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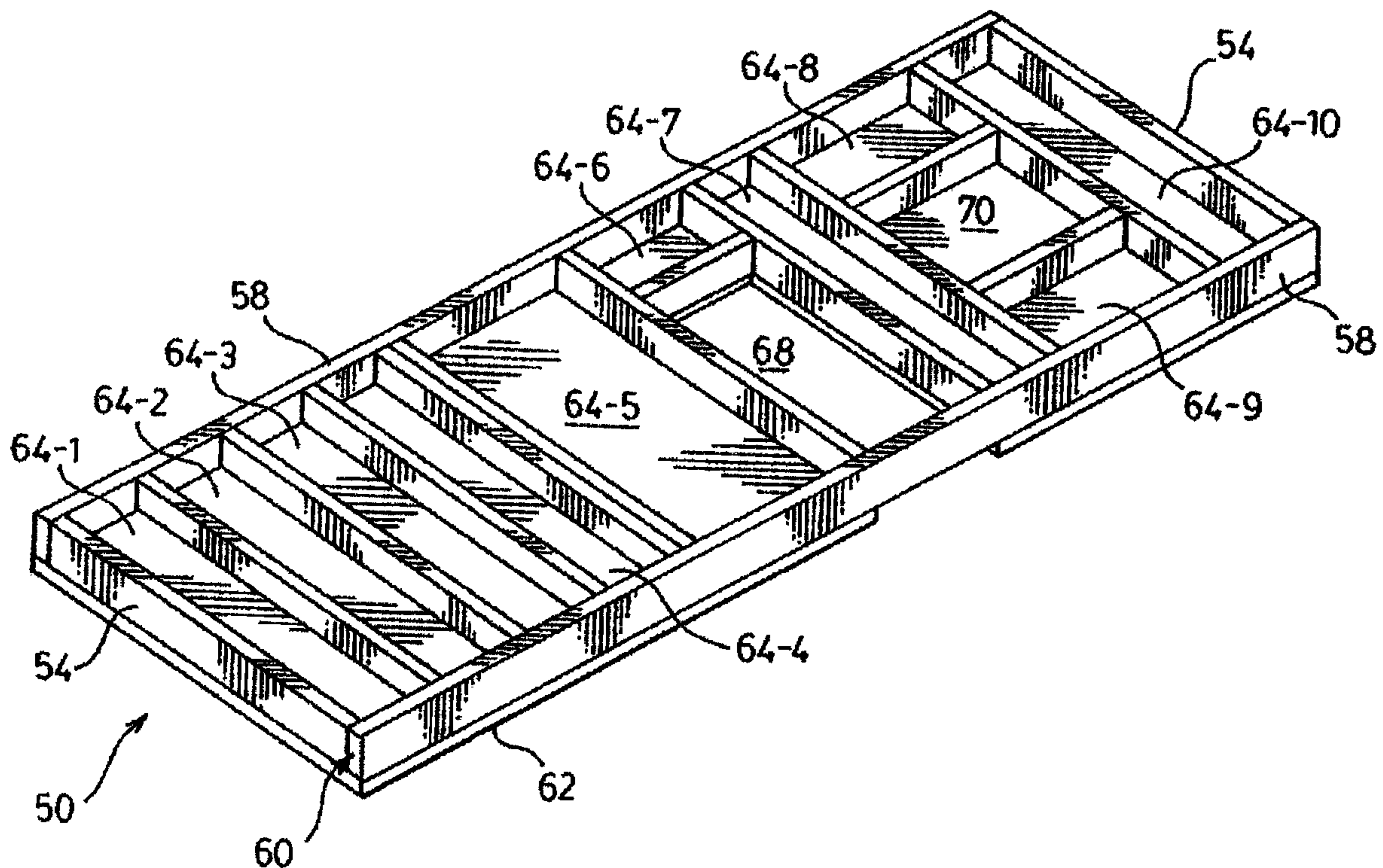
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(54) Titre : SYSTÈME ET METHODE DE FABRICATION DE CLOISONS

(54) Title: WALL FABRICATION SYSTEM AND METHOD



(57) Abrégé/Abstract:

A wall fabrication system and method is provided. In an embodiment, an assembly line comprises one or more framing stations and one or more insulation stations. The frame stations are configured to build a wall frame consisting of wall studs and a covering such as drywall. The wall studs and drywall define cavities in the frame which are to be insulated. Optionally, mechanical components such as electrical and plumbing can be installed. The wall section is then transferred to the insulation station. The insulation station is configured to fill the cavities in the wall frame with closed cell foam which is injected in flowable form into each cavity.



ABSTRACT

A wall fabrication system and method is provided. In an embodiment, an assembly line comprises one or more framing stations and one or more insulation stations. The frame stations are configured to build a wall frame consisting of wall studs and a covering such as drywall. The wall studs and drywall define cavities in the frame which are to be insulated. Optionally, mechanical components such as electrical and plumbing can be installed. The wall section is then transferred to the insulation station. The insulation station is configured to fill the cavities in the wall frame with closed cell foam which is injected in flowable form into each cavity.

WALL FABRICATION SYSTEM AND METHOD

FIELD OF THE INVENTION

[0001] The present invention relates generally to building construction and in particular to a wall fabrication system and method.

5 BACKGROUND OF THE INVENTION

[0002] Housing is a critical aspect of social living. The construction of houses and other dwellings is therefore a well-known and highly refined art. Construction techniques and esthetic styles are well known for single family dwellings, detached and semi-detached houses, condominiums, apartment buildings, town houses, and the like.

10 **[0003]** Automation is also broad reaching and used heavily in a broad range of industries and is used to build cars, trucks, planes, electronics, appliances and many other products. Automation techniques are increasingly being applied to the housing industry, and indeed are used heavily in the manufacture of modular and panelized homes. Automation is not yet, however, widely applied to the manufacture of traditional site-built homes.

15 **[0004]** When insulating walls in traditional site-built homes, it is common to employ skilled labourers to stuff bats of fiberglass insulation within the cavities defined by wall studs. However, it can be difficult to properly fill the cavity, and the fiberglass bats can be prone to sagging so that the upper portions of the wall are not properly insulated. Likewise, not all cavities have uniform shapes and so the bats need to be cut to size, leaving the possibility for
20 gaps. Another disadvantage with fiberglass insulation is that a properly placed vapour barrier is also required. Such a vapour barrier is usually provided via plastic sheets that are applied to the interior side face of the wall. The vapour barrier can be difficult to install, and in any event presents extra cost and time in the home construction process. Another problem with vapour barriers is that mould growth and air leakage can result from punctures that can
25 easily occur in the plastic sheets. Also, application of a moisture barrier in a damp area could actually trap existing moisture within the wall, particularly where the plastic sheeting becomes wrinkled, with all the attendant problems thereto.

[0005] Another common type of insulation is closed cell foam. Closed cell foam can be acquired in rigid sheets, and thus are not prone to sag in the same manner as fiberglass.
30 However, the sheets of foam still need to be cut to size in order to fill irregular shaped

cavities. Also, a vapour barrier can still be preferred when using sheets of closed cell foam.

[0006] It is also known to spray closed cell foam in a liquid form into the wall cavities. A spray gun can be used to fill the cavity with the closed cell foam, which then cures and forms an insulating barrier. However, this reintroduces a version of the sagging problem with fiberglass insulation, as the liquid insulation tends to flow downwards in the wall cavity, resulting in an uneven distribution of the insulation within the wall cavity. Overspray is also a serious problem – should the foam be applied to the studs, it can be difficult to attach drywall or other paneling or covering to the wall. Labourers spraying closed cell foam are also exposed to significant environmental hazards and are preferably equipped with gear to reduce inhalation of harmful fumes from spraying closed of cell foams.

SUMMARY OF THE INVENTION

[0007] In an aspect of the invention there is provided a wall section comprising a first set of substantially parallel supports and a second set of substantially parallel supports disposed substantially perpendicular to the first set. The parallel sets of supports are affixed to each other at their junctions. The wall section also comprises a covering applied to one side of the supports. The covering and the sets of supports define a plurality of cavities in the wall section. The wall section also comprises a curable, flowable material that is downwardly injected into one or more of the cavities while the supports are in a horizontal position. Once the material is cured, the wall section can then be moved to the construction site and used to fabricate a home.

[0008] The wall section can further comprise a second covering that is applied to a second side of the supports that is opposite to the first side of the supports.

[0009] The foam material can adhere to both the first covering and the supports in such a manner that the covering is adhered to the supports by the foam material.

[0010] The covering can be drywall, or wood sheathing, or any other type of wall paneling.

[0011] The supports can be made from wood or metal or any other suitable material.

[0012] Depending on the choice of flowable material, when the flowable material cures into a solid form, a torsional and tensional rigidity of the wall section can be increased thereby.

[0013] Depending on the choice of flowable material, when the flowable material cures the insulation factor of the wall section can be increased thereby. The thermal resistance (or R value) per inch of flowable material typically surpasses the R value per inch of traditional fiberglass bats. For example, a traditional bat of 3.5 inch fiberglass has an R value of about 12, whereas three inches of closed foam has an R value of about eighteen. In general terms, traditional fiberglass bats have an R value of about 3.4 per inch of fiberglass, whereas closed cell foam has an R value of about six per inch.

[0014] Depending on the choice of flowable material, when the flowable material cures it can provide an air barrier from one side of the wall section to the other side of the wall section. Furthermore, the flowable material can be chosen to have a low vapour permeance, and, when coupled with a vapour-barrier primer (applied as a paint to the drywall), then a vapour barrier can be formed that is suitable to substantially eliminate the need for plastic sheeting as a vapour barrier.

[0015] The flowable material can be closed cell foam. Closed cell foam can result in increased strength, increased insulation (thermal resistance), and act as an air barrier and has a low vapour permeance.

[0016] In other aspects, the flowable material can be open cell foam.

[0017] Another aspect of the invention provides a method of insulating a wall section of a site-built home. The wall section comprises a first set of substantially parallel supports and a second set of substantially parallel supports that are disposed substantially perpendicular to the first set. The parallel and vertical supports are affixed to each other at their junctions. The wall section also comprises a covering positioned on one side of the supports. The covering and the sets of supports define cavities in the wall section. The method comprises:

orienting the wall section horizontally such that the cavities face upwards; and,

injecting a curable flowable material downwardly into one or more of the cavities.

