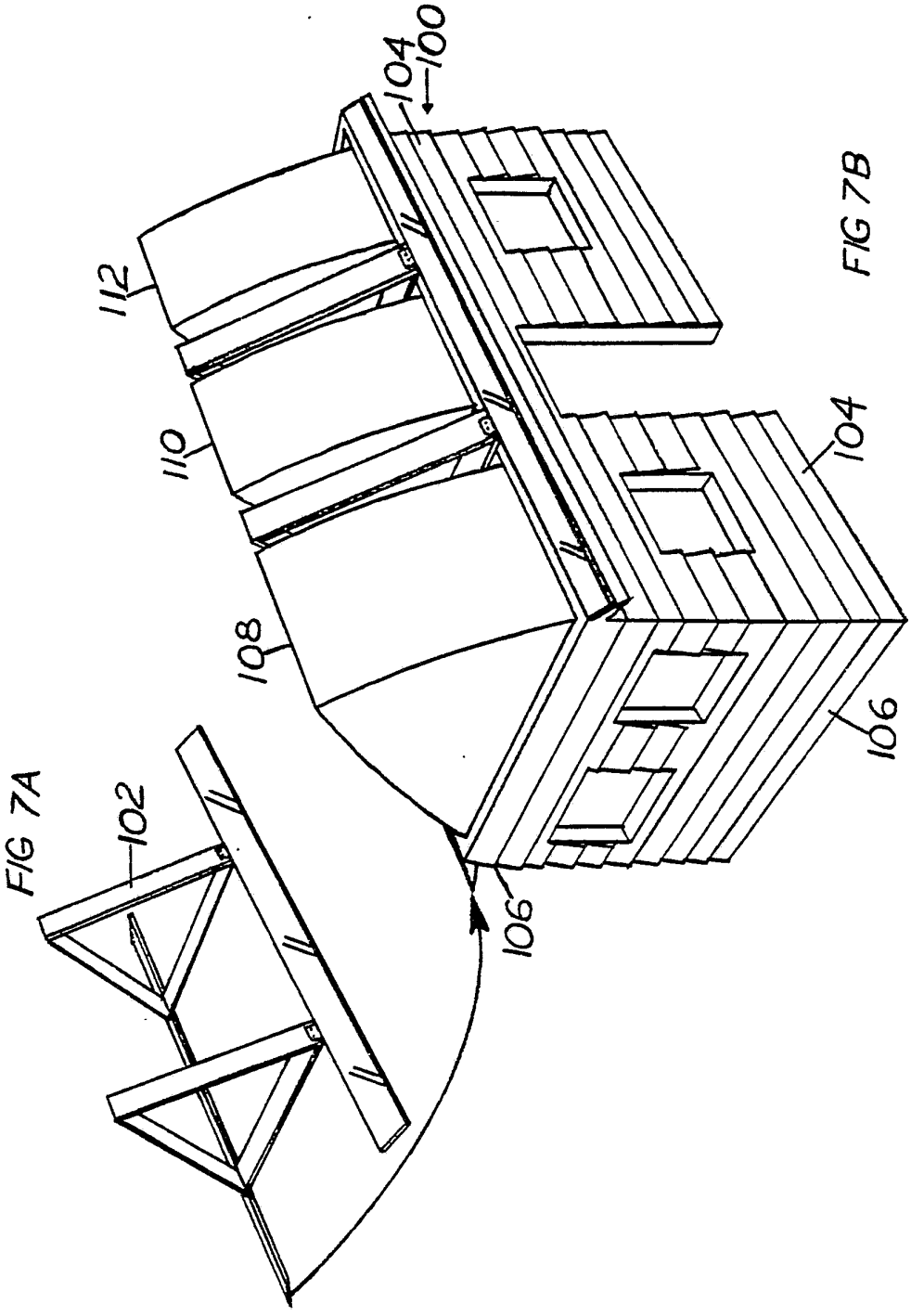

FIG 7A

FIG 7B

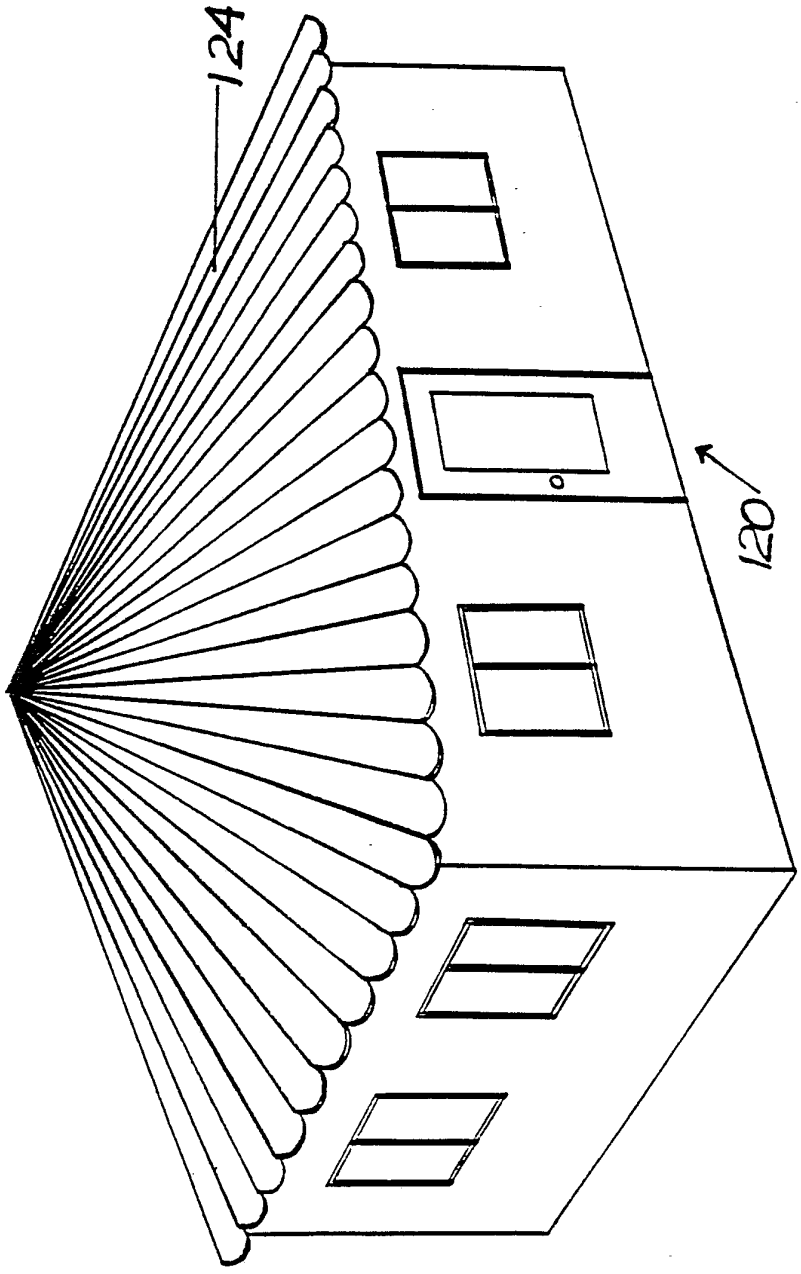

FIG8

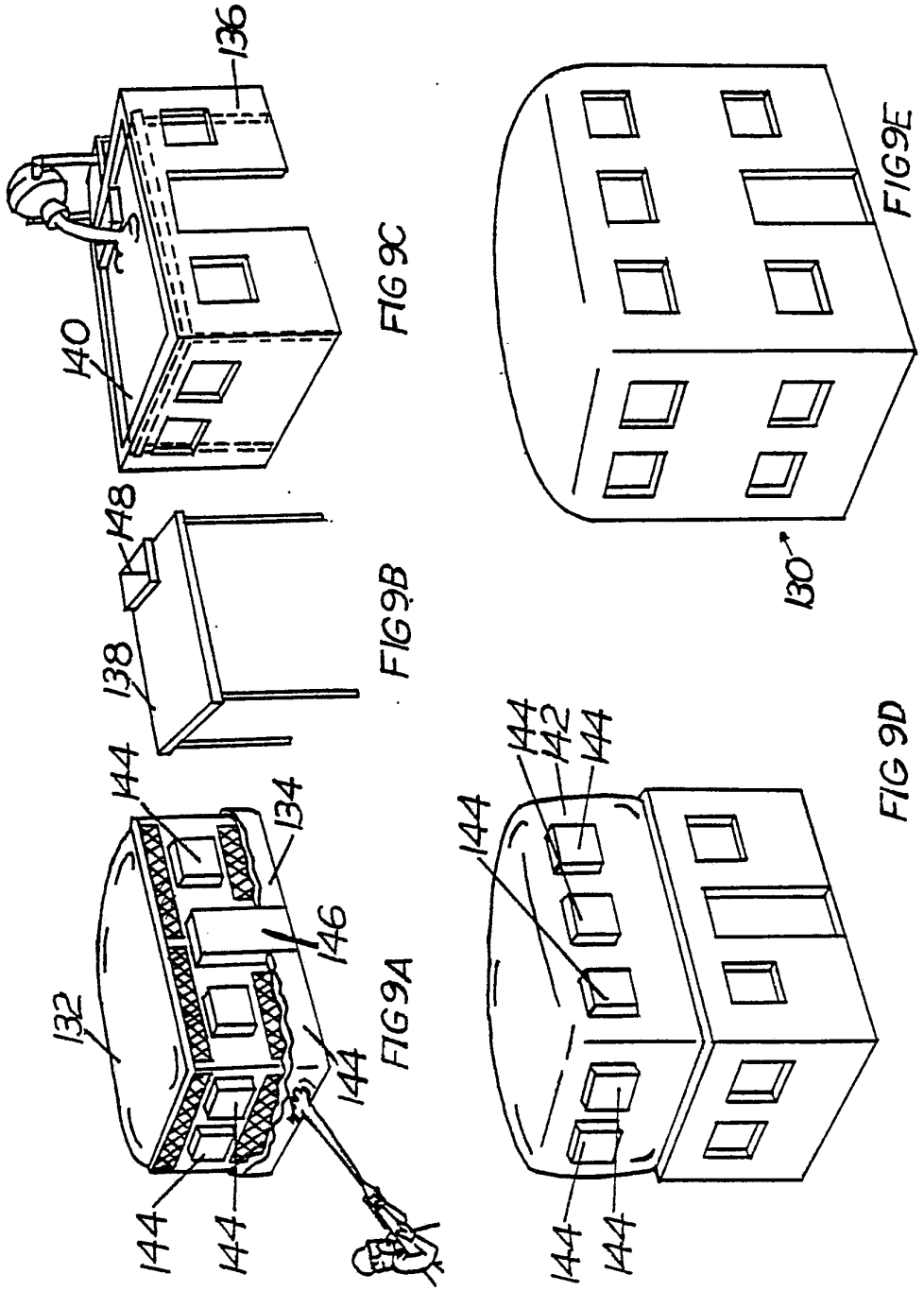

FIG 9C

FIG 9B

FIG 9A

FIG 9D

FIG 9E

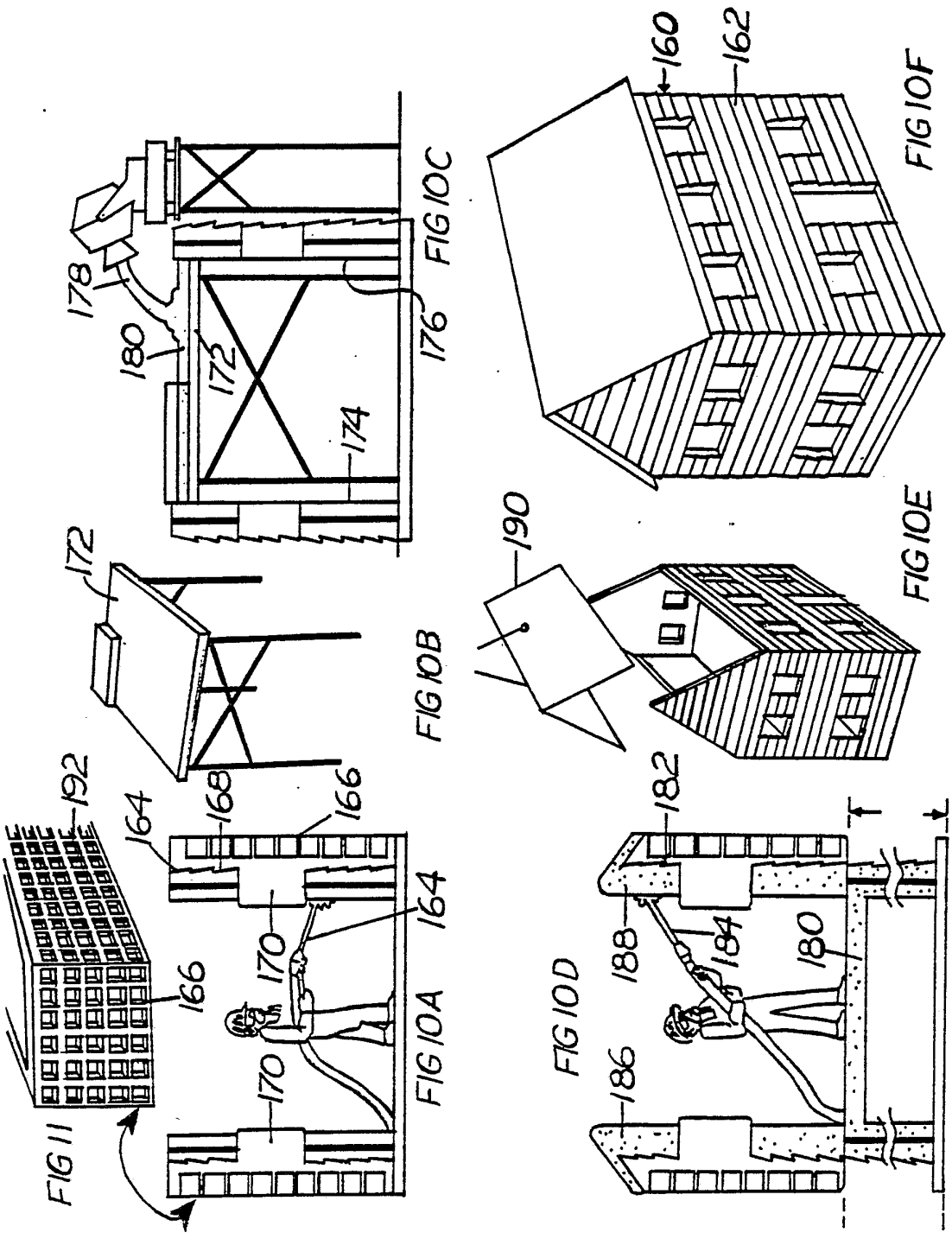
FIG 11
192
166
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170
FIG 10A
172
FIG 10B
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FIG 10C
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FIG 10E
160
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FIG 10F
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188
184
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186
FIG 10D

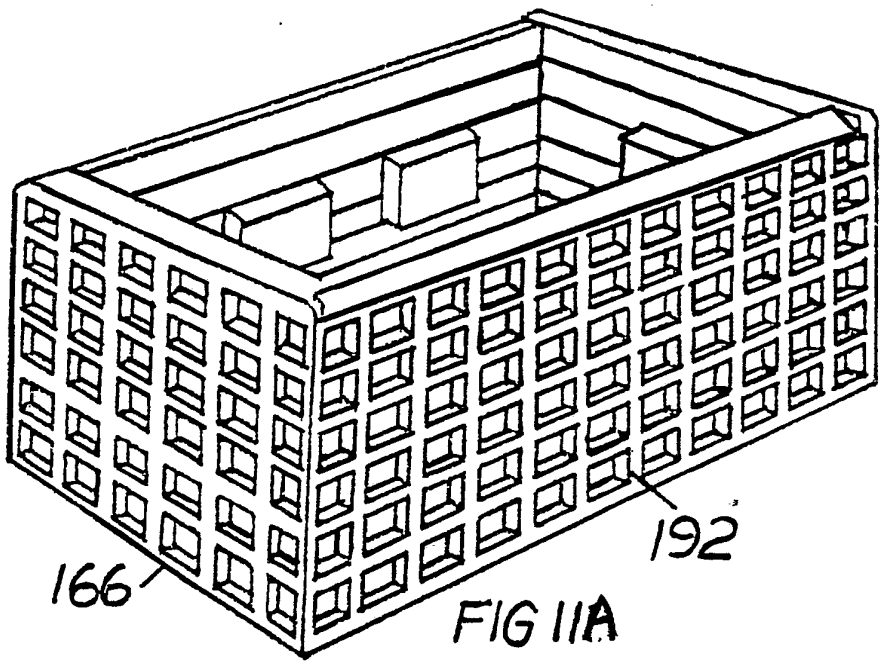


FIG 11A

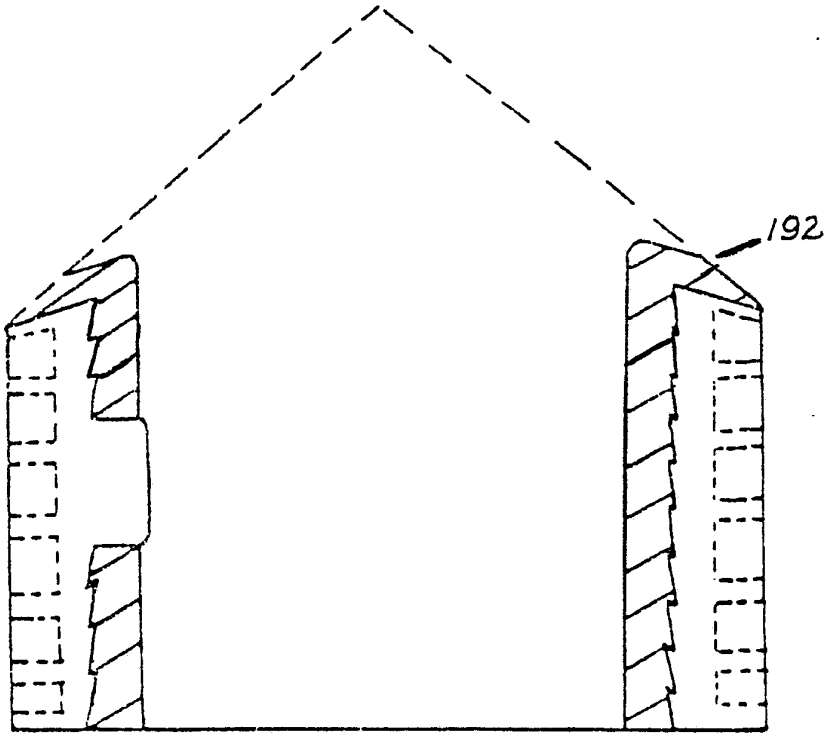


FIG 11B

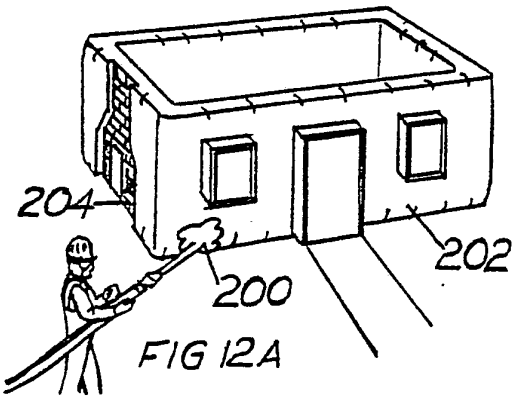


FIG 12A

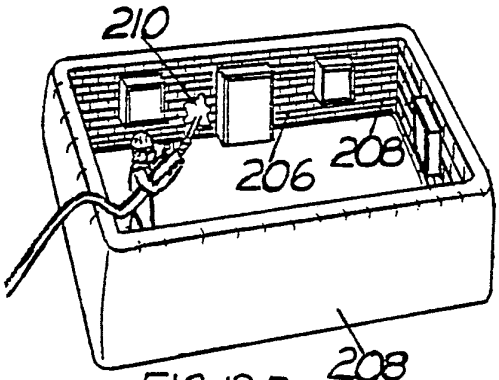


FIG 12B

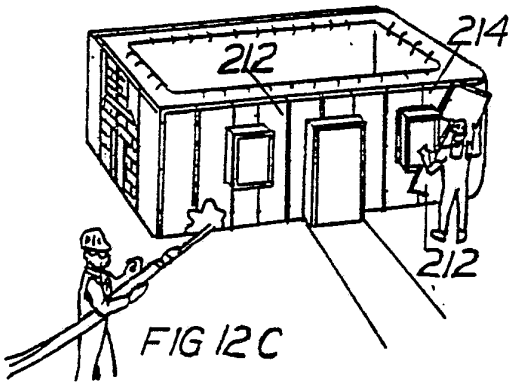


FIG 12C

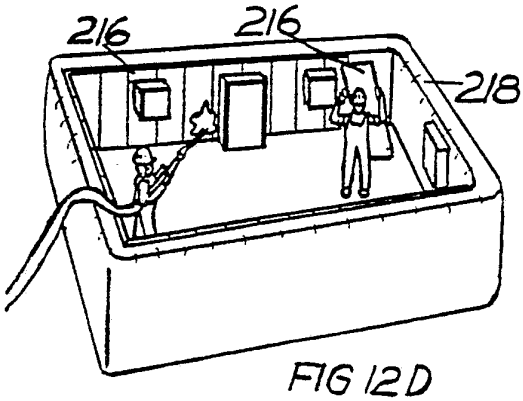


FIG 12D

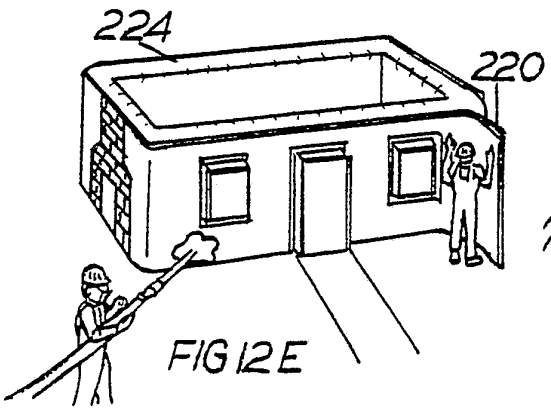


FIG 12E

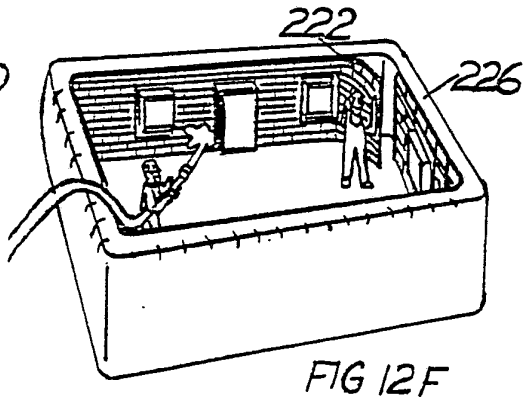
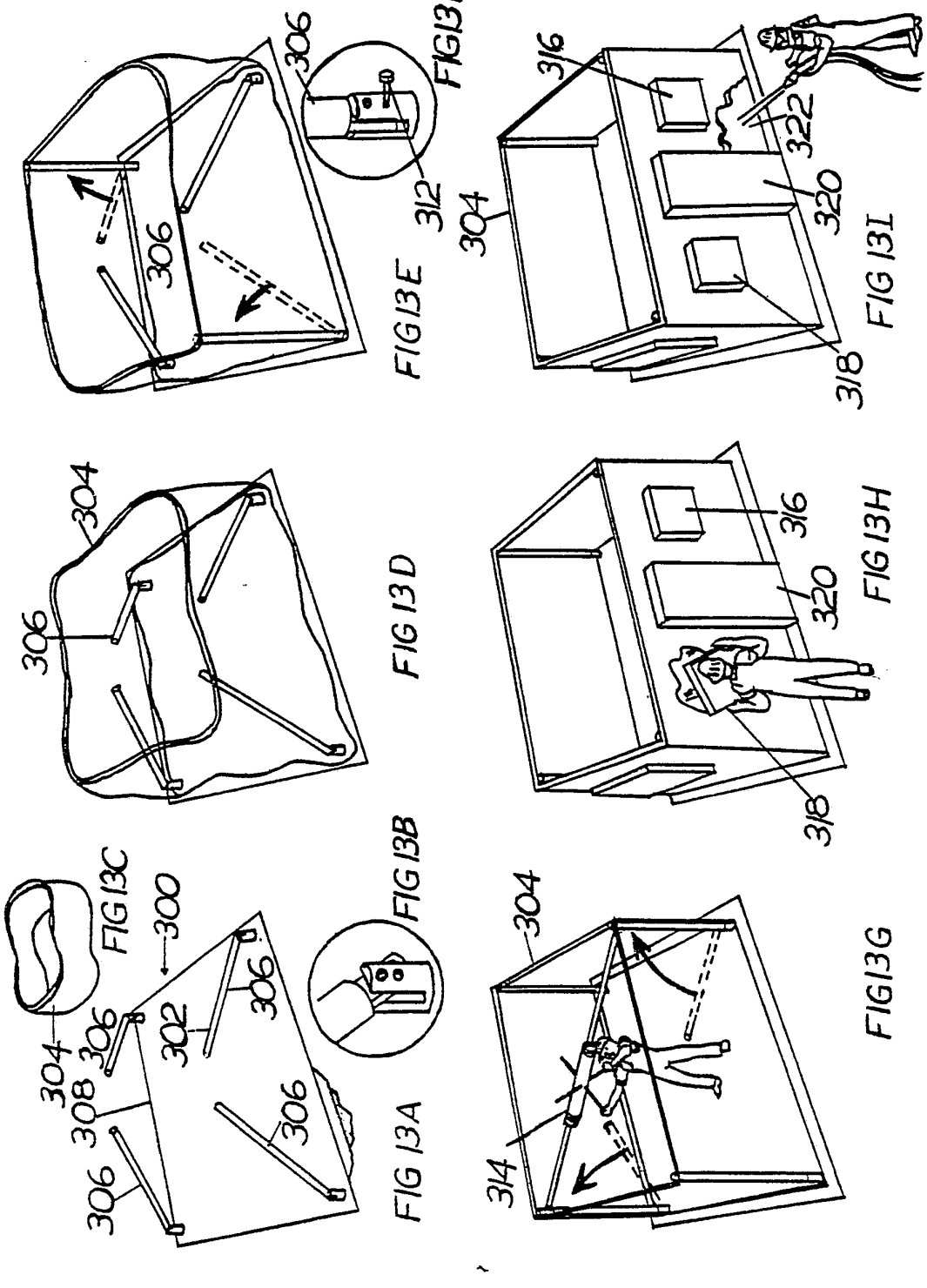


FIG 12F


306
FIG 13E
312
FIG13F
316
322
304
320
318
FIG 13I
304
306
FIG 13D
316
320
FIG 13H
318
FIG 13C
300
304
306
308
306
302
306
306
FIG 13A
FIG 13B
304
314
FIG13G