[0018] The method can further comprise applying a second covering to a second side of the supports that is opposite to the first side of the supports.

[0019] The method can further comprise applying the flowable material to both the first covering and portions of the supports that are perpendicular to the first covering and waiting until the foam material cures such that the covering is adhered to the supports.

[0020] Another aspect of the invention provides a system for manufacturing a wall section comprising one or more framing stations for producing wall sections. The wall sections comprise a first set of substantially parallel supports and a second set of substantially parallel supports disposed substantially perpendicular to the first set of supports.

5 The wall sections include a covering applied to one side of the supports. The covering and the sets of supports each define cavities in each wall section.

[0021] The system can also comprise one or more insulation stations for receiving wall sections from the framing stations and for injecting a curable flowable material downwardly into one or more of the cavities while the supports are in a horizontal position.

10 **[0022]** The framing stations and the insulation stations can be configured to produce and insulate, respectively, wall sections that have different configurations.

[0023] The system can further comprise automation equipment, such as robotic equipment, for the framing stations and the insulation stations.

15 **[0024]** The system can further comprise a computer configured to control the automation equipment in the framing stations and the insulation stations according to a production schedule in order to continuously produce and insulate a plurality of wall sections having different configurations.

20 **[0025]** A wall fabrication system and method is provided. In an aspect, an assembly line comprises one or more framing stations and one or more insulation stations. The framing stations are configured to build a wall frame consisting of wall studs and a covering such as drywall. The wall studs and drywall define cavities in the frame which are to be insulated. Optionally, mechanical components such as electrical, plumbing, central vacuum, telephone and the like can be installed into the wall section. The wall section is then transferred to the insulation station. The insulation station is configured to fill the cavities in the wall frame with
25 closed cell foam which is injected in flowable form into each cavity.

[0026] A wall section comprising:

a first set of substantially parallel supports;

a second set of substantially parallel supports disposed substantially perpendicular to said first set;

30 a covering applied to one side of said supports;

said covering and said sets of supports defining cavities; and

a curable flowable material downwardly injected into one or more of said cavities, said curable flowable material being injected in the form of a plurality of beads into said one or more cavities in a predefined path comprising both a first direction, and a second direction substantially perpendicular to said first direction, while said supports are in a horizontal position.

[0027] A method of insulating a wall section of a site-built home, said wall section comprising a first set of substantially parallel supports; a second set of substantially parallel supports disposed substantially perpendicular to said first set; a covering positioned on one side of said supports; said covering and said sets of supports defining cavities; the method comprising:

orienting said wall section horizontally such that said cavities face upwards; and

injecting curable flowable material downwardly into one or more of said cavities, said curable flowable material being injected in the form of a plurality of beads into said one or more cavities in a predefined path comprising both a first direction, and a second direction substantially perpendicular to said first direction.

[0028] A system for manufacturing a wall section comprising:

one or more framing stations for producing wall sections that comprise a first set of substantially parallel supports;

a second set of substantially parallel supports disposed substantially perpendicular to said first set;

a covering applied to one side of said supports;

said covering and said sets of supports defining cavities;

one or more insulation stations for receiving wall sections from said framing stations and for injecting a curable flowable material downwardly into one or more of said cavities while said supports are in a horizontal position, said curable flowable material being injected in the form of a plurality of beads into said one or more cavities in a predefined path comprising both a first direction, and a second direction substantially perpendicular to said first direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The invention will now be described, by way of example only, with reference to certain embodiments and the attached Figures in which:

[0030] Figure 1 is an isometric view of a wall section;

5 **[0031]** Figure 2 is a schematic representation of an assembly line for manufacturing and insulating the wall section of Figure 1;

[0032] Figure 3 is an isometric view of the insulation station of the assembly line of Figure 2;

[0033] Figure 4 shows the insulation station of Figure 3 in greater detail;

10 **[0034]** Figure 5 is a partial cross section showing a wall cavity being filled using the injector of the insulation station of Figure 3;

[0035] Figure 6 shows the wall section of Figure 3 after having been filled by the insulation station of Figure 3;

15 **[0036]** Figure 7 is a partial sectional view of the wall section in Figure 6 with a second sheet of drywall being applied thereto; and,

[0037] Figure 8 is a partial sectional view of the wall section of Figure 6 after the second sheet of drywall has been attached thereto.

[0038] Figure 9 shows a variation on the wall section of Figure 6.

20 **[0039]** Figure 10 shows the wall section of Figure 9 with various programming parameters identified thereon.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0040] Referring now to Figure 1, a wall section for a traditional site-built home is indicated generally at 50. Wall section 50 comprises a plurality of substantially parallel vertical studs 54 transversely affixed to a plurality of substantially parallel horizontal studs 58. Not all vertical studs 54 and horizontal studs 58 are labeled in Figure 1. Studs 54, 58 define a frame 60 that is covered on one side by drywall 62 or other type of covering such as plywood, wood or the like. Studs 54, 58 act as supports for wall section 50.

[0041] It should be understood that terms such as "horizontal" and "vertical" are used for convenience to assist in understanding the discussion herein, but do not imply herein that

studs of a frame need to be arranged in such a manner.

[0042] Studs 54, 58 can be wood and/or metal and/or any other suitable type of home framing material for a traditional site-built home. Studs 54, 58 are affixed to each other using nails, staples and/or any other type of suitable fastener. Drywall 62 (typically a plurality of sheets of drywall) is affixed to frame 60 with nails, staples, screw and/or glue or any other type of suitable fastener. As will be discussed in greater detail below, drywall 62 can be only partially affixed to frame 60, so that drywall 62 is secured to frame 60 so as to simply hold drywall 62 in place so that wall section 50 can be further processed, but not secured to the extent that would traditionally be needed to fully secure drywall 62 to frame 60 in final installation on site. For example, the Ontario Building Code 1977 states that "Spacing of 5/8" long steel drill screws shall be not more than 300 mm along supports, except that on vertical surfaces the screws may be spaced at 400 mm where the supports are no more than 400 mm o/c." The teachings herein can obviate traditional fasteners and/or mitigate the number of screws that are required according to the Ontario Building Code.

[0043] Wall section 50 is thus characterized by a plurality of cavities 64-1, 64-2, 64-3 ... 64-9. (Generically, cavity 64, and collectively, cavities 64). Wall section 50, in a present embodiment, is also characterized by a door 68, and a window 70.

[0044] It should be understood that the size of wall section 50, the configuration, placement and number of studs 54, 58, and the configuration, placement and number of cavities, and the configuration, placement and number of cavities of doors or windows (if any) therein is not particularly limited. While not shown in Figure 1, it is also contemplated that each wall section 50 will also include all mechanical components, including, for example electrical, plumbing, heating ventilation air-conditioning ("HVAC") conduits, central vacuum conduits, telephone, cable television, and/or Ethernet and/or outlets relating to any of the foregoing.

[0045] Referring now to Figure 2, wall section 50, in its entirety, is typically constructed on an assembly line 74 in a manufacturing facility. An example of such a manufacturing facility described in Applicant's co-pending application entitled Housing Manufacturing System and Method and filed in the Canadian Patent Office on October 11, 2006 and bearing application number 2,563,187.

[0046] Assembly line 74 thus includes one or more framing station(s) 78 and one or more insulation station(s) 82. Insulation station 82 will be discussed in greater detail below.

Framing station 78 is configured to produce wall section 50. It is also contemplated that assembly line 74 is "flexible", so that while framing station 78 is configured to produce wall section 50, framing station 78 is also configured to produce wall sections that have configurations that are different than wall section 50. In other words, various wall sections produced on assembly line 74 can be different, according to a desired production run for different configurations of traditional site-built homes. Assembly line 74 can also be fully or partially automated, with computers instructing robotic equipment to manufacture each wall section. In a presently preferred embodiment, assembly line 74 is substantially automated, including the transfer of wall sections from station 78 to station 82. Thus, assembly line 74 includes a central scheduling computer 86 that maintains a production schedule 90 with production runs for station 78 and station 82. Production schedule 90 thus includes instructions for the configuration of wall section 50 and configurations for every other wall section that is to be produced using framing station 78 and insulated at insulation station 82. Computer 86 is configured to deliver instructions to operators and/or robotic equipment in framing station 78 as to the configuration of each wall section to be produced. Computer 86 is also configured to notify insulation station 82 as to the configuration of each wall section 78 that has been produced so that insulation station 82 can fulfill the insulation task.

[0047] Referring to Figure 3, insulation station 82 is shown in greater detail, which shows wall section 50 within station 82. In Figure 3, insulation station 82 includes a robotic X-Y Gantry 91. Gantry 91 includes a pair of rails 94. A transverse rail 98 is positioned perpendicular to rails 94. Transverse rail 98 is motorized and configured to run along the length of rails 94. An injector 102 is mounted to transverse rail 98 and is movable along the length of rail 98. A computerized controller 106 is connected to gantry 91 and can issue instructions thereto in order to move injector 102 to any location above wall section 50. While the present embodiment contemplates a gantry 91, it should be understood that other robotic configurations are also contemplated.

[0048] Controller 106 is in turn connected to computer 86 and is configured to receive instructions from computer 86 as to the configuration of the particular wall section 50 within station 82 as found on production schedule 90.

[0049] Injector 102 is configured to dispense closed cell foam 110 in a flowable form into each cavity 64. Injector 102 is connected to a reservoir (not shown) of foam that is located proximal to station 82. In a presently preferred embodiment, rails 94 and 98 are substantially horizontal and wall section 50 is also positioned substantially horizontally, so that injector 102

is above wall section 102 and all foam 110 dispensed from injector 102 flows substantially downwardly.

[0050] Controller 106 is thus configured to instruct gantry 91 so as to move injector 102 above the extent of each cavity 64, and to issue instructions to a valve associated with injector 102 that causes injector 102 to either dispense foam 110, or to cause injector 102 to “shut off” and not dispense foam. The valve can also be variable so that the rate of flow of foam 110 is variable. Whether injector 102 is dispensing foam or not, injector 102 is movable along rails 94, 98 according to instructions from controller 106.

[0051] Referring now to Figure 4, a second wall section 50a located within station 82, while being filled with foam 110 by injector 102, is shown in greater detail. Wall section 50a includes cavities 64a and a window 70a. Wall section 50a is also shown with mechanical components, in the form of electrical conduit 114a run within cavities 64a-6, 64a-7 and 64a-8.

[0052] In a presently preferred embodiment, controller 106 is preprogrammed with a plurality of paths to follow in order to fill each cavity 64. Controller 106 is preprogrammed to move injector 102 within each cavity 64a according to each predefined path, and dispense a bead of foam 110 along that path. Controller 106 is also preprogrammed to move injector 102 between each cavity 64a without dispensing any foam. The rate of travel of injector 102, and flow rate of foam 110 can be chosen in order to optimize speed of filling each cavity 64, reduce and/or minimize the overall amount of travel of injector 102 within each cavity 64a and/or reduce and/or minimize the amount of travel of injector 102 between each cavity 64a where injector 102 is not dispensing any foam. In addition to the foregoing, however, the size of the bead that is injected is chosen so as to optimize any settling and/or expansion that may occur within each cavity 64a and the cure times of the foam. It can be desired to control the manufacturing steps for each station 78 and 82 such that the cycle time for each station 78 and 82 are substantially the same, and thus the operation of injector 102 can be configured accordingly.

[0053] Referring now to Figure 5, for further control over-filling of cavities 64a, it can also be desired to configure injector 102 to be movable along an axis perpendicular to rail 98, in order to control the depth of foam 110. In a present embodiment, however, as best seen in Figures 7 and 8, the depth of foam 110 for each cavity is chosen so as to be slightly less than the depth of studs 54, 58. The actual depth of foam that is dispensed may be less than the final fill depth, in order to account for any expansion of foam that can occur during the curing process.

[0054] Referring now to Figure 6, wall section 50a is shown having cavities 64a therein completely filled with foam 110 by a plurality of beads 122 of foam 110. It will be noted that the pattern of fill for each cavity 64a is unique to that cavity. Table I provides an exemplary summary of each pattern of fill.

5 Table I

Cavity	Cavity Description	Bead	Sequence	Bead Description
64a-1	8 feet x 1.5 feet	122-1	1	Runs lengthwise, filling one-third of width of cavity 64a
64a-1	8 feet x 1.5 feet	122-2	2	Runs lengthwise, filling one-third of width of cavity 64a
64a-1	8 feet x 1.5 feet	122-3	3	Runs lengthwise, filling one-third of width of cavity 64a
64a-2	0.5 feet x 0.9 feet	122-13	19	Runs along width of cavity 64a-2
64a-3	0.5 feet x 0.9 feet	122-14	18	Runs along width of cavity 64a-3
64a-4	0.5 feet x 0.9 feet	122-15	17	Runs along width of cavity 64a-3
64a-5	0.5 feet x 2.7 feet	122-4	4	Runs lengthwise, filling one half of width of cavity 64a-5
64a-5	0.5 feet x 2.7 feet	122-5	5	Runs lengthwise, filling one half of width of cavity 64a-5
64a-6	0.5 feet x 2.7 feet	122-6	6	Runs lengthwise, filling one half of width of cavity 64a-6
64a-6	0.5 feet x 2.7 feet	122-7	7	Runs lengthwise, filling one half of width of cavity 64a-6
64a-7	0.5 feet x 2.7 feet	122-8	18	Runs along width, filling one third of cavity 64a-7
64a-7	0.5 feet x 2.7 feet	122-9	9	Runs along width, omitting fill for location of electrical outlet
64a-7	0.5 feet x 2.7 feet	122-10	10	Runs along width of cavity 64a-7
64a-8	8 feet x 1 foot	122-11	11	Runs 2/3 of length and filling one-third of width of cavity 64a-8
64a-8	8 feet x 1 foot	122-12	12	Runs 2/3 of length and filling one-third of width of cavity 64a-8
64a-8	8 feet x 1 foot	122-18	13	Runs along width between other beads and omitting fill for location of

Cavity	Cavity Description	Bead	Sequence	Bead Description
				electrical outlet
64a-8	8 feet x 1 foot	122-19	14	Runs along width between other beads and omitting fill along path of electrical conduit
64a-9	8 feet x 1 foot	122-16	16	Runs remainder of length and filling one-third of width of cavity 64a-8
64a-9	8 feet x 1 foot	122-17	15	Runs remainder of length and filling one-third of width of cavity 64a-8

[0055] The contents of Table I can thus be converted into programming instructions for controller 106, with each cavity 64a being filled by injector 102 in the order according the sequence in Table I.

[0056] Referring now to Figures 7 and 8, once wall section 50 has been filled with insulating foam 110, a second covering can be affixed to frame 60. In a present embodiment the second covering is in the form of drywall 126. Figures 8 in particular shows that the depth of foam is such that a small gap exists between foam 110 and drywall 126.

[0057] However, there is no gap between foam 110 and drywall 62. This underscores one of the advantages of the present invention, as foam 110 adheres to drywall 62, thereby affixing drywall 62 to frame 60 in a manner that can be more secure than at least some prior art methods which include the sole use of nails and/or staples and/or glue. Since the use of mechanical fasteners (e.g. nails and/or staples) can be substantially eliminated, or at least reduced, drywall 62 is much less susceptible to the phenomenon of "nail-pops" whereby drywall nails, over time, appear to be driven out of wooden studs 54, 58 and protrude from the surface of drywall 62, with an unsightly effect. This annoying phenomenon can be common on traditional wooden wall panels, as moisture evaporates from studs 54, 58 and giving the appearance of pushing the nails out of the wood frame as the wood shrinks away from the frame. It can be one of the most significant causes of warranty claims on new homes and therefore it is strongly desirable to obviate nail-pops.

[0058] Also, as another advantage, since cavities 64 are filled while wall section 50 is horizontal, the depth of foam 110 is substantially uniform. Likewise the insulating properties are also substantially uniform along the length of wall section 50. Likewise, the mechanical adherence of drywall 62 to frame 60 is substantially uniform throughout the entire extent of drywall 62.

[0059] Also, as another advantage, the substantially uniform fill of each wall section 50 can obviate the need for a traditional vapour-barrier of plastic sheeting to be applied, particularly when a vapour-barrier primer is applied to the wall section 50.

[0060] Also, as another advantage, the filling of each wall section 50 with foam 110 can increase the overall strength, both in torsion and in tension, of each wall section 50. As a result, when wall sections are manufactured in a facility for shipping to the construction site, wall sections manufactured according to the teachings herein are more resilient during the shipping process and less susceptible to damage than traditional, prior art wall sections.

[0061] It is believed that the teachings herein can, in certain applications, obviate the use of fasteners for drywall 62 to stud 58 altogether, as the adhesion between the foam and the drywall 62 and stud 58 is sufficient. Also the use of closed cell foam, can permit the reduction in the thickness of an exterior wall cavity from six inches to four inches, since the closed cell foam has an R value per inch that is greater than the R value per inch of traditional fiberglass insulation bats. This reduction in wall cavity thickness reduces the amount of lumber used and reduces stresses on the environment. Thus, a four inch wall cavity using the teachings herein can have the same, or better, air-conditioning and heating costs as a six inch wall cavity that employs traditional fiberglass bats. As a still further advantage, an engineered ventilated station can be configured to thereby reduce exposure to fumes given off during application. When foam is sprayed vertically into wall cavities on a construction site, the operator has to wear ventilation gear, yet an engineered ventilation system can mean that the operator need wear no gear when foam is sprayed using the teachings herein. Further, in a factory environment as described herein, the option exists to substantially completely recover the gases and prevent them from release into environment, and there by substantially reduce off-gassing into the environment.

[0062] Referring now to Figures 9 and 10, a variation on wall section 50a is indicated as wall section 50b. Figures 9 and 10 show the specific sequence of passes for each cavity of wall section 50b. Appendix I hereto describes the application parameters of foam for each cavity of wall section 50b.

[0063] The present invention thus provides, amongst other things, a novel system and method for manufacturing wall sections of houses by providing an assembly line for producing and insulating wall sections.

[0064] While the foregoing describes certain specific embodiments of the present

invention, it should be understood that variations, combinations and sub-sets of those embodiments are contemplated.

Appendix I**Exemplary Application Parameters for Wall Section 50b****FOAM INFORMATION**

5

FOAM DATA (PROPERTIES)

1.03	[--]	Resin Specific Gravity at 25C (Walltite)	
1.22	[--]	Isocyanate S.G. at 25C (Lupranate 17)	
1.00 : 1	[x : 1]	Ratio of Isocyanate to Resin by Volume	
1.18	[x : 1]	Ratio of Isocyanate to Resin by Weight	
33.60	[kg / m ³]	Theoretical Density of Fully Cured Foam	2.10 [lb / ft ³]
2.25	[R / cm]	Final R-Value of Foam per Thickness	5.70 [R / in]

FOAM APPLICATION DATA

8.50	[bdf / kg]	Approximate Application Yield at 1"	3.85 [bdf / lb]
49.86	[kg / m ³]	Final Density of Applied Foam	3.11 [lb / ft ³]
8.62	[kg / min]	AW5757 Spray Head Application Rate	19.00 [lb / min]

SPRAY APPLICATION PARAMETERS

10 **NOTE 1** - Wall cavities will be filled in straight line passes beginning at a calculated distance from the top or bottom plate at one end and ending at a calculated distance from the top or bottom plate at the other end. The spray head may or may not dwell at one or both ends of the cavity to provide extra fill to accommodate the corners. All of the spray characteristics must be calculated as a function of the parameters listed below. Some parameters are values taken from the WUP file while others may be parameters that are set by engineering or supervision. No values should be adjustable by the operator alone.

20 **NOTE 2** - All values of constants and parameters (adjustable or not) should be considered as real values, not integers. Calculations are presently configured to be linear in nature, but allowances are made, or may need to be implemented for nonlinear relationships. It is possible that many of the adjustable parameters or constants listed below may be equal to 0. Formulae should be built into the machine software in a way that allows for them to be adjusted, modified or added to using other parameters if need be.

25 **NOTE 3** – A presently preferred maximum spray width is limited to about twelve inches. However, this should be an adjustable parameter. See below for calculation. A presently preferred minimum spray width is set to be about four inches.