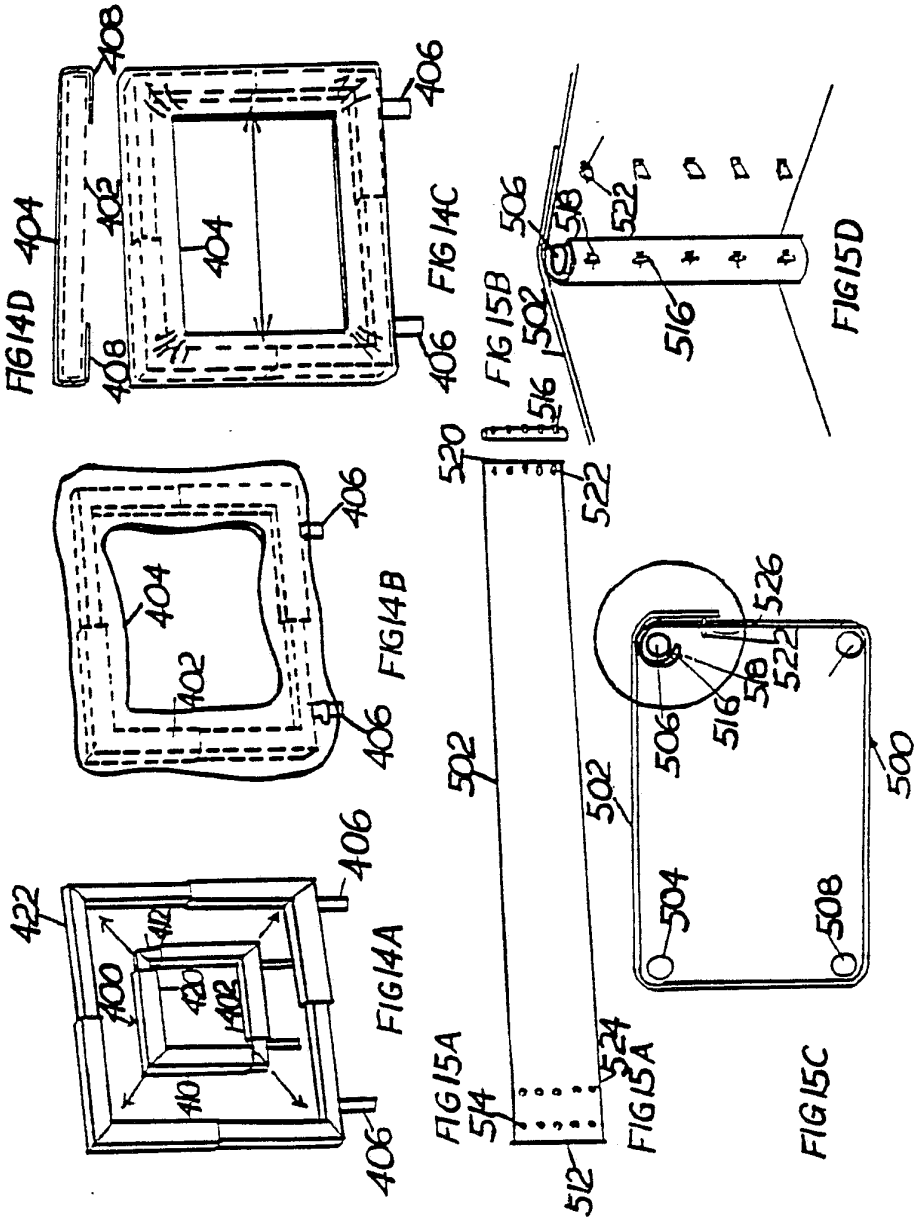


FIG14A
FIG14B
FIG14C
FIG14D
FIG15A
FIG15B
FIG15C
FIG15D
400
402
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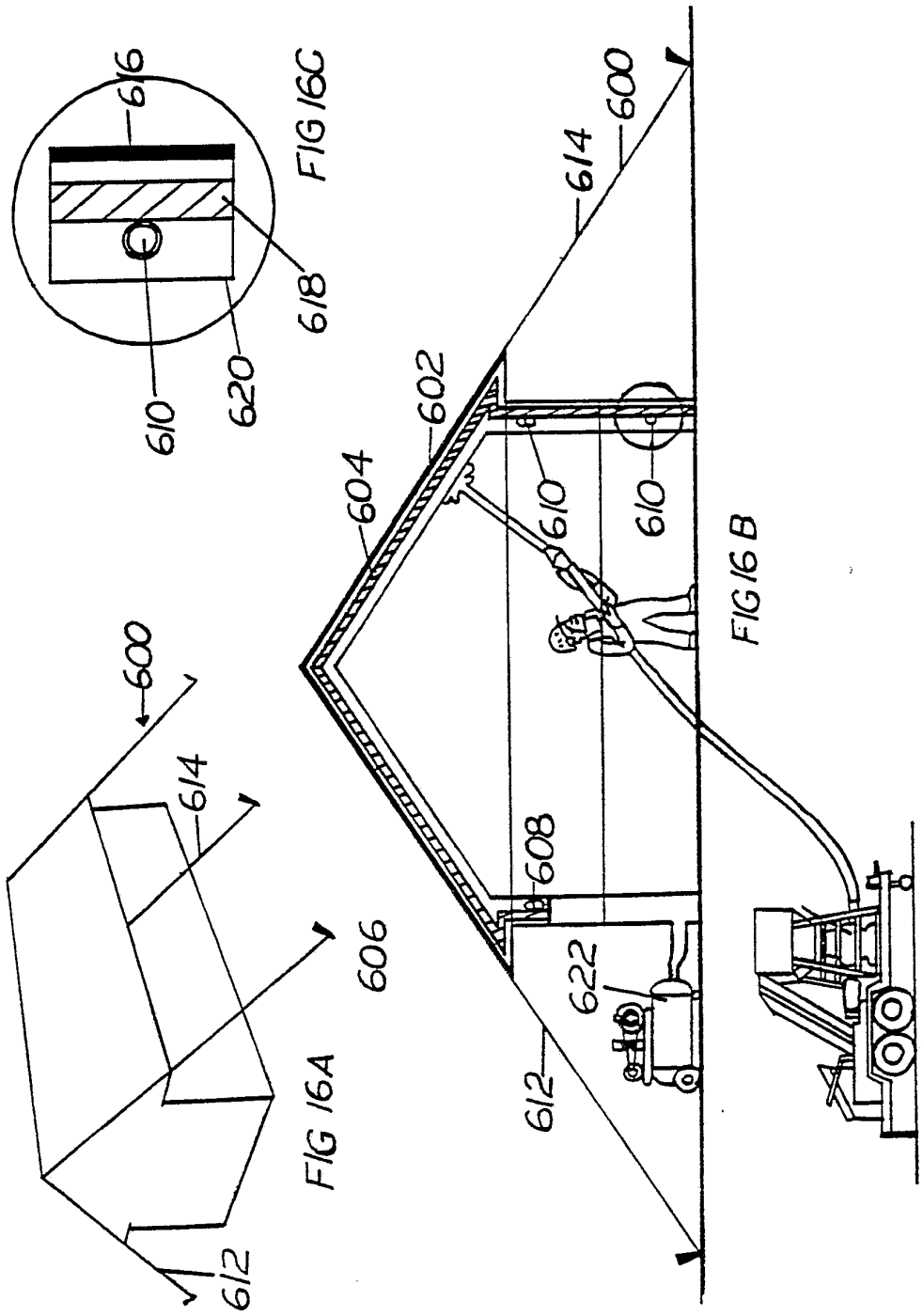


FIG 16A

FIG 16C

FIG 16B

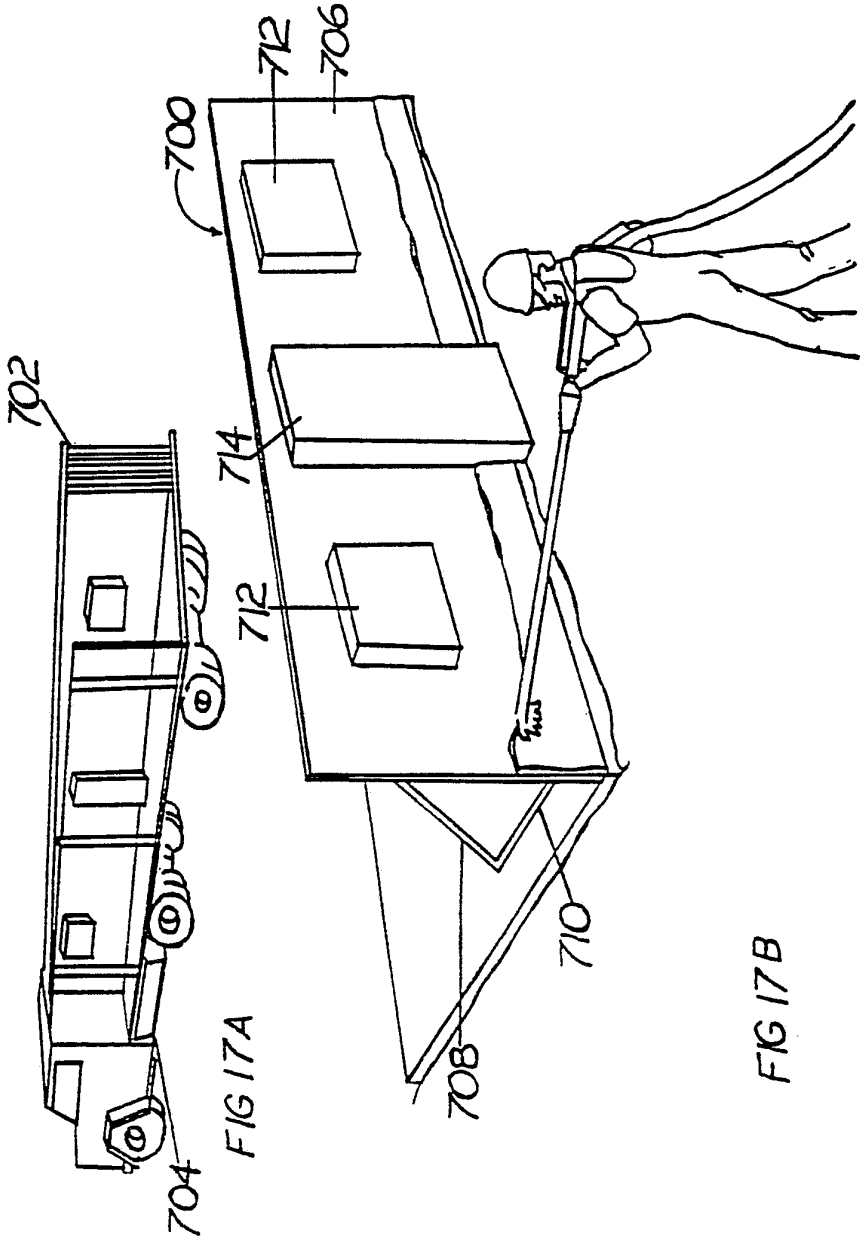


FIG 17A

FIG 17B

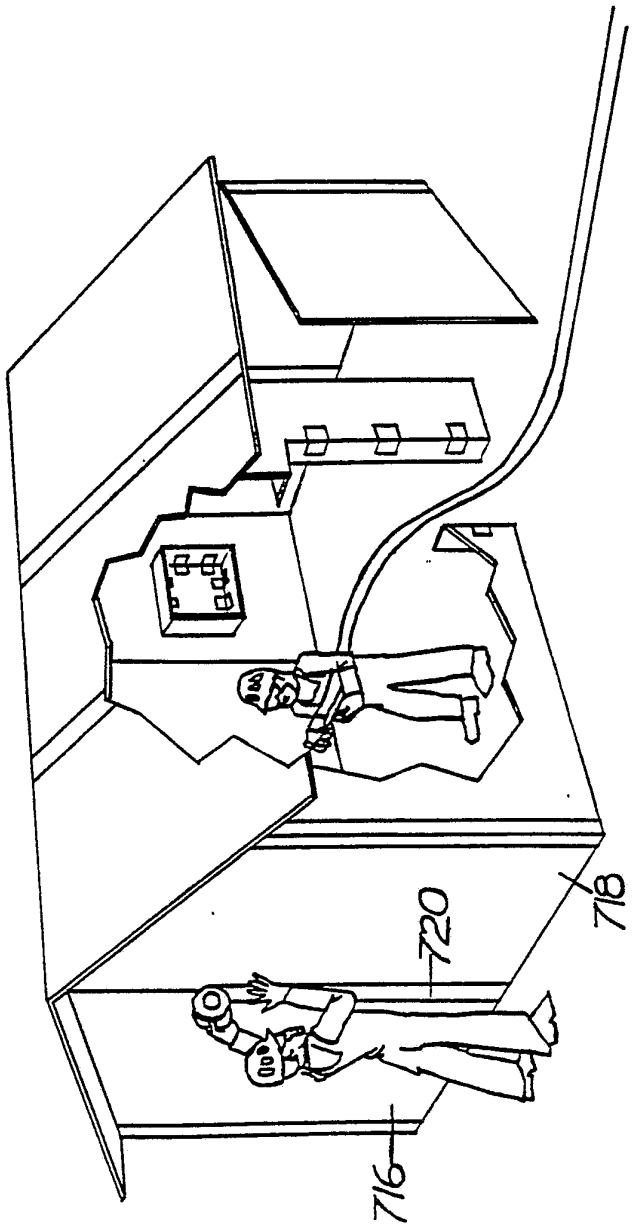


FIG 17C

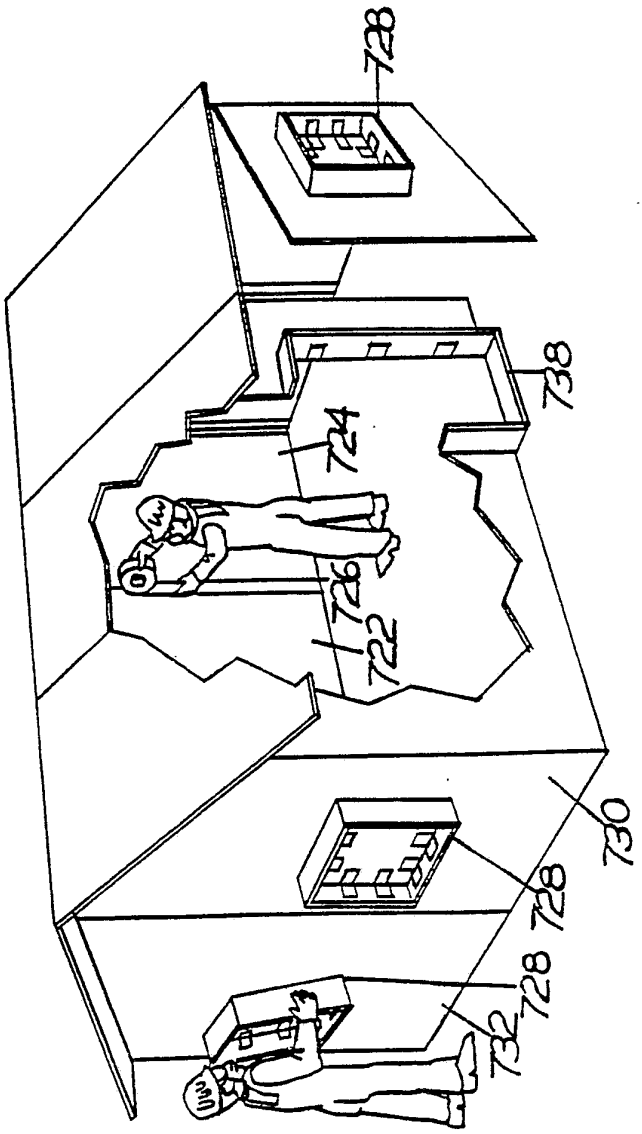


FIG 17D

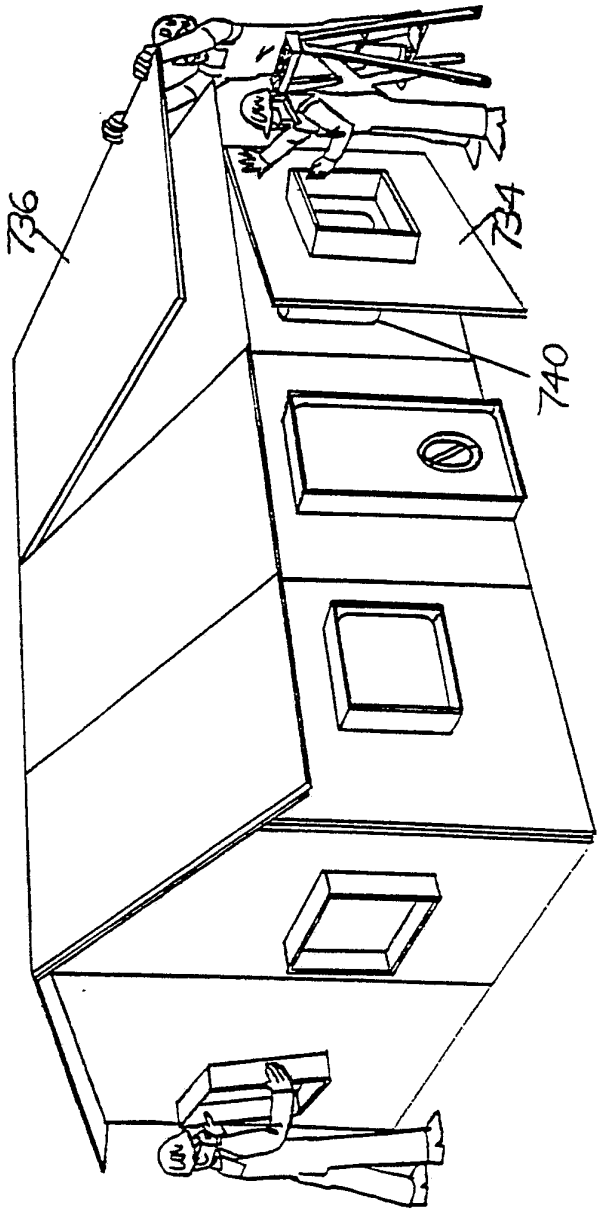


FIG 17E

FIG 18A

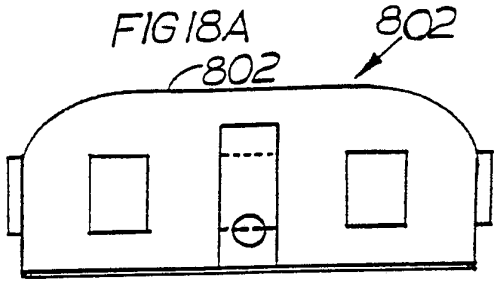
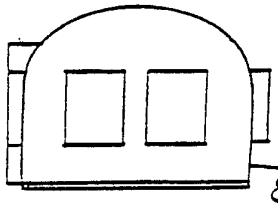


FIG 18B



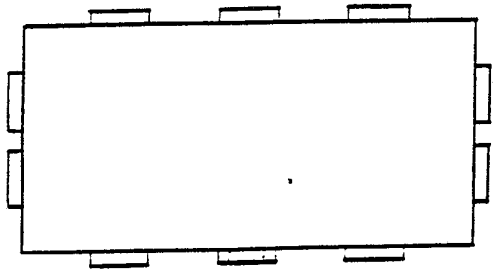


FIG 18C

FIG 18D

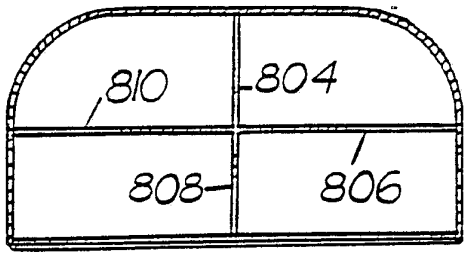
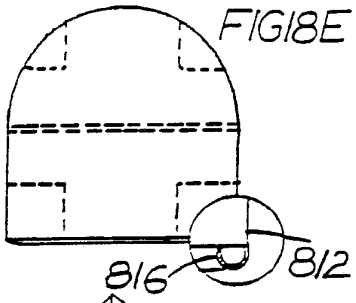