INSULATION AND CAVITY PARAMETER DEFINITION**IT [in] Insulation Thickness****Definition** Desired average thickness of foam insulation in the wall cavity.**Formula** This parameter will be an adjustable value that can only be set by engineering or supervision.**Initialize** IT = 3**MW [in] Minimum Cavity Width****Definition** Minimum cavity width allowable to be sprayed. Cavities smaller than this should not be sprayed.**Formula** This parameter will be an adjustable value that can only be set by engineering or supervision.**Initialize** MW = 4**OW [in] One Pass Width****Definition** For multiple pass cavities, this defines the minimum multiple pass spray width.**Formula** This parameter will be an adjustable value that can only be set by engineering or supervision.**Initialize** OW = 6**Example** At OW = 6", any cavity larger than 12" will be divided into 2 spray paths.

At OW = 6", any cavity larger than 18" will be divided into 3 spray paths.

At OW = 6", any cavity larger than 24" will be divided into 4 spray paths.

FD [lb / ft³] Foam Density**Definition** Applied foam density (the average density of foam applied to a cavity including the foam skins).**Formula** This parameter will be an adjustable value that can only be set by engineering or supervision.**Initialize** FD = 3.11**AR [lb / min] Application Rate****Definition** Application rate of foam equipment (depending on foam equipment settings and nozzle used).**Formula** This parameter will be an adjustable value that can only be set by engineering or supervision.**Initialize** AR = 19.0**CAVITY SIZE AND MULTIPLE PASS CALCULATIONS****CW [in] Cavity Width****Definition** Width of the cavity to be sprayed.**Formula** This value will be determined by the WUP file as the distance between stud faces.**Example** For studs that are 1.5" wide and a center distance between studs of 24", CW would be 22.5".**NP [#] Number of Passes****Definition** This is the number of passes required to fill the cavity. This number should always be an integer.**Formula** NP = $\text{ROUNDDOWN} \{ (CW) / (OW) \}$ { for CW >= OW }**Formula** NP = 1 { for CW < OW }**Example** For CW = 22.5" and OW = 6" ; NP would be 3.**PW [in] Width of Pass to be Sprayed****Definition** This is the width of the spray path as applied to the substrate.**Formula** PW = (CW) / (NP)**Example** For CW = 22.5" and NP = 3 ; PW would be 7.5"**CL [in] Cavity Length****Definition** This is the length of the cavity to be filled**Formula** This value will be determined by the WUP file as the distance between top and bottom plate faces.**Example** For a 96" wall with 1.5" top and bottom plates, CL would be 93"**SD [in] Stud Depth****Definition** This is the depth of the studs that make up the wall cavity (ie - wall stud thickness).**Formula** This value will be determined by the WUP file.**Example** For 2x4 walls SD = 3.5" ; For 2x6 walls SD = 5.5", etc.

PASS CALCULATIONS**HN [in] Height of Spray Nozzle from Substrate****Definition** This value will be larger for wider cavities and smaller for narrower cavities.**Formula** $HN = (c1)(PW)^2 + (b1)(PW) + a1$ { for $HN \geq SD$ }**Formula** $HN = SD$ { for $HN < SD$ }**where** $a1, b1, c1$ = adjustable parameters**Initialize** $a1 = 0$; $b1 = 1.25$; $c1 = 0$ **Example** For $PW = 7.5"$; HN would be 9.375".**GB [in] Gap Offset Distance from Nozzle Centerline to Beginning Plate****Definition** This value defines the starting distance of the nozzle from the beginning plate.**Formula** $GB = (c2)(PW)^2 + (b2)(PW) + a2$ **where** $a2, b2, c2$ = adjustable parameters**Initialize** $a2 = 0$; $b2 = 0.5$; $c2 = 0$ **Example** For $PW = 7.5"$; GB would be 3.75".**GE [in] Gap Offset Distance from Nozzle Centerline to Ending Plate****Definition** This value defines the stopping distance of the nozzle from the ending plate.**Formula** $GE = (c3)(PW)^2 + (b3)(PW) + a3$ **where** $a3, b3, c3$ = adjustable parameters**Initialize** $a3 = 0$; $b3 = 0.5$; $c3 = 0$ **Example** For $PW = 7.5"$; GE would be 3.75".**TP [sec] Time Spraying on Pass****Definition** Total "on time" that the spray system needs to spray for a singular spray pass.**Formula** $TP = ((PW)(CL)(IT) / 1728) \times ((FD) / (AR)) \times 60$ **where** 1728 converts in^3 to ft^3 and 60 converts minutes into seconds**Example** For a 7-1/2"x93"x3" pass at $FD = 3.11$ and $AR = 19.0$; TS would be 11.89 seconds.**LP [in] Length of Spray Pass****Definition** The length of an individual spray pass.**Formula** $LP = (CL) - (GB) - (GE)$ **Example** For $CL = 93"$; $GB = 3.75"$; $GE = 3.75"$; LP would be 85.5"**TB [sec] Time Spraying Stationary at Beginning of Spray Pass****Definition** Time that the spray system needs to spray at the beginning location prior to moving down the pass.**Formula** $TB = ((PW)(GB)(IT) / 1728) \times ((FD) / (AR)) \times 60$ **where** 1728 converts in^3 to ft^3 and 60 converts minutes into seconds**Example** For a $PW = 7.5"$; $GB = 3.75"$; $IT = 3"$ at $FD = 3.11$ and $AR = 19.0$; TB would be 0.48 seconds.**TE [sec] Time Spraying Stationary at End of Spray Pass****Definition** Time the spray system needs to spray stationary at the end location prior to turning off the foam.**Formula** $TE = ((PW)(GE)(IT) / 1728) \times ((FD) / (AR)) \times 60$ **where** 1728 converts in^3 to ft^3 and 60 converts minutes into seconds**Example** For a $PW = 7.5"$; $GE = 3.75"$; $IT = 3"$ at $FD = 3.11$ and $AR = 19.0$; TE would be 0.48 seconds.**VN [in / sec] Velocity of Nozzle Along Spray Path****Definition** This value defines the linear velocity of the spray nozzle along the spray pass when in motion.**Formula** $VN = (LP) / ((TP) - (TB) - (TE))$ **Example** For $LP = 85.5"$; $TP = 11.8\text{sec}$; $TB = 0.48\text{sec}$; $TE = 0.48\text{sec}$; VN would be 7.89 in/sec

Sample Pass Plan for Passes 1 through 7, as shown in Figures 9 and 10

5 Figures 9 and 10 show a sample wall approximately 96 inches long by 96" tall fabricated with 2x4 stud framing. It has one layer of drywall on the bottom side and it has pre-installed electrical boxes and conduit. The electrical boxes and conduit are to be treated as obstacles that can not be foamed. Since the foam expands in all directions, foam will flow underneath and around items like the conduit and will fill in around the electrical boxes.

10 Prior to foaming the panel, the software derives a PASS PLAN to divide up the wall cavities into sections as per the information provided above. Figures 9 and 10 represent an example of such a derivation. There are a total of 20 passes to fill the wall with insulation. It will be important to note that the speed of the gun travel, the height of the gun off the drywall face, the start location and end location and the time spent standing still at the start and end locations are all important to be sure that the proper amount of insulation is put into the
15 cavity. Do not foam the window.

Using the calculations supplied above, the following are an example of how each of the first few passes would be made by the foam machine.

Initialized Values			
IT	3.00	[in]	
MW	4.00	[in]	
OW	6.00	[in]	
FD	3.11	[lb / ft ³]	
AR	19.00	[lb / min]	
Pass 1		Description	
CW	22.50	[in]	1) The nozzle would station itself at the start of the pass.
NP	3	[#]	2) The nozzle would be 9.38 inches from the drywall.
PW	7.50	[in]	3) The nozzle would be centered on the 7.5 inch wide pass and be 3.75 inches from the bottom plate.
CL	93.00	[in]	
SD	4.00	[in]	4) Once the foam spray is turned on, it would be stationary at the start location for 0.48 seconds.
HN	9.38	[in]	
GB	3.75	[in]	5) It would then travel the pass line at a velocity of 7.82 in/sec.
GE	3.75	[in]	6) Once at the end location, 3.75 inches from the top plate, it would remain stationary for 0.48 seconds and then the foam flow would be turned off.
TP	11.89	[sec]	
LP	85.50	[in]	
TB	0.48	[sec]	7) Once off, it would proceed to the start location of Pass 2.
TE	0.48	[sec]	8) Upon reaching the start location for Pass 2, it would begin the procedure for filling Pass 2.
VN	7.82	[in / sec]	
Pass 2		Pass 3	
CW	22.50	[in]	CW 22.50 [in]
NP	3	[#]	NP 3 [#]
PW	7.50	[in]	PW 7.50 [in]
CL	93.00	[in]	CL 93.00 [in]
SD	4.00	[in]	SD 4.00 [in]
HN	9.38	[in]	HN 9.38 [in]
GB	3.75	[in]	GB 3.75 [in]
GE	3.75	[in]	GE 3.75 [in]
TP	11.89	[sec]	TP 11.89 [sec]
LP	85.50	[in]	LP 85.50 [in]
TB	0.48	[sec]	TB 0.48 [sec]
TE	0.48	[sec]	TE 0.48 [sec]
VN	7.82	[in / sec]	VN 7.82 [in / sec]
		Pass 4	
		CW	5.50 [in]
		NP	1 [#]
		PW	5.50 [in]
		CL	16.00 [in]
		SD	4.00 [in]
		HN	6.88 [in]
		GB	2.75 [in]
		GE	2.75 [in]
		TP	1.50 [sec]
		LP	10.50 [in]
		TB	0.26 [sec]
		TE	0.26 [sec]
		VN	10.66 [in / sec]

Pass 5			Pass 6			Pass 7		
CW	5.50	[in]	CW	5.50	[in]	CW	16.00	[in]
NP	1	[#]	NP	1	[#]	NP	2	[#]
PW	5.50	[in]	PW	5.50	[in]	PW	8.00	[in]
CL	18.00	[in]	CL	16.00	[in]	CL	22.50	[in]
SD	4.00	[in]	SD	4.00	[in]	SD	4.00	[in]
HN	6.88	[in]	HN	6.88	[in]	HN	10.00	[in]
GB	2.75	[in]	GB	2.75	[in]	GB	4.00	[in]
GE	2.75	[in]	GE	2.75	[in]	GE	4.00	[in]
TP	1.69	[sec]	TP	1.50	[sec]	TP	3.07	[sec]
LP	12.50	[in]	LP	10.50	[in]	LP	14.50	[in]
TB	0.26	[sec]	TB	0.26	[sec]	TB	0.55	[sec]
TE	0.26	[sec]	TE	0.26	[sec]	TE	0.55	[sec]
VN	10.66	[in / sec]	VN	10.66	[in / sec]	VN	7.33	[in / sec]

CLAIMS

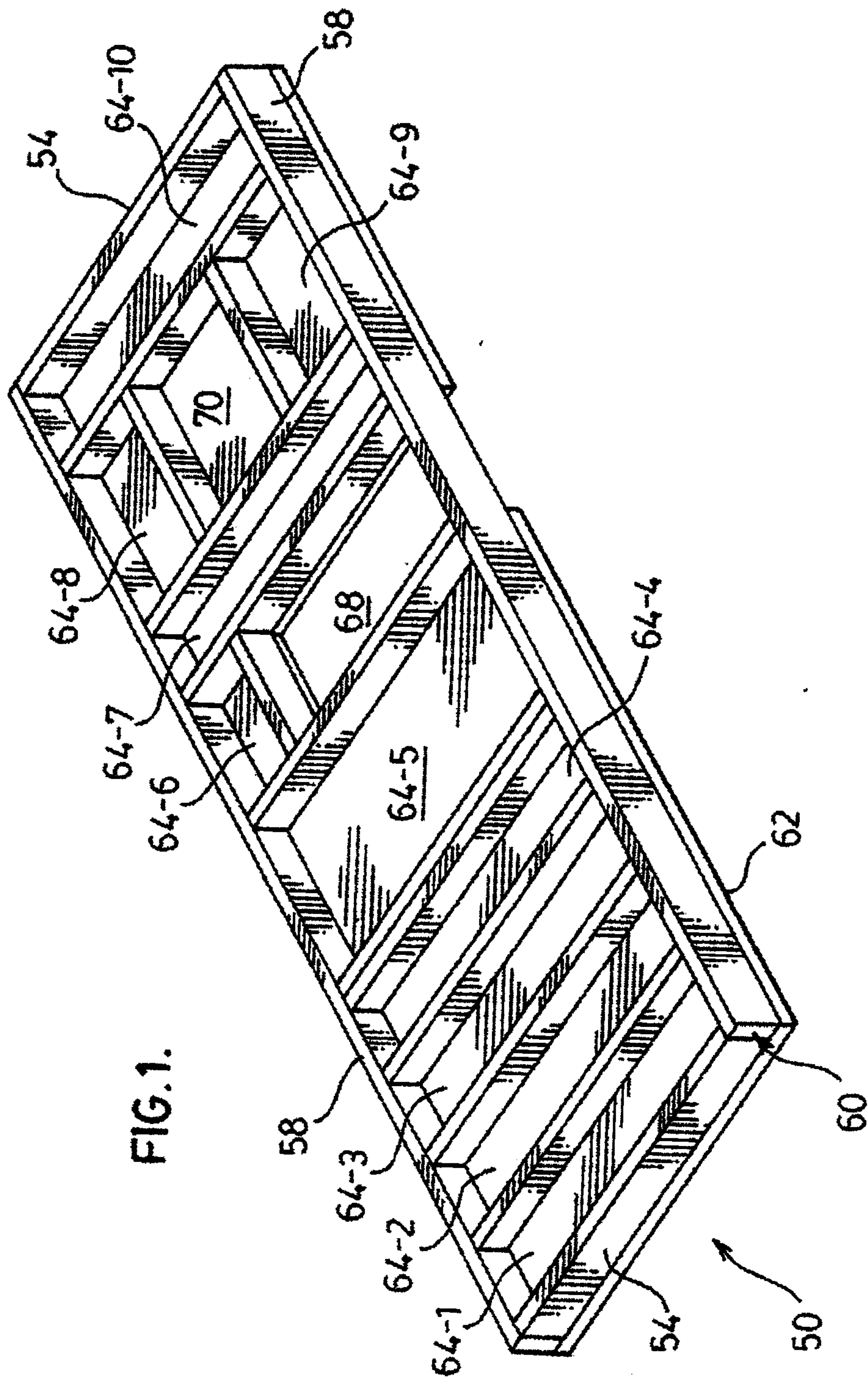
1. A wall section comprising:
 - a first set of substantially parallel supports;
 - a second set of substantially parallel supports disposed substantially perpendicular to said first set;
 - a covering applied to one side of said supports;
 - said covering and said sets of supports defining cavities; and
 - a curable flowable material downwardly injected into one or more of said cavities, said curable flowable material being injected in the form of a plurality of beads into said one or more cavities in a predefined path comprising both a first direction, and a second direction substantially perpendicular to said first direction, while said supports are in a horizontal position.
2. The wall section of claim 1 further comprising a second covering applied to a second side of said supports that is opposite to said first side of said supports.
3. The wall section of claim 1 wherein said curable flowable material adheres to both said first covering and said supports such that said covering is adhered to said supports by said curable flowable material.
4. The wall section of claim 1 wherein said covering is drywall.
5. The wall section of claim 1 wherein said supports are made from wood.
6. The wall section of claim 1 wherein said supports are made from metal.
7. The wall section of claim 1 wherein said flowable material is closed cell foam.
8. The wall section of claim 1 wherein when said flowable material cures a torsional and tensional rigidity of said wall section is increased thereby.
9. The wall section of claim 1 wherein when said flowable material cures, the insulation factor of said wall section is increased thereby.

10. The wall section of claim 1 wherein when said flowable material cures, at least a partial vapour barrier from one side of said wall section to the other side of said wall section is provided thereby.
11. A method of insulating a wall section of a site-built home, said wall section comprising a first set of substantially parallel supports; a second set of substantially parallel supports disposed substantially perpendicular to said first set; a covering positioned on one side of said supports; said covering and said sets of supports defining cavities; the method comprising:
- orienting said wall section horizontally such that said cavities face upwards; and
 - injecting curable flowable material downwardly into one or more of said cavities, said curable flowable material being injected in the form of a plurality of beads into said one or more cavities in a predefined path comprising both a first direction, and a second direction substantially perpendicular to said first direction.
12. The method of claim 11 wherein further comprising applying a second covering to a second side of said supports that is opposite to said first side of said supports.
13. The method of claim 11 wherein said curable flowable material is applied to both said first covering and portions of said supports that are perpendicular to said first covering and further comprising the step of:
- waiting until said curable flowable material cures such that said covering is adhered to said supports.
14. The method of claim 11 wherein said covering is drywall.
15. The method of claim 11 wherein said supports are made from wood.
16. The method of claim 11 wherein said supports are made from metal.
17. The method of claim 11 wherein said curable material is closed cell foam.
18. The method of claim 11 wherein when said curable flowable material is selected such that when said flowable material cures a torsional and tensional rigidity of said wall section is increased thereby.

19. The method of claim 11 wherein said curable flowable material is selected such that when said flowable material cures said material increases the insulation factor of said wall section.
20. The method of claim 11 wherein said curable flowable material is selected such that when said flowable material cures, said material provides at least a partial vapour barrier from one side of said wall section to the other side of said wall section.
21. A system for manufacturing a wall section comprising:
- one or more framing stations for producing wall sections that comprise a first set of substantially parallel supports;
 - a second set of substantially parallel supports disposed substantially perpendicular to said first set;
 - a covering applied to one side of said supports;
 - said covering and said sets of supports defining cavities;
 - one or more insulation stations for receiving wall sections from said framing stations and for injecting a curable flowable material downwardly into one or more of said cavities while said supports are in a horizontal position, said curable flowable material being injected in the form of a plurality of beads into said one or more cavities in a predefined path comprising both a first direction, and a second direction substantially perpendicular to said first direction.
22. The system of claim 21 wherein said framing stations and said insulation stations are configured to produce and insulate, respectively, wall sections that have different configurations.
23. The system of claim 22 further comprising automation equipment for said framing stations and said insulation stations.
24. The system of claim 23 further comprising a computer configured to control said automation equipment in said framing stations and said insulation stations according to a production schedule in order to continuously produce and insulate a plurality of wall sections having different configurations.
25. The system of claim 21 wherein said covering is an inside wall of a home.

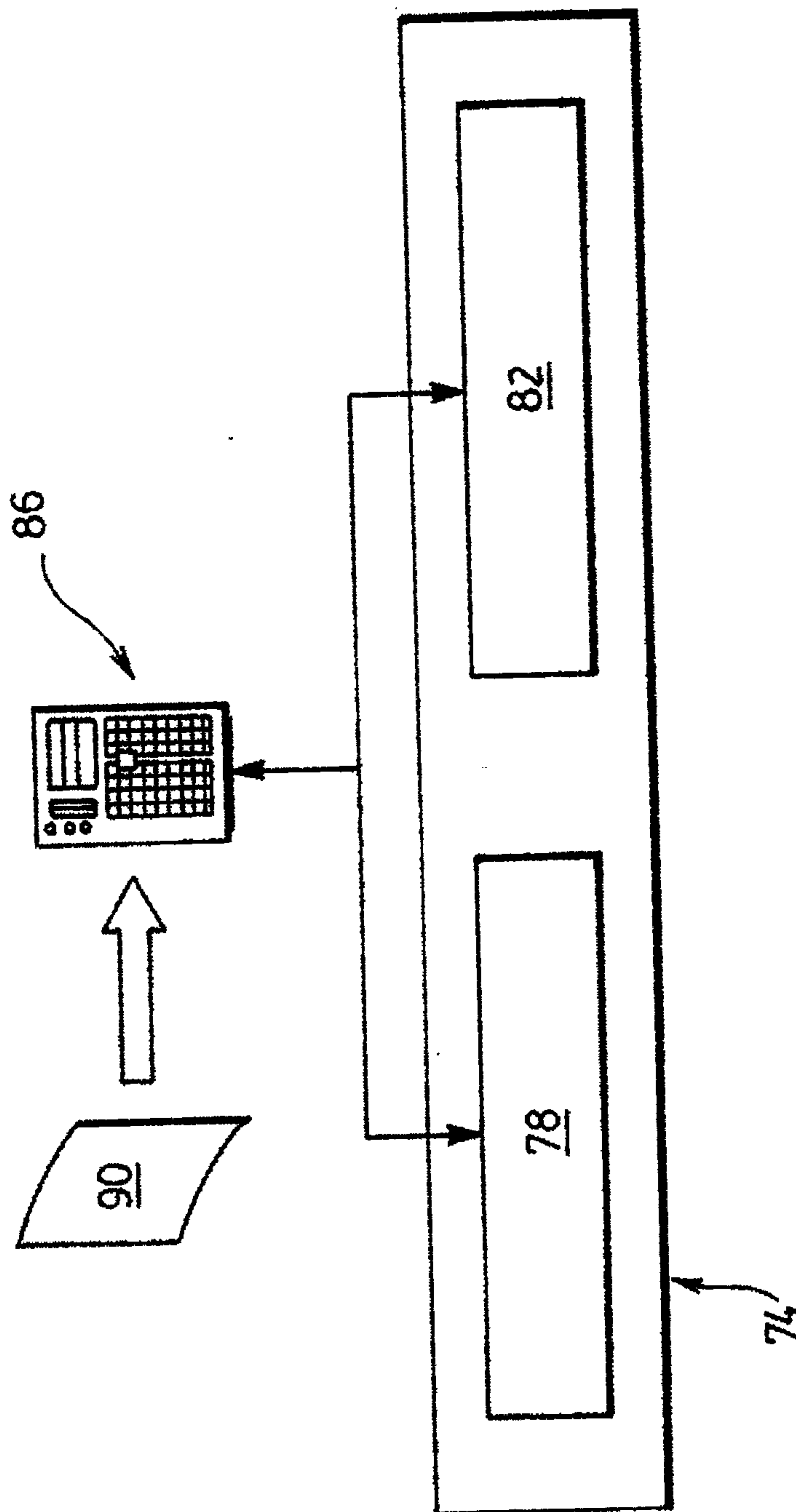
26. The system of claim 21 wherein said covering is an outside wall of a home.