FIG18E



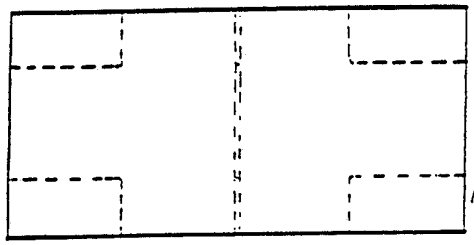


FIG 18F

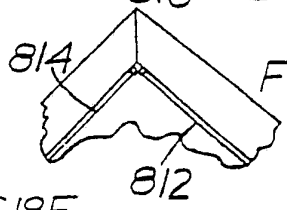


FIG18G

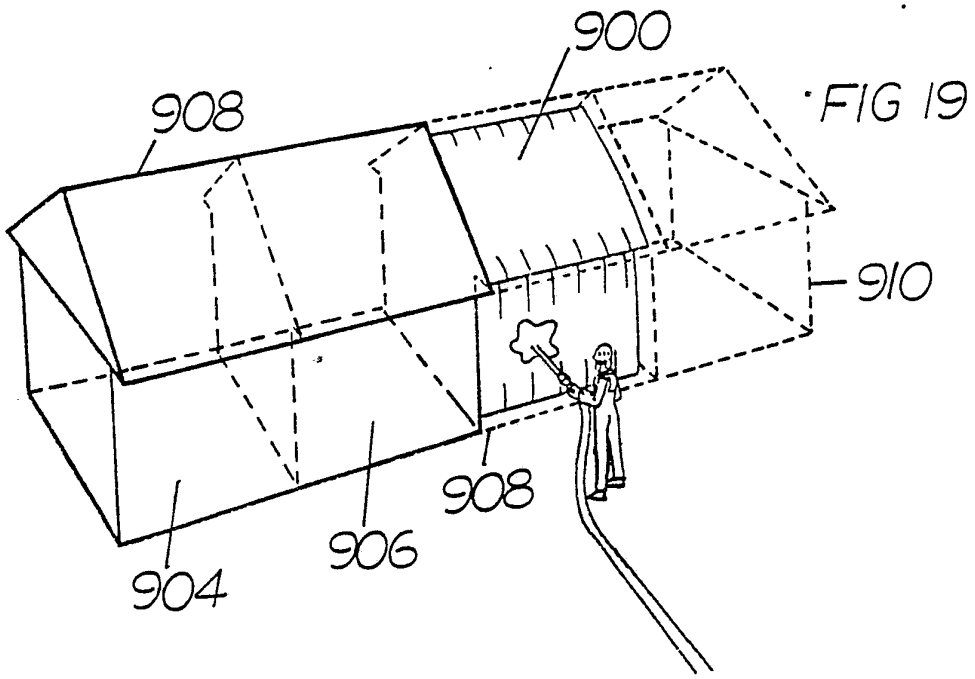


FIG 19

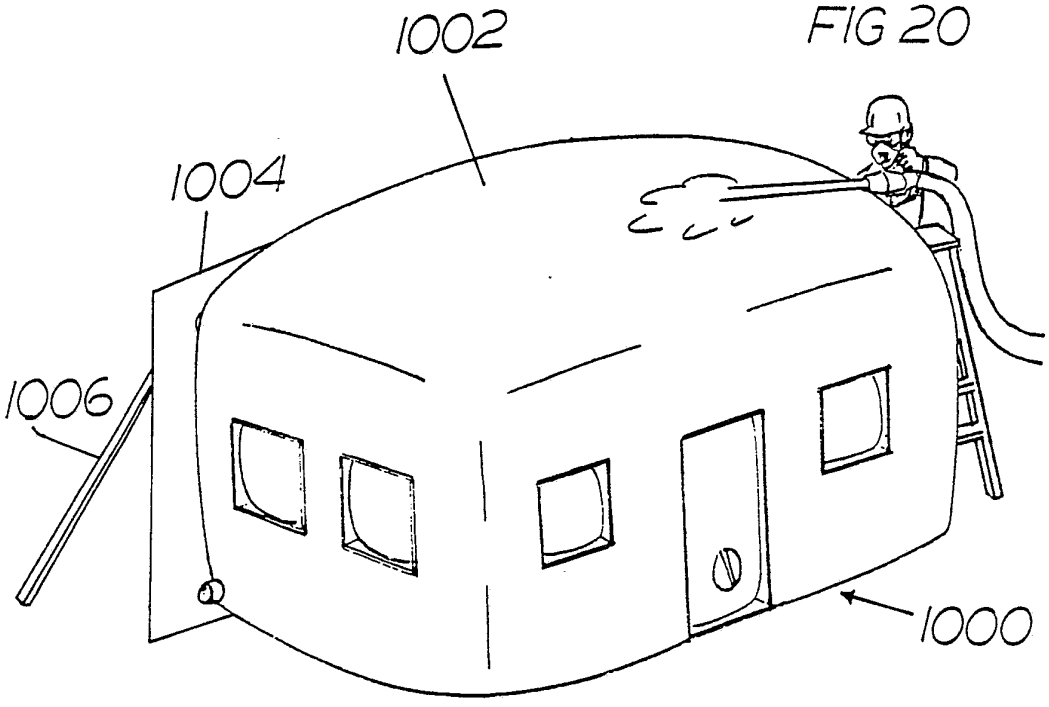


FIG 20

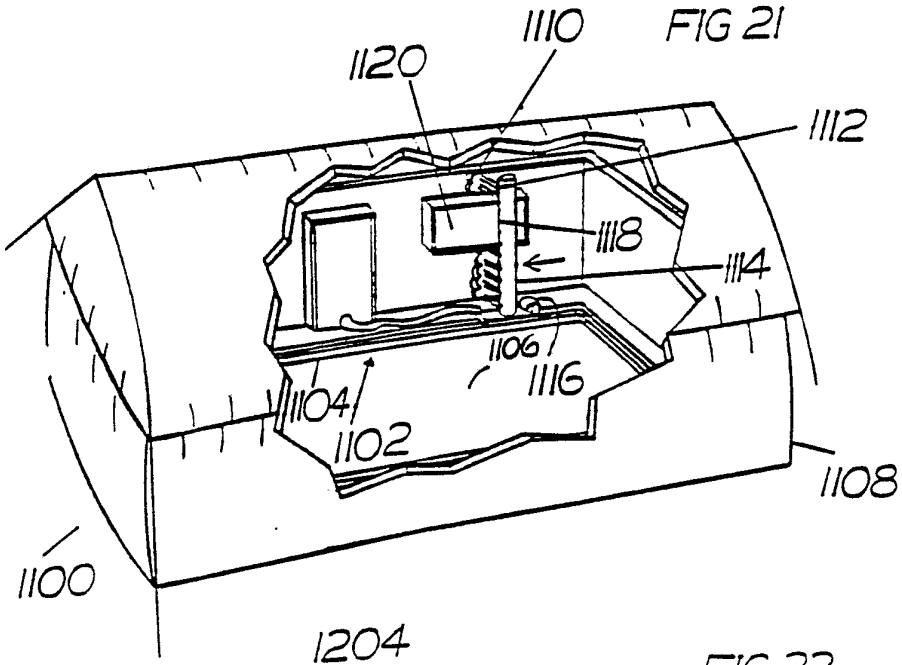

1110
1120
1112
1118
1114
1106
1116
1104
1102
1108
1100

FIG 21

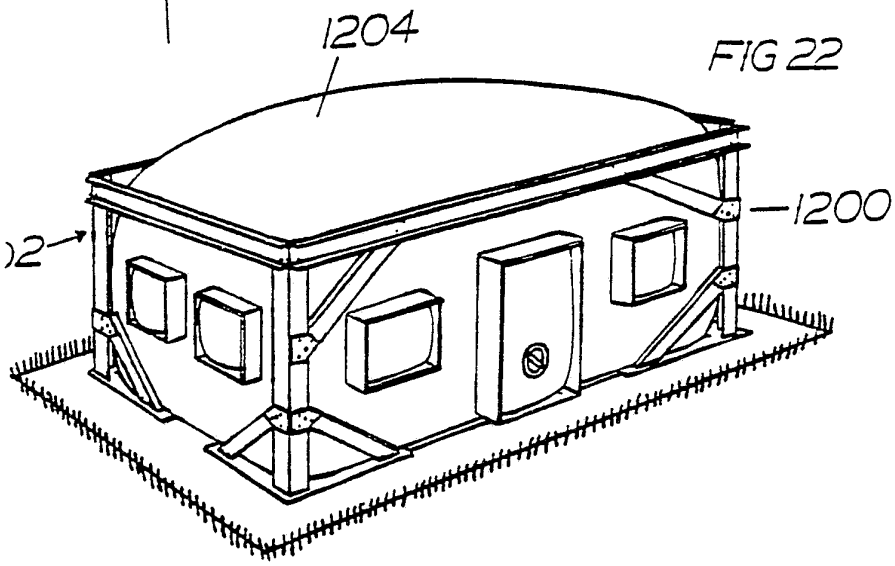

1204
1200
)2

FIG 22

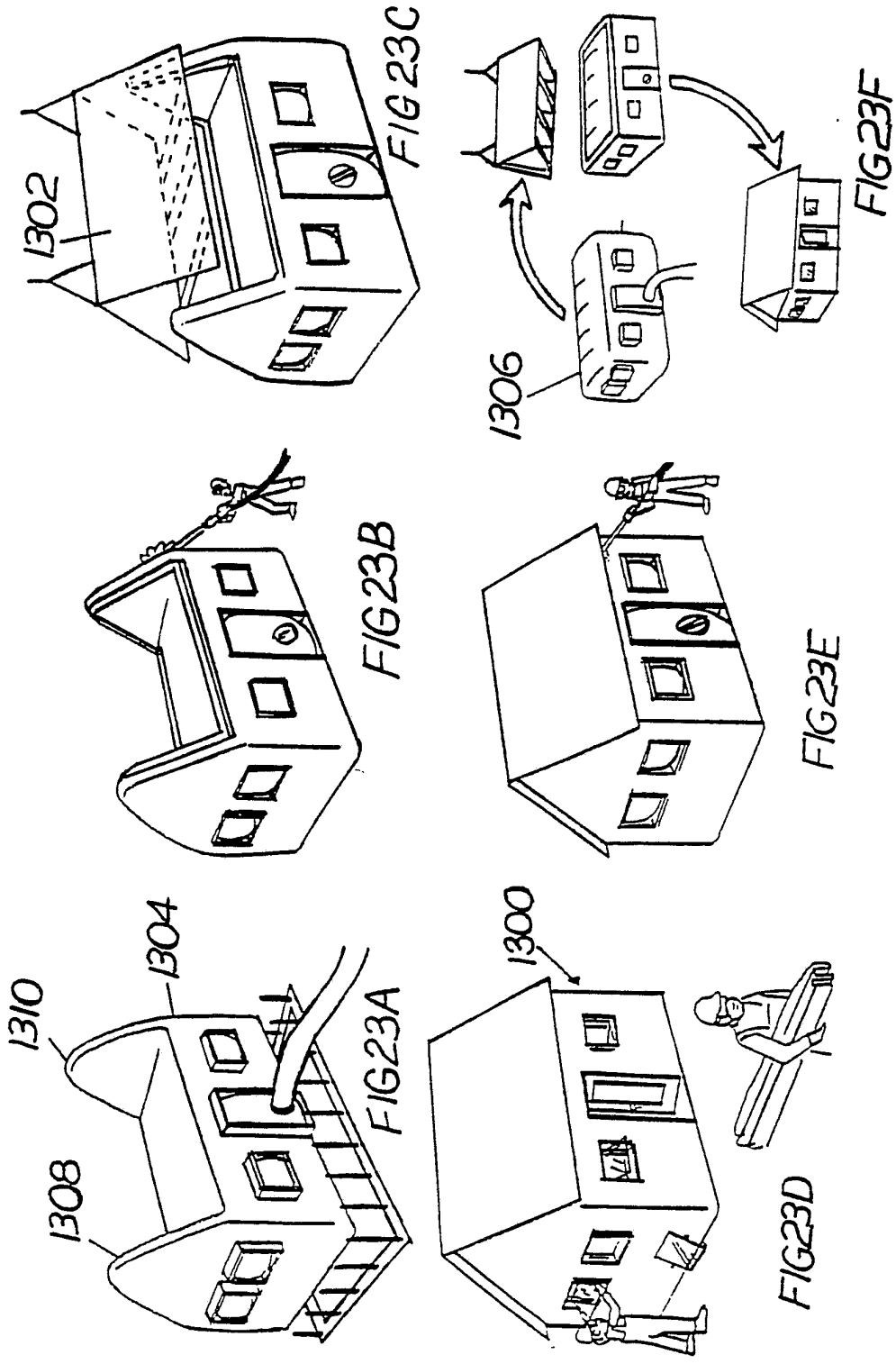


FIG 23C FIG 23F FIG 23B FIG 23E FIG 23A FIG 23D

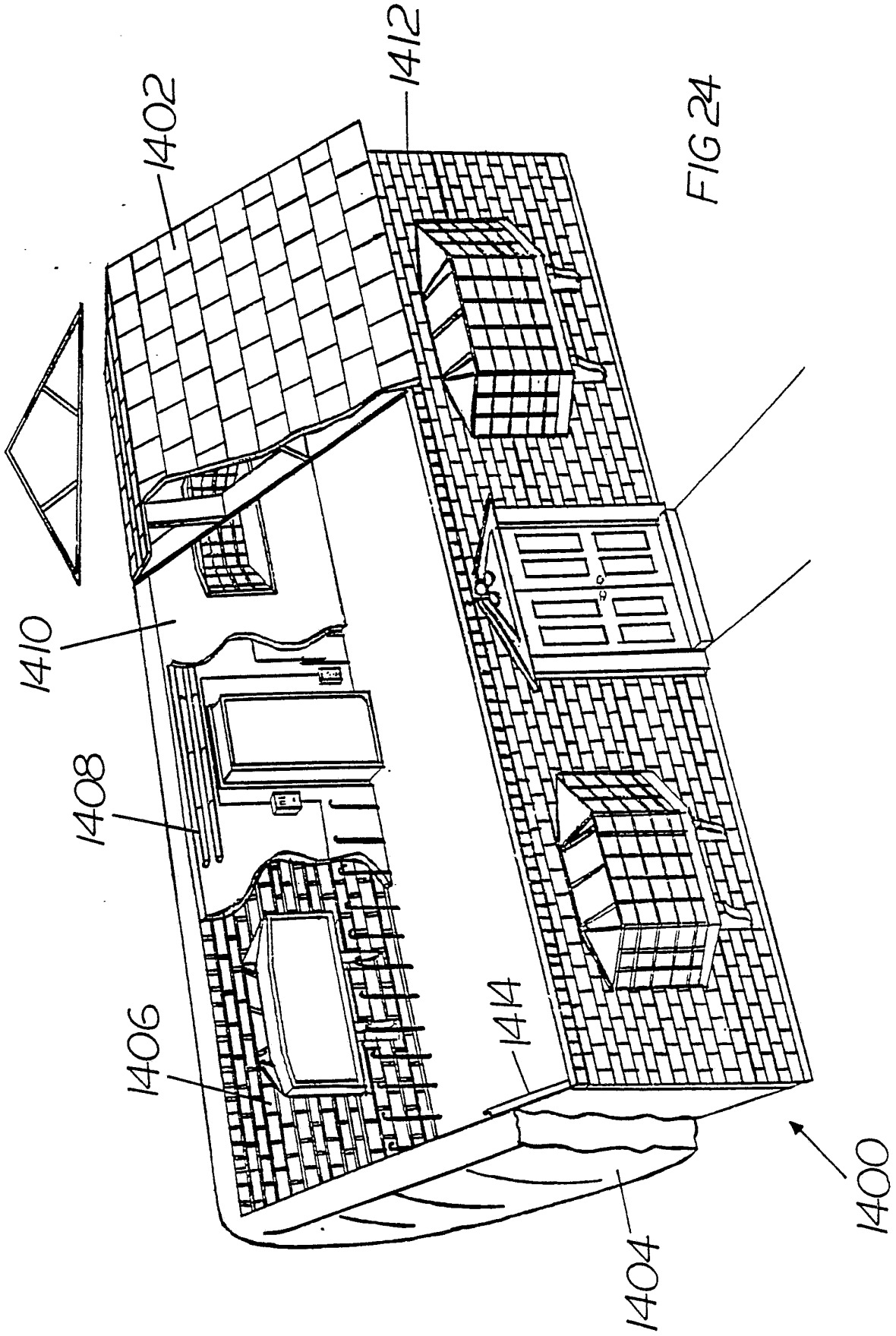


FIG 24

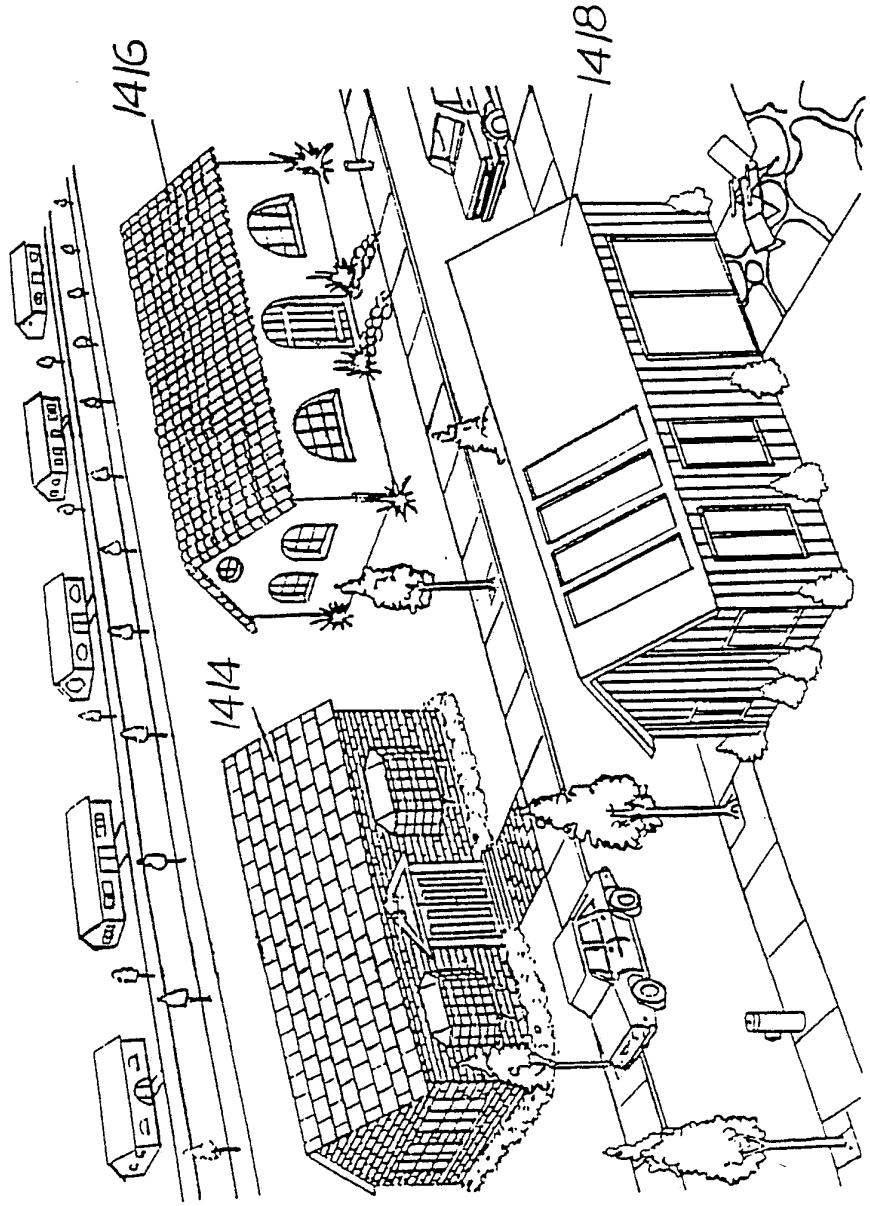
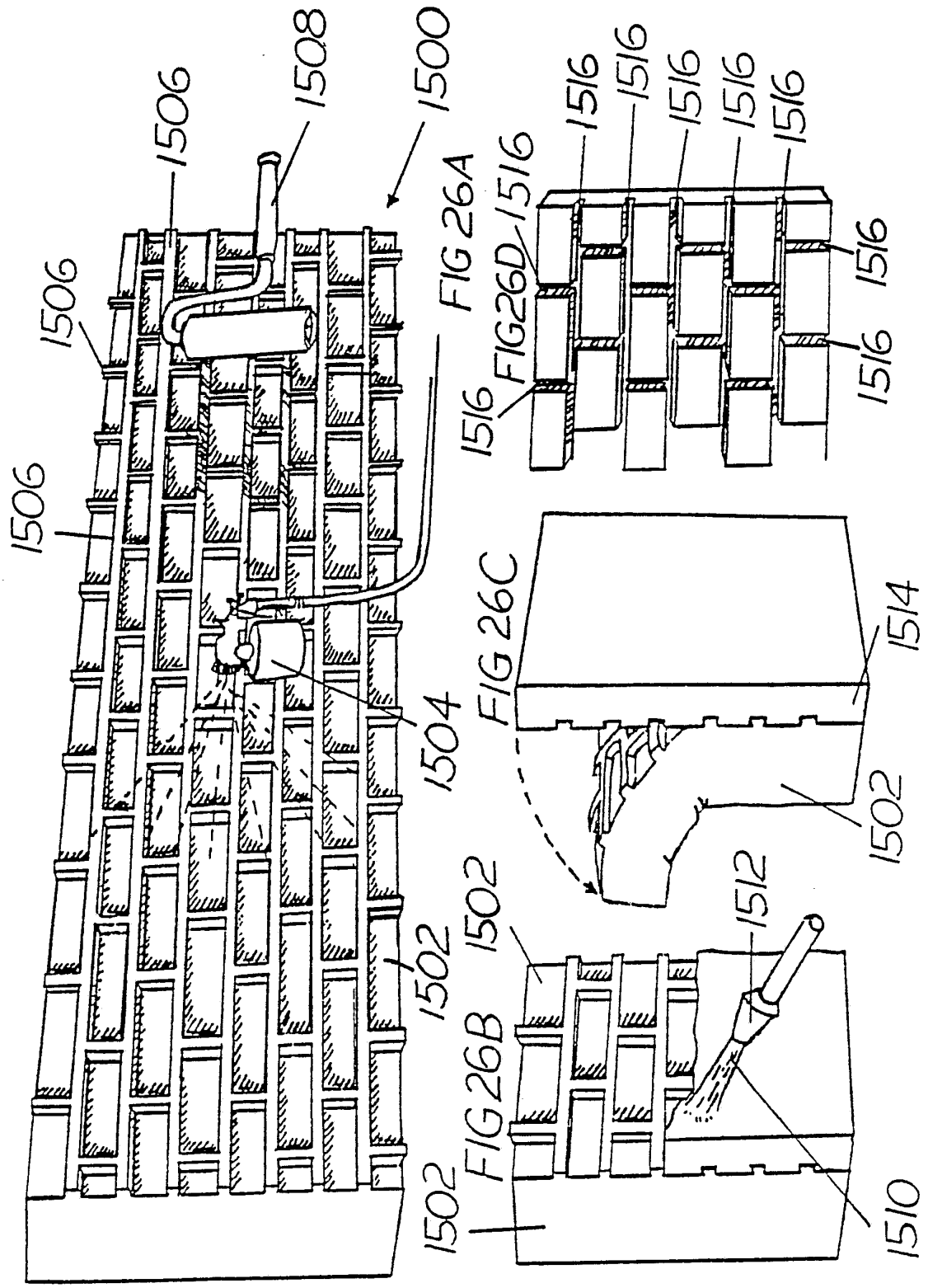