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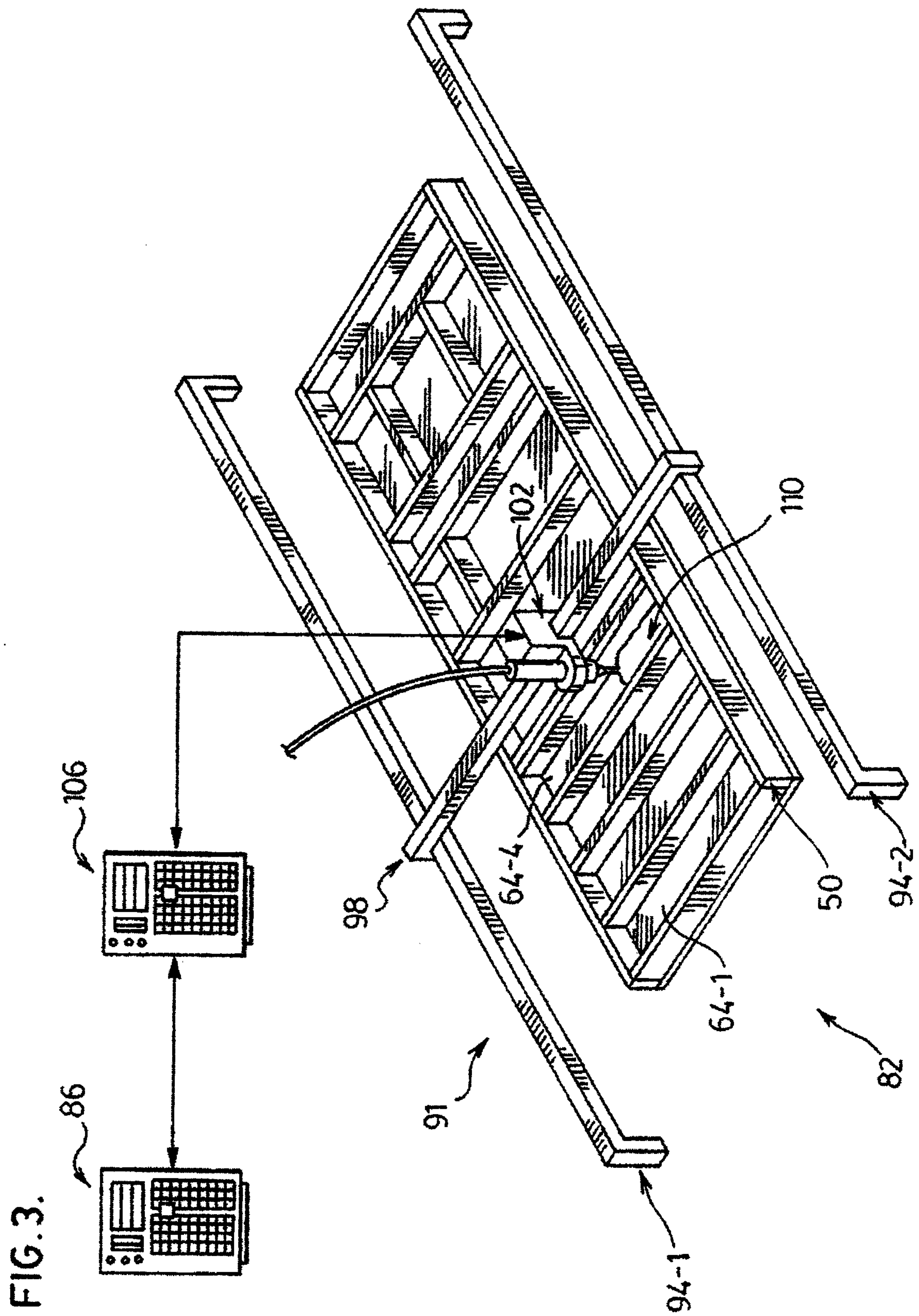


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FIG. 2

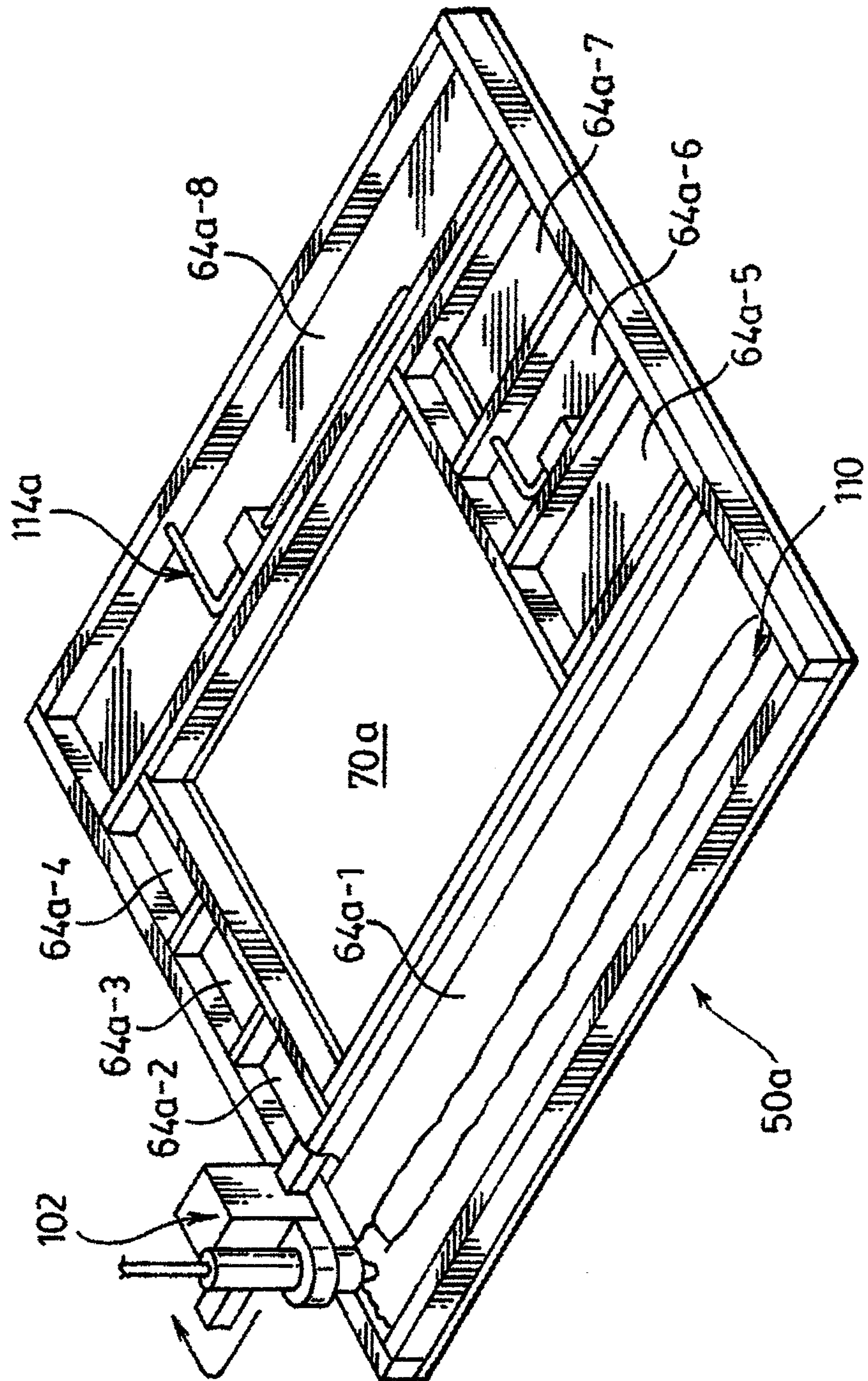


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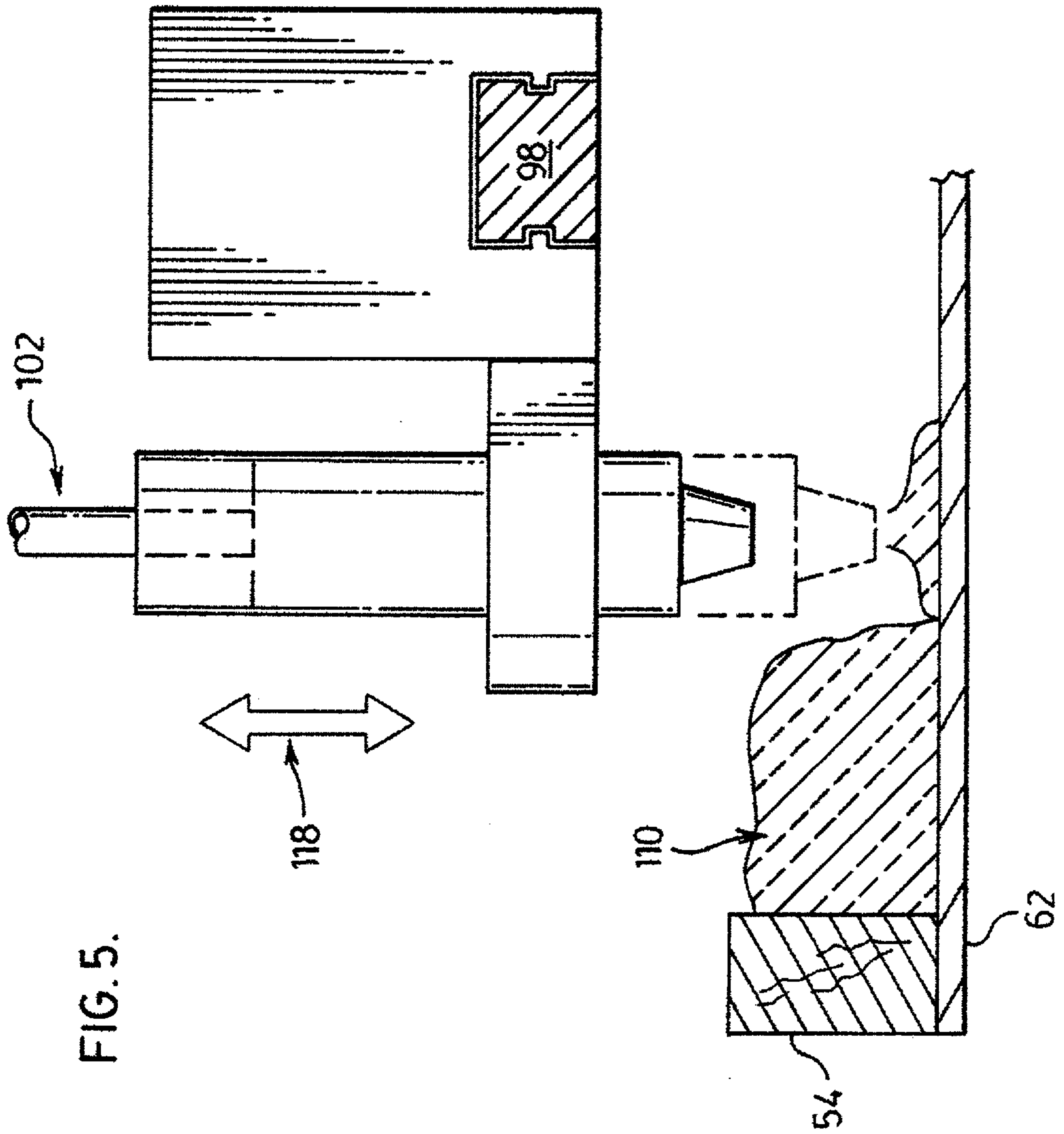


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FIG. 4.



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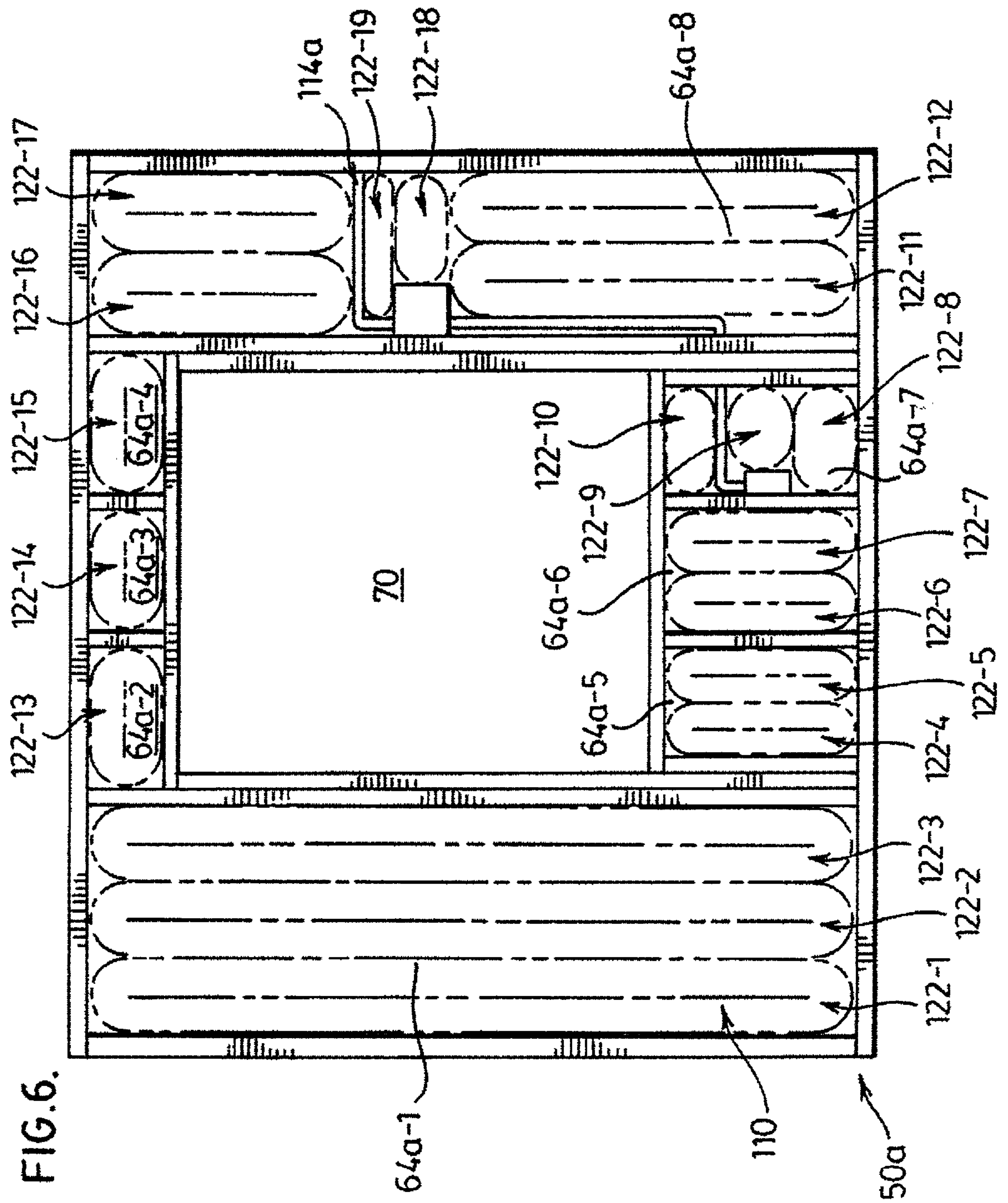
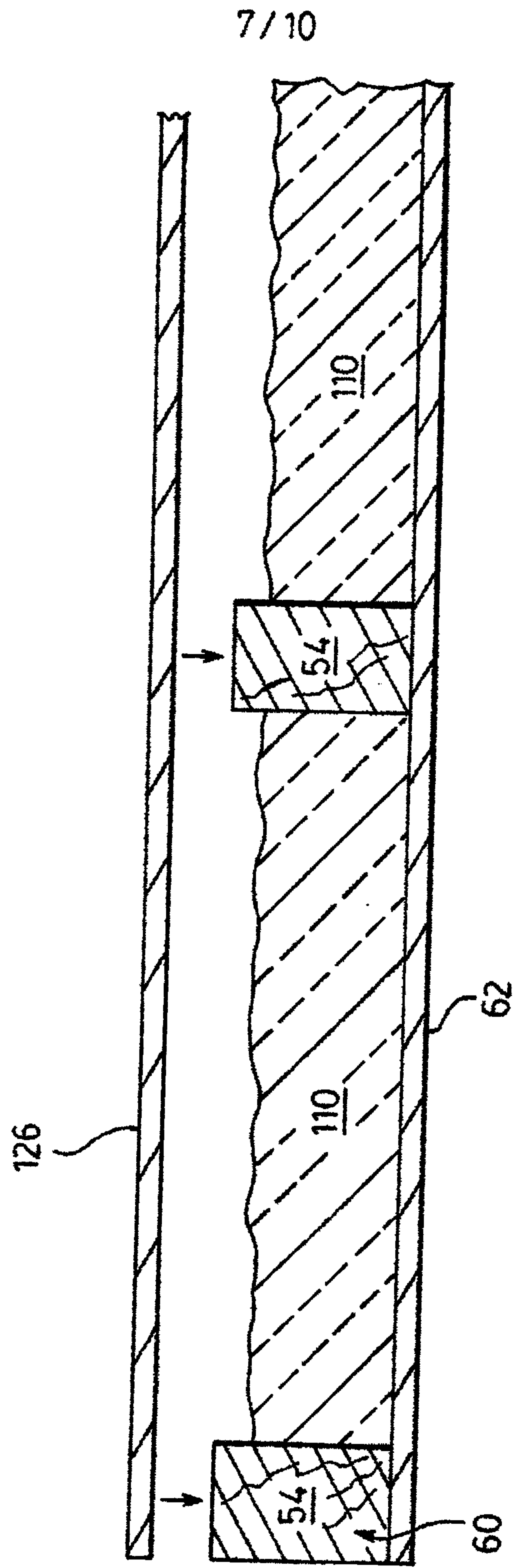


FIG.7.