FIG 25


1500
1502
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1506
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1510
1512
1514
1516
FIG 26A
FIG 26B
FIG 26C
FIG 26D

FIG 27A

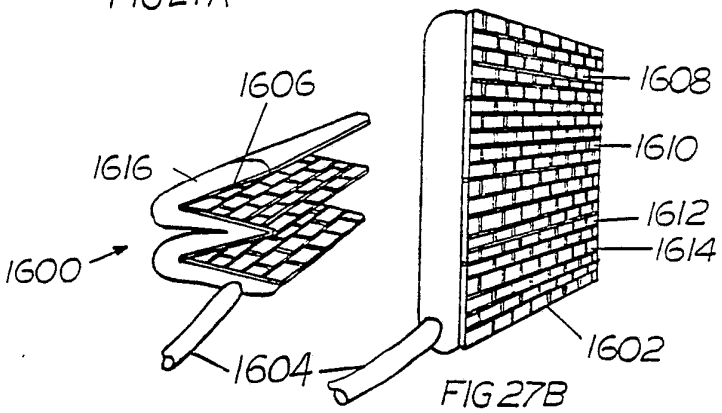


FIG 27B

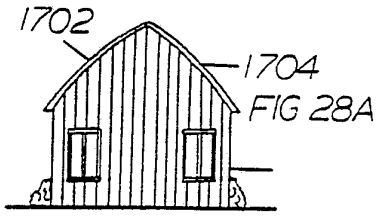


FIG 28A

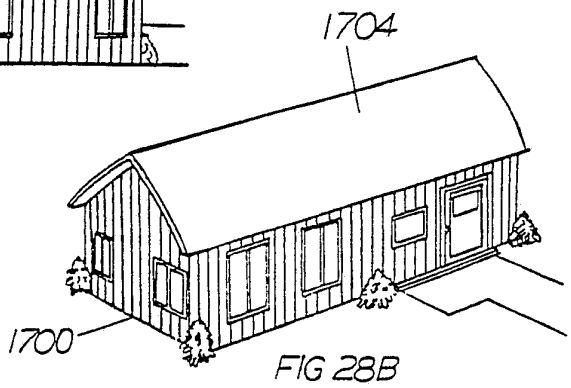


FIG 28B

FIG 29

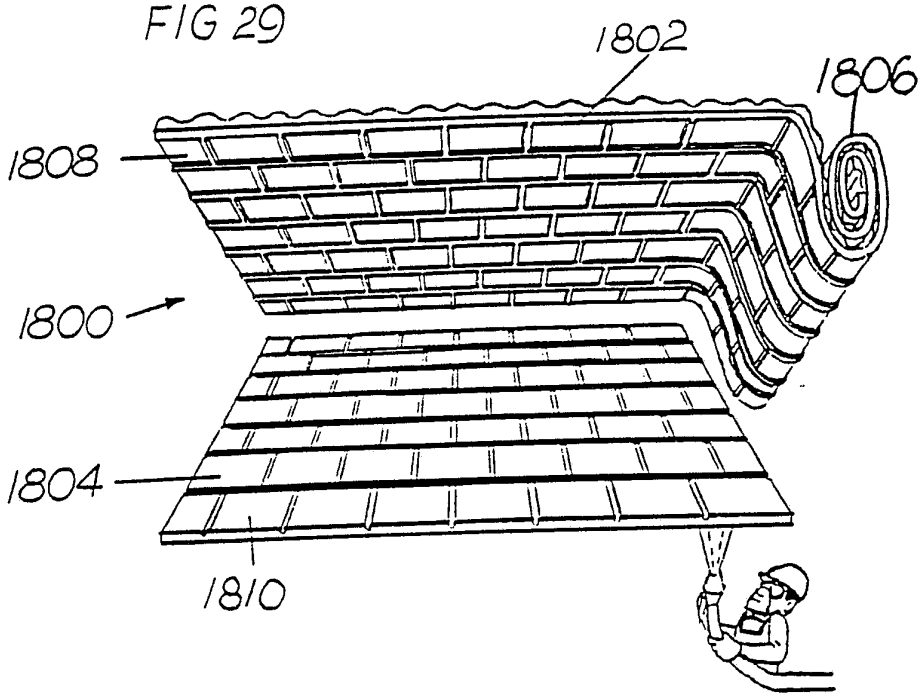


FIG 30A

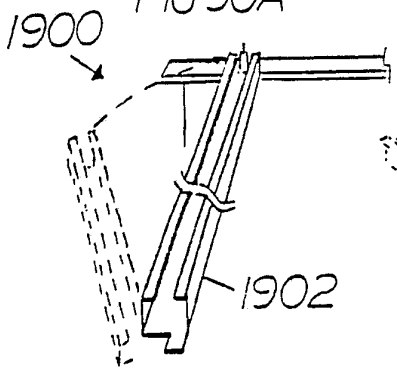


FIG 30B

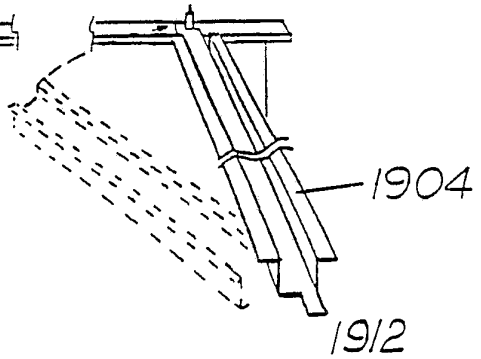
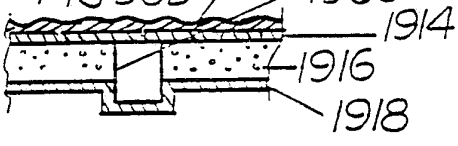


FIG 30C

FIG 30D



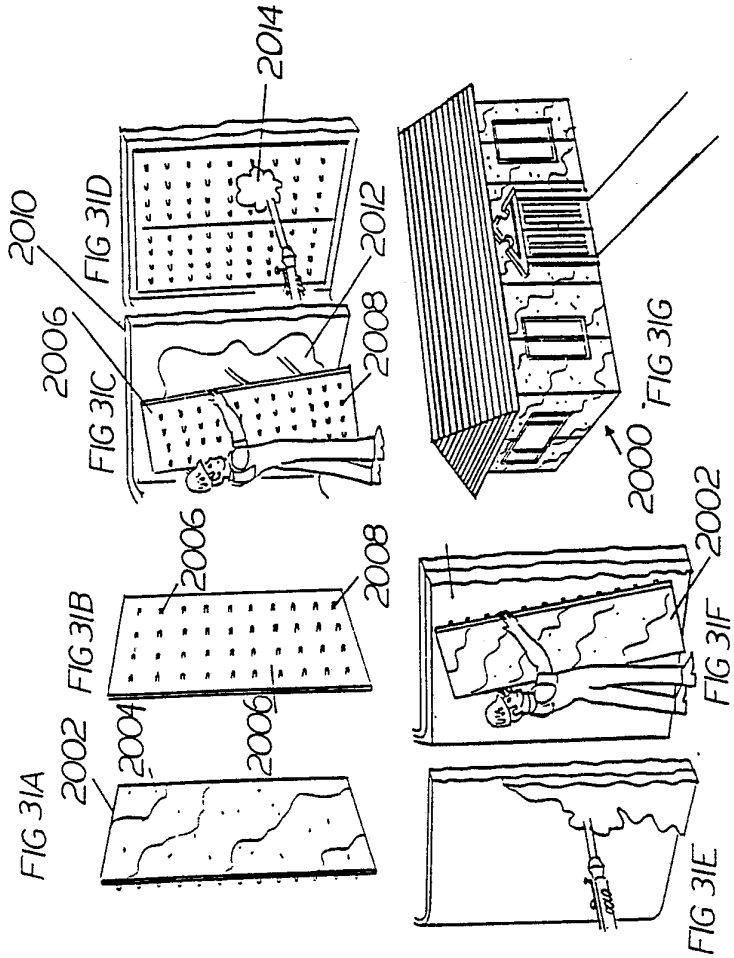
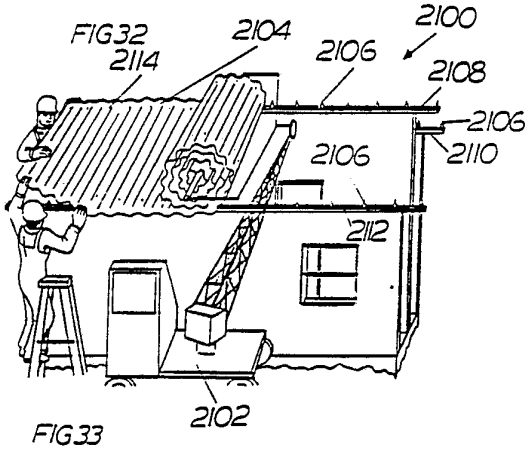

2014
2010
FIG 31D
2012
2006
2008
FIG 31C
FIG 31G
2000
2006
2008
FIG 31B
2002
FIG 31F
2004
2006
2002
FIG 31A
FIG 31E

FIG32


2114
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2100
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2106
2110
2106
2112
2102

FIG33

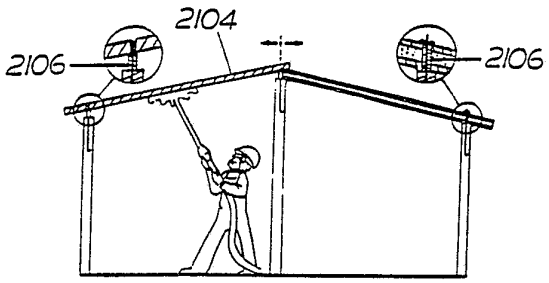
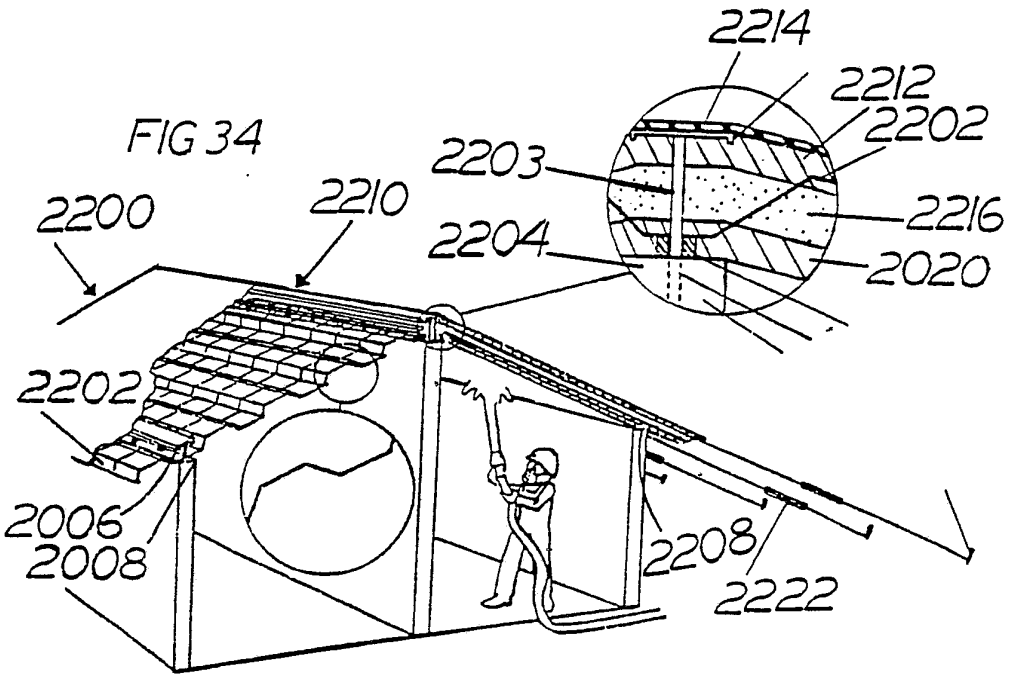

2104
2106
2106

FIG 34


2214
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2203
2216
2204
2020
2200
2210
2202
2006
2008
2208
2222