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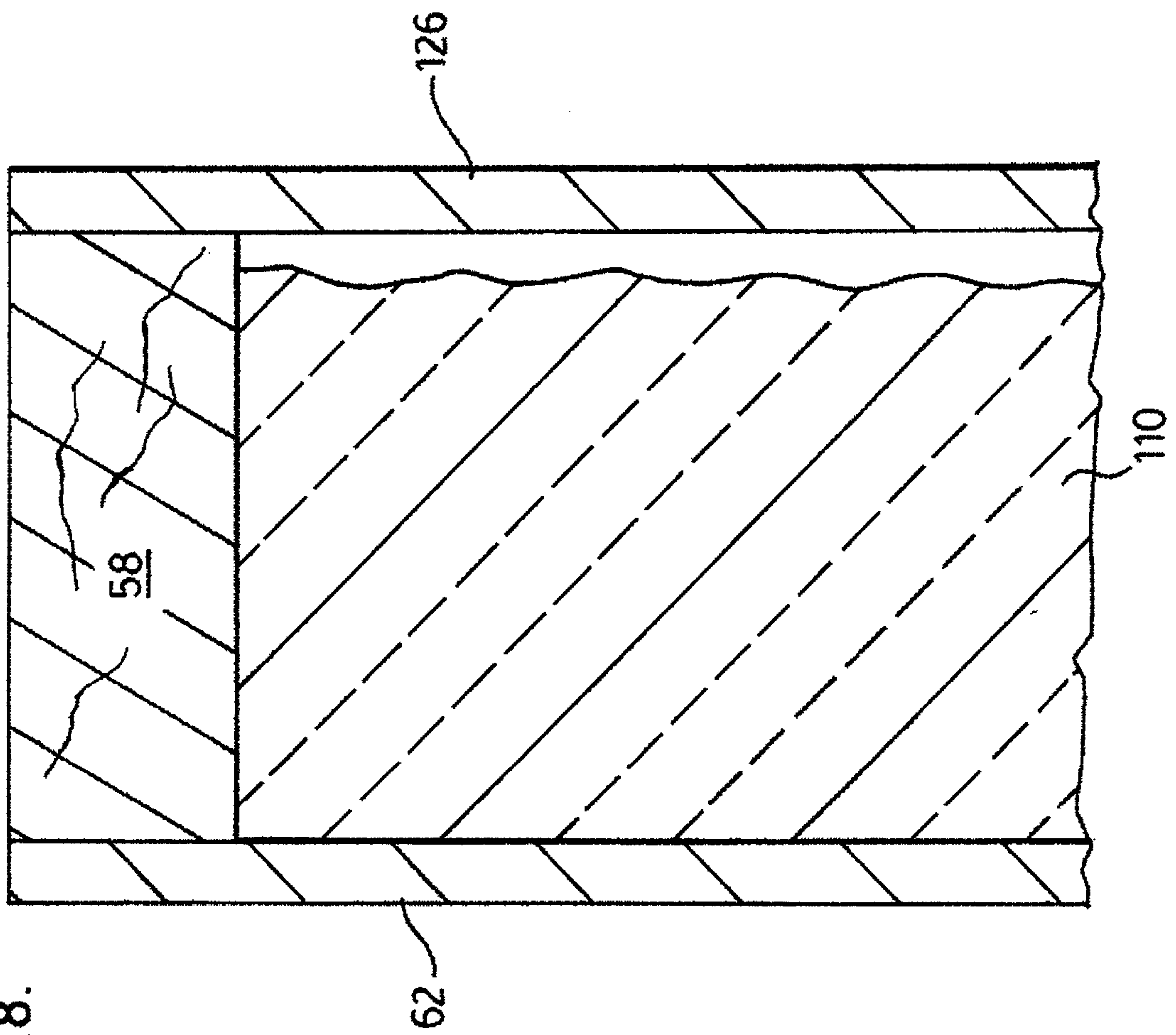
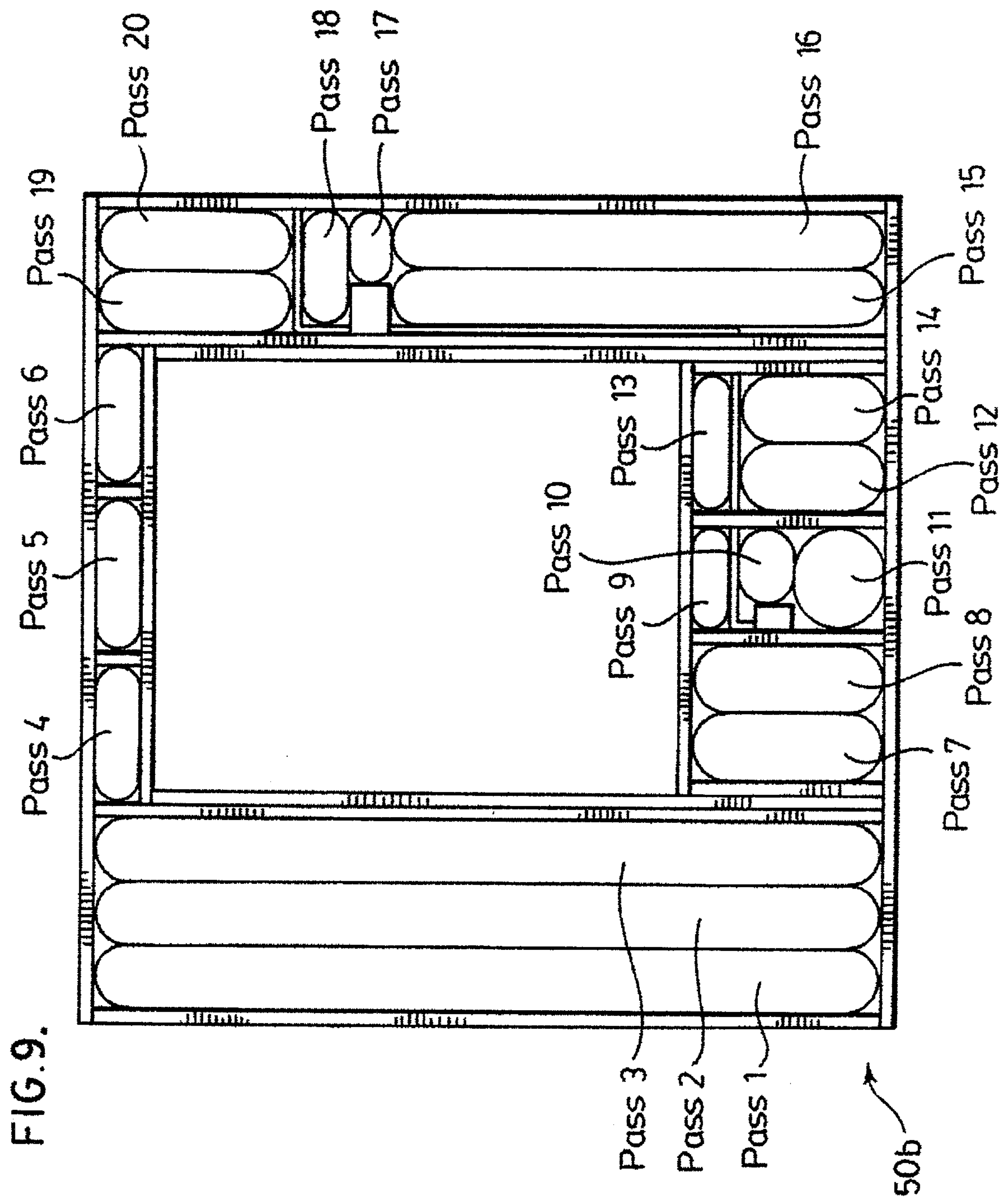


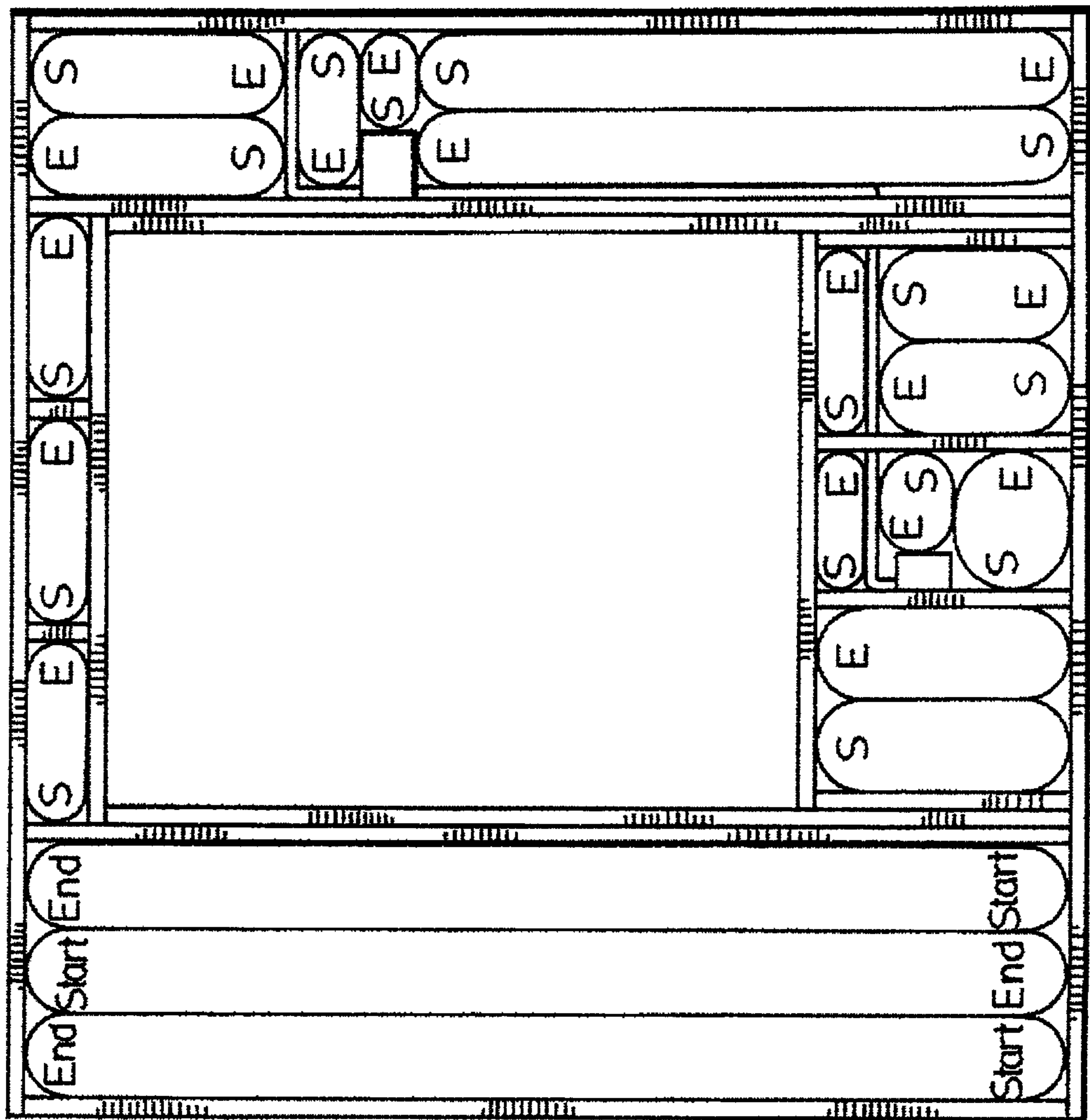
FIG.8.

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FIG. 10.



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