FIG 35

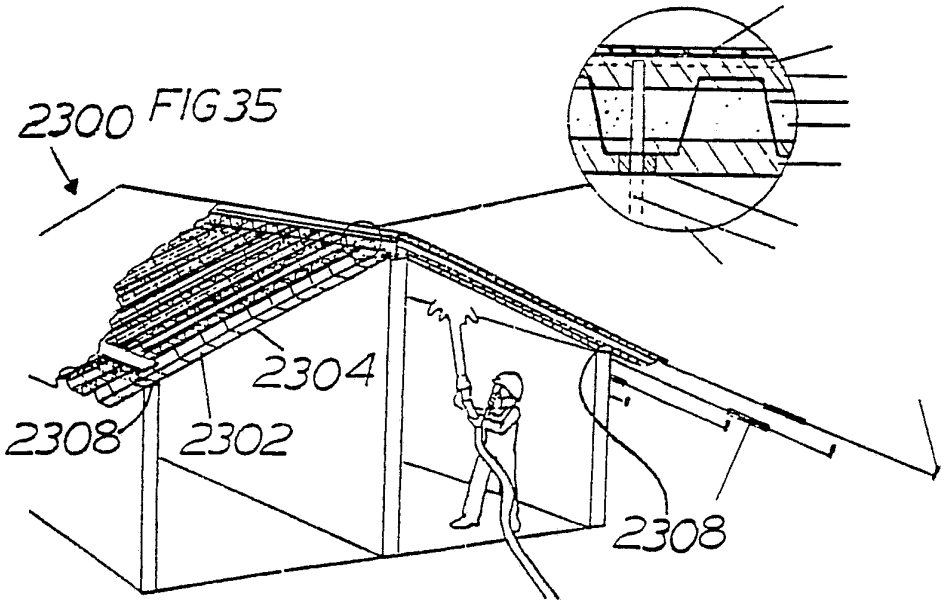

2300
2304
2308
2302
2308

FIG 36

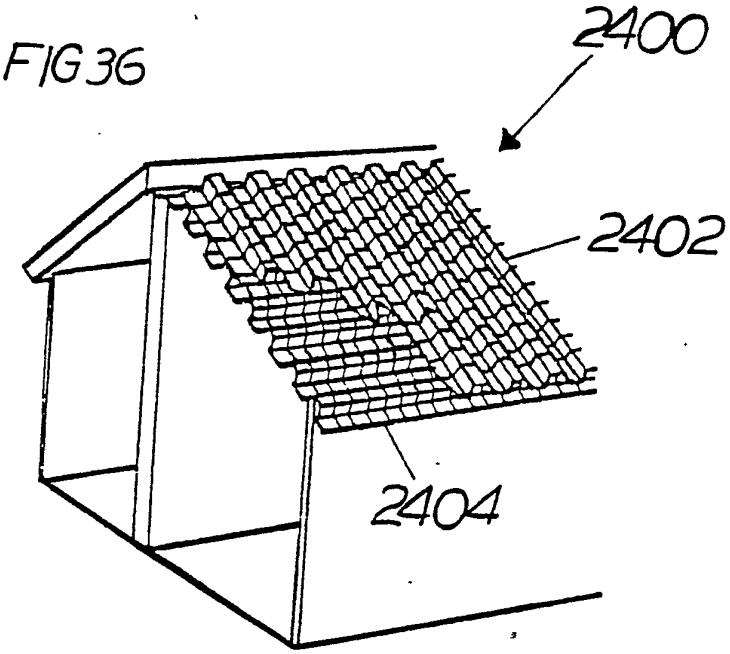


FIG 37

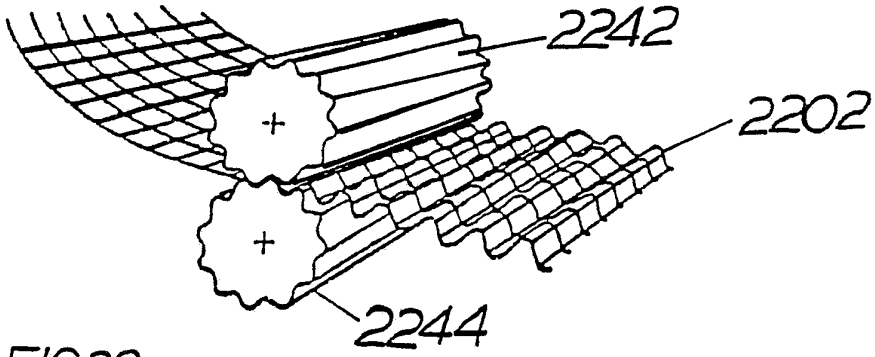
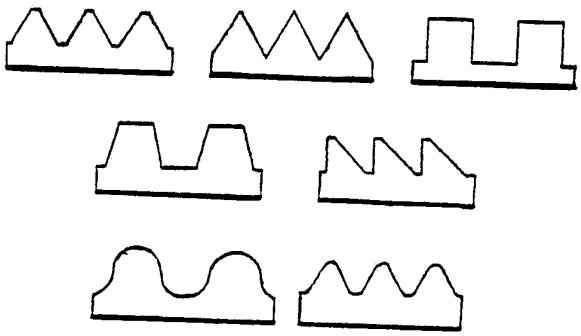


FIG 38



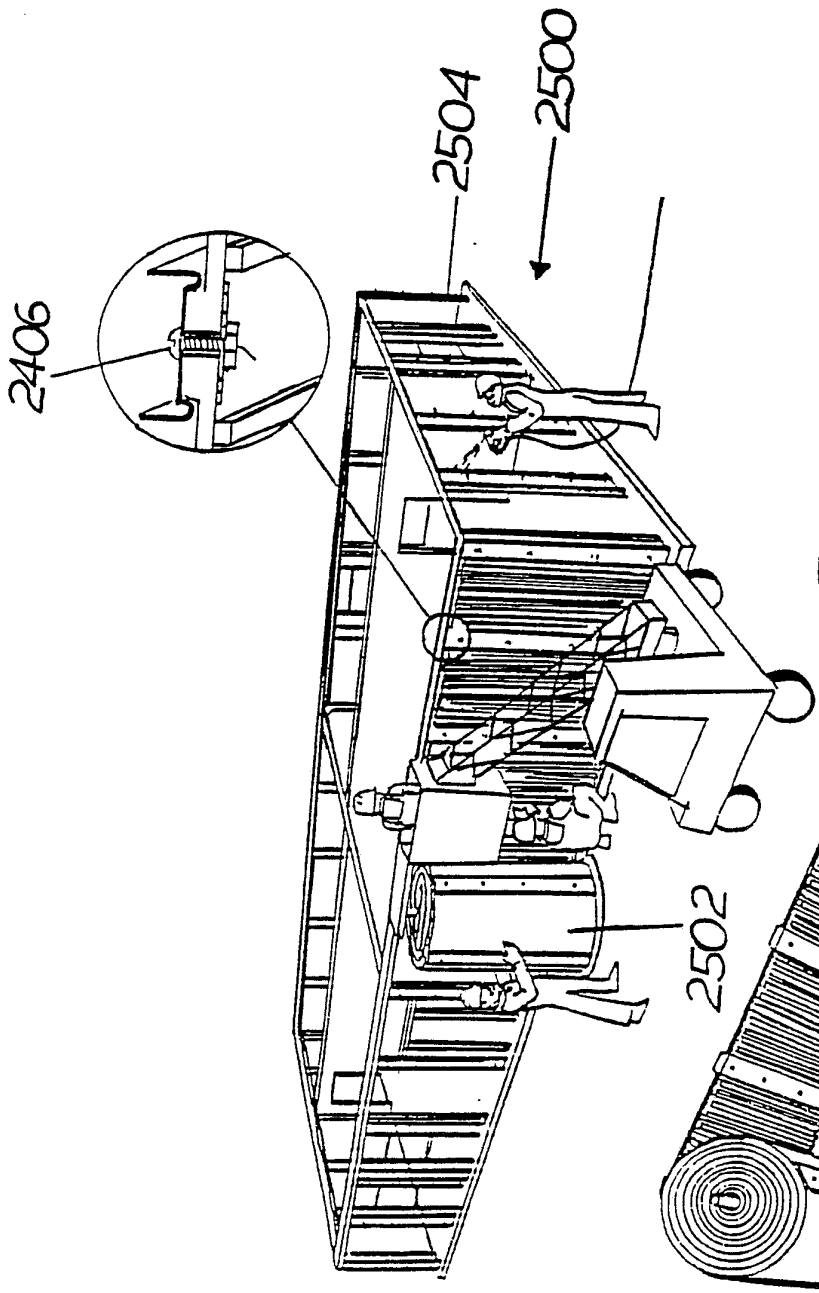


FIG 39A

FIG 39B

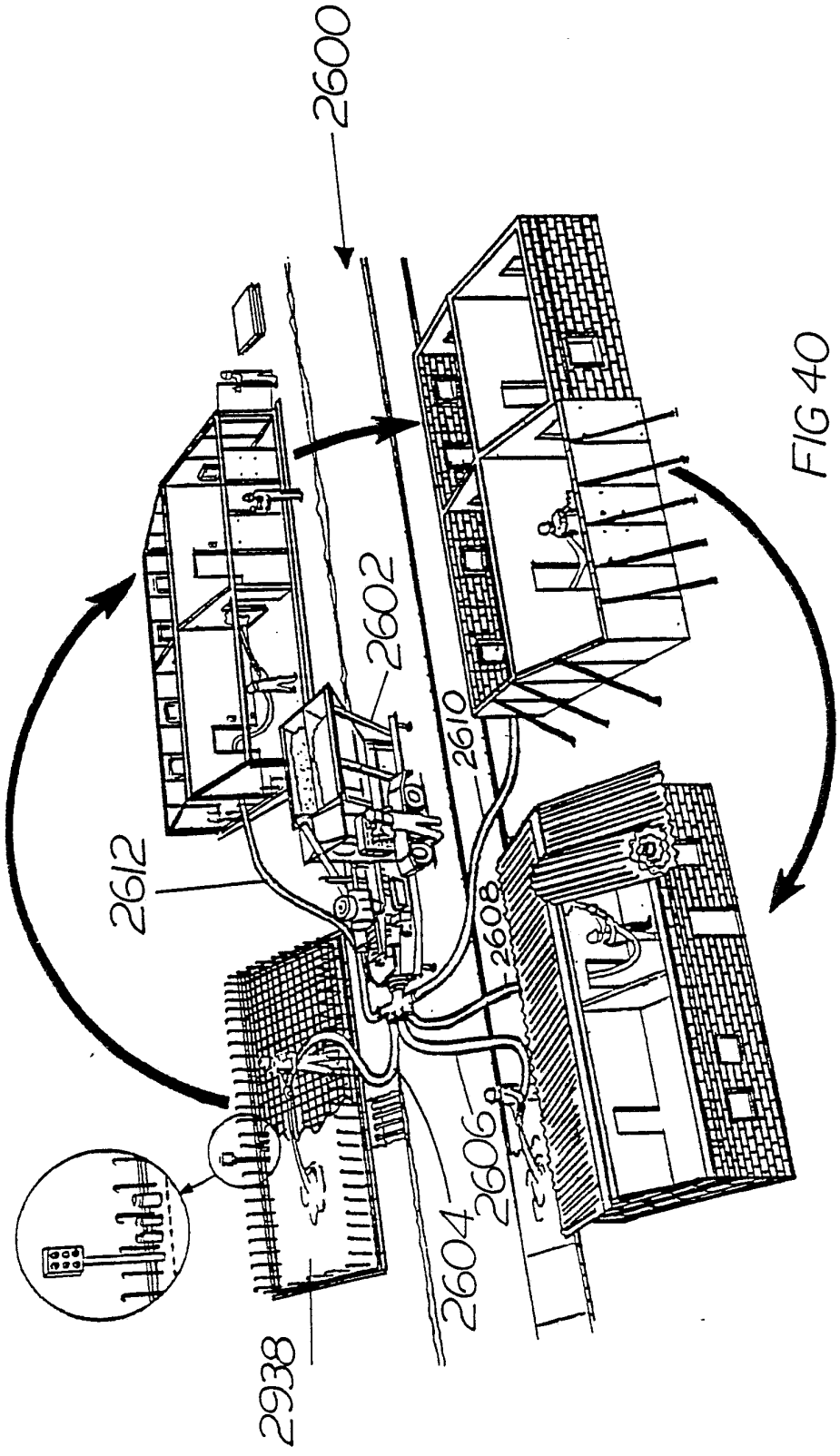


FIG 40

FIG 41A

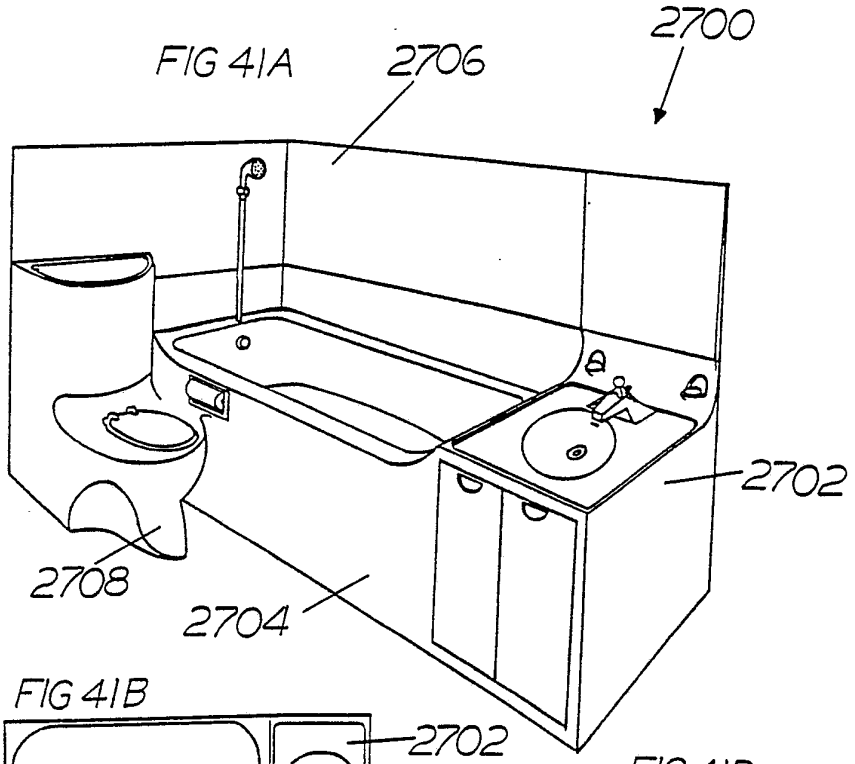


FIG 41B

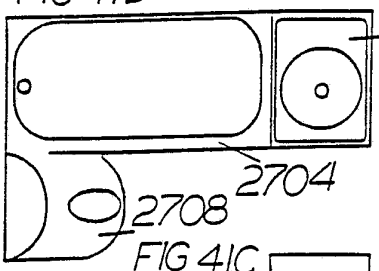


FIG 41C

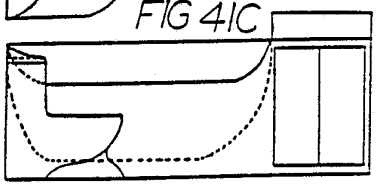


FIG 41D

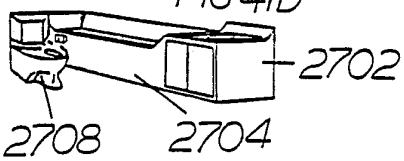
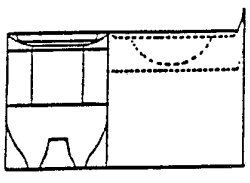


FIG 41E



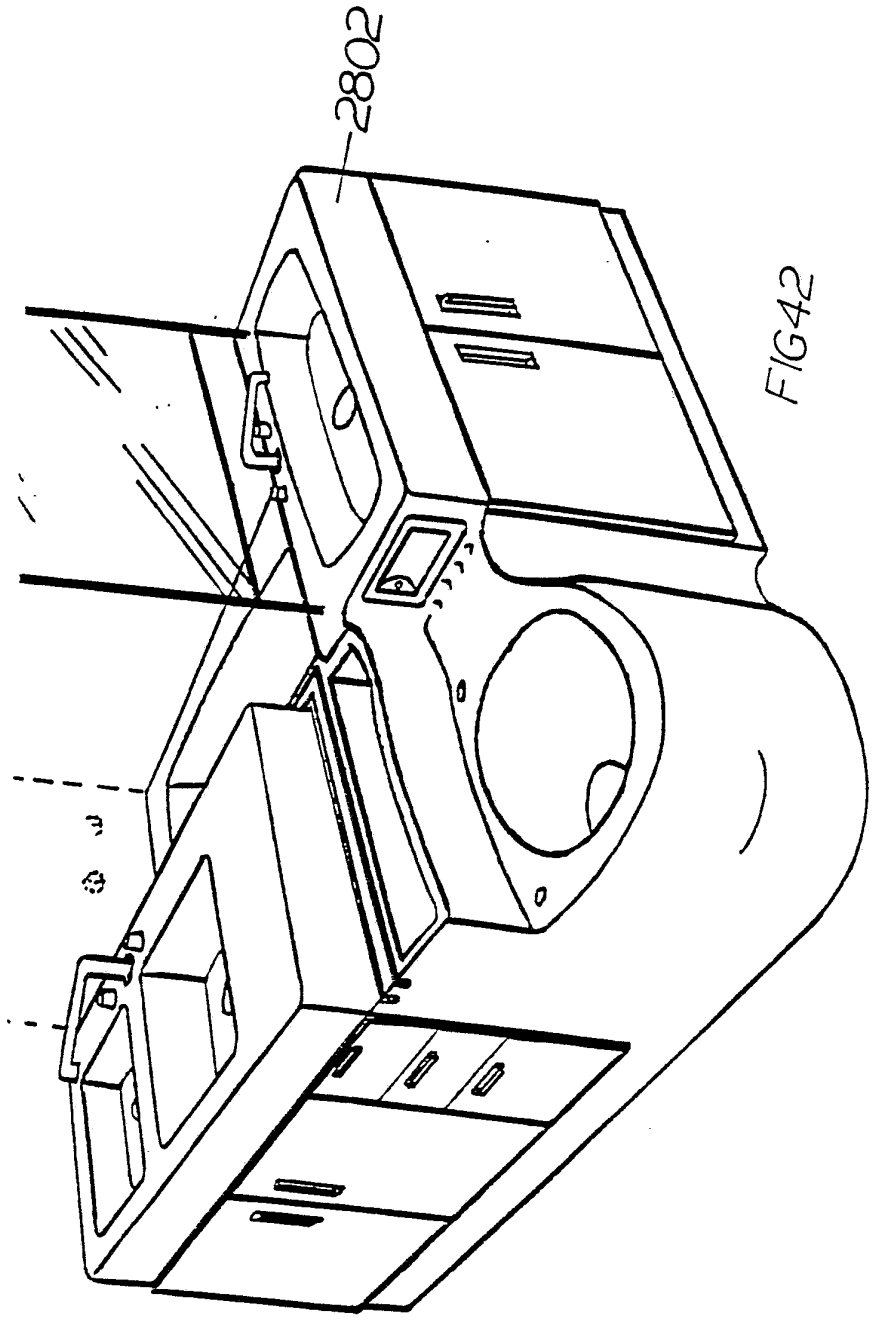


FIG42

FIG 43

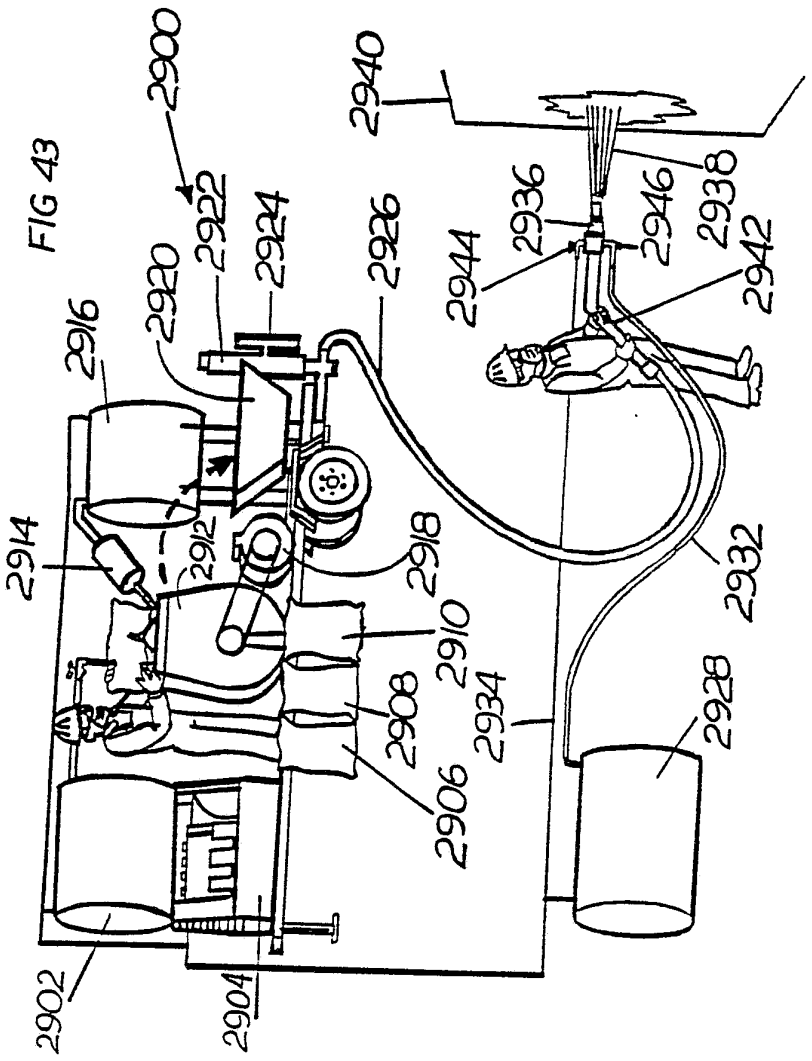

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FIG44

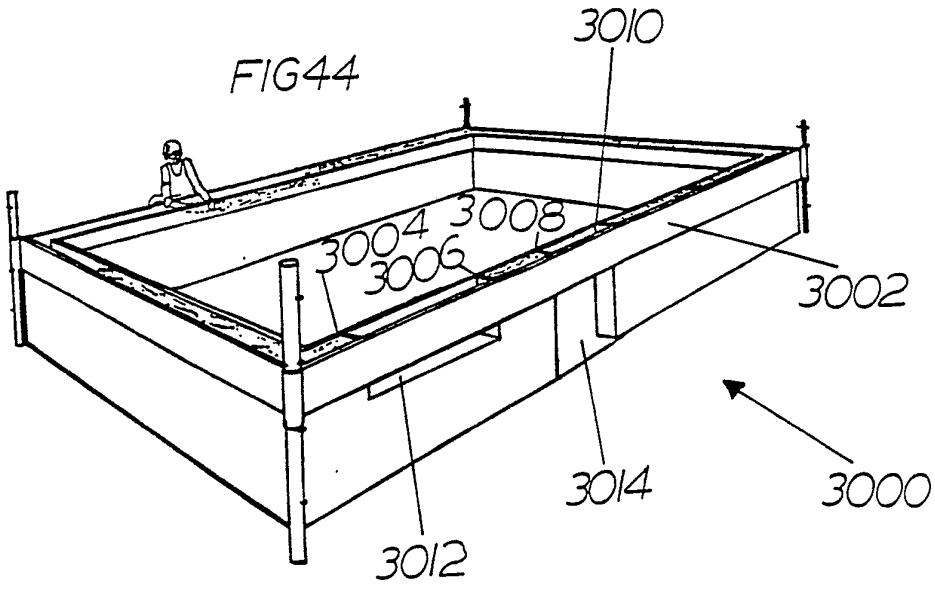
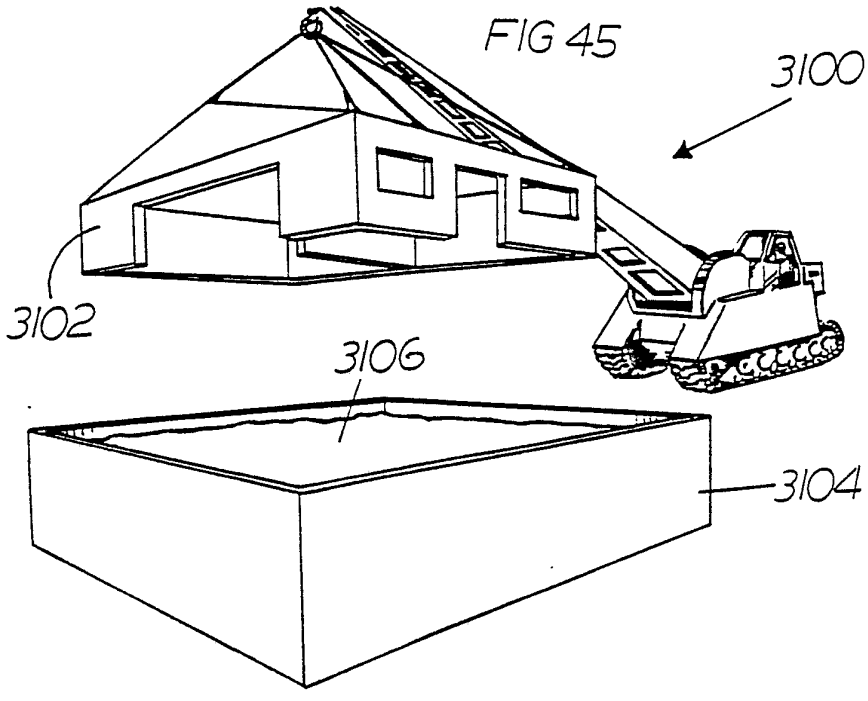


FIG 45



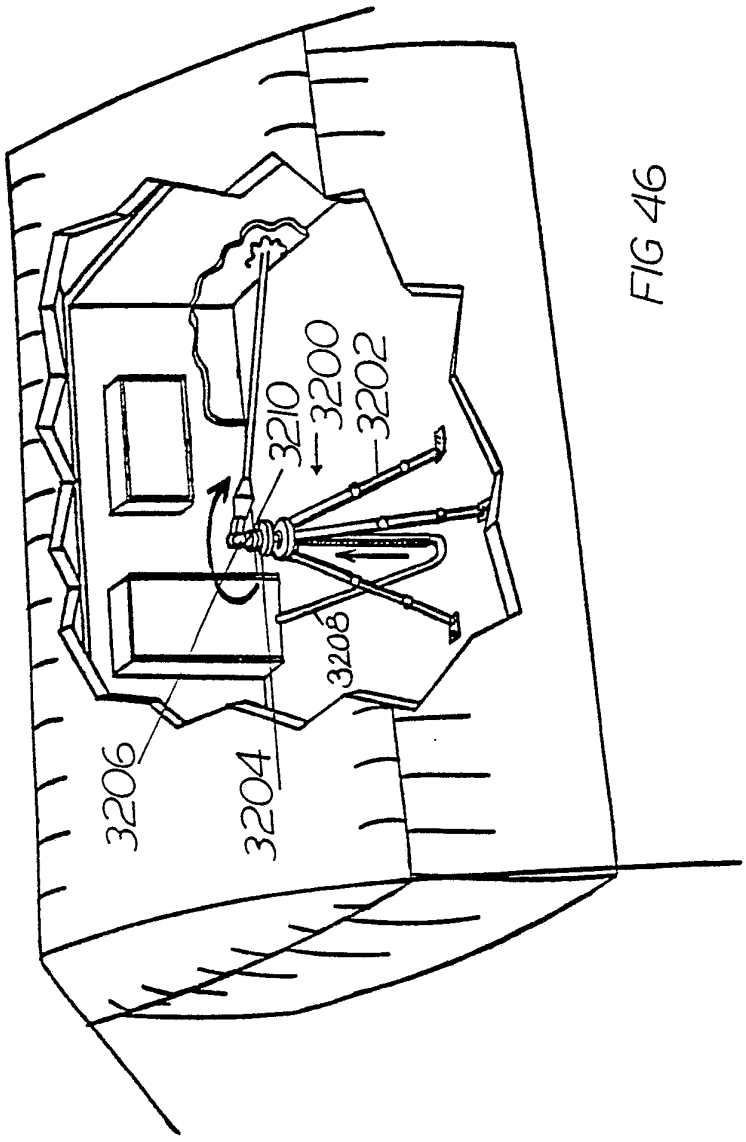


FIG 46

INTERNATIONAL SEARCH REPORT

International Application No PCT/US87/01635

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC. (4) B29C 41/08, 7/32, E04G 11/02, E04B 1/34

U.S. Cl. 249/65, 52/2, 52/749, 264/31

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
	52/2, 4.43, 34, 79.1, 309.12, 314, 612, 749 264/31-35, 45.2, 45.6, 46.6, 256, 228, 229, 133, 135, 303-305, 264/338, 333, 314, 425/Dig 112, 249/63, 64, 65, 39

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US,A, 4,365,455, Published 28 December 1982, Braine. See entire document	16,30,34,37 47-49, 57
Y	US,A, 4,324,074, Published 13 April 1982, South et. al. See entire document.	6,13,14,21, 25,51,52
X	US,A, 4,221,441, Published 9 September 1980, Bain See entire document	39-41
X	US,A, 4,102,956, Published 25 July 1978 Heifetz See entire document	58
Y	US,A, 3,622,656, Published 23 November 1971, Dewey Jr. See entire document	2,12-18,20-26,31,36,37 45
Y	US,A, 3,231,644, Published 25 January 1966, Ming-Yang Chang. See entire document	17,42,43,53
X	US,A, 3,139,464 Published 30 June 1964, Bird See entire document	1-28,30,32-38,44-46,50, 54-58

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]

10 October 1987

Date of Mailing of this International Search Report [2]

24 NOV 1987

International Searching Authority [1]

ISA/US

Signature of Authorized Officer [20]

Lynn M. Sohacki

Lynn M. Sohacki

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US,A, 2,903,018, Published 8 September 1959, Goff.	48
A	US,A, 2,595,142 Published 29 April 1952, Herck.	29,46
A	US,A, 2,295,708, Published 15 September 1942, Bitter.	44
A	US,A, 1,316,812 Published 23 September 1919, Stevde.	28

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

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

1. ☐ Claim numbers ....., because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers....., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.