Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2678636 C 2013/01/15

(11)(21) 2 678 636

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(22) Date de dépôt/Filing Date: 2009/09/14

(41) Mise à la disp. pub./Open to Public Insp.: 2010/03/12

(45) Date de délivrance/Issue Date: 2013/01/15

(30) Priorités/Priorities: 2008/09/12 (US61/096,374); 2009/02/19 (US12/388,798)

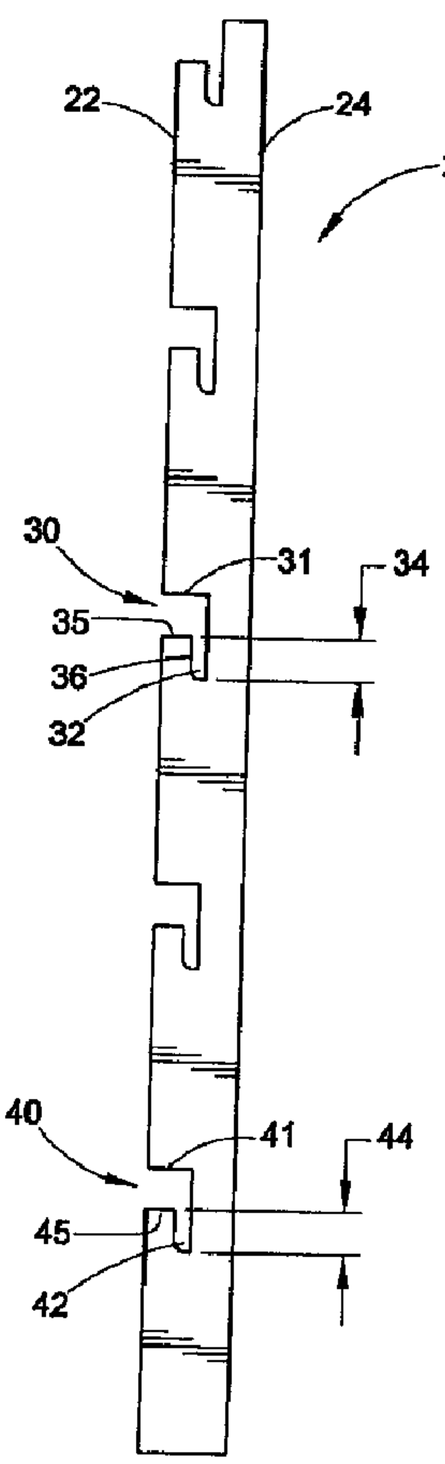
(51) Cl.Int./Int.Cl. *E04F 13/075* (2006.01)

(72) Inventeur/Inventor:
CULPEPPER, JASON LEE, US

(73) Propriétaire/Owner:
PROGRESSIVE FOAM TECHNOLOGIES, INC., US

(74) Agent: PIASETZKI NENNIGER KVAS LLP

(54) Titre : SYSTEME DE PAREMENT ISOLANT
(54) Title: INSULATING SIDING SYSTEM



(57) Abrégé/Abstract:
An insulating siding system contains two components: a sheathing panel and a siding panel. The sheathing panel contains slots or grooves, while the siding panel contains connectors that fit into the slots or grooves. The siding panels are fit or attached to the sheathing panel without the need for fasteners, such as nails or staples, to penetrate the siding panel, creating a uniform exterior.

INSULATING SIDING SYSTEM

ABSTRACT OF THE DISCLOSURE

An insulating siding system contains two components: a sheathing panel and a siding panel. The sheathing panel contains slots or grooves, while the siding panel contains connectors that fit into the slots or grooves. The siding panels are fit or attached to the sheathing panel without the need for fasteners, such as nails or staples, to penetrate the siding panel, creating a uniform exterior.

INSULATING SIDING SYSTEM

BACKGROUND

The present disclosure relates to systems for providing insulation and siding panels on the exterior of a building, such as a house. Methods and processes for making and/or using such insulating siding systems are also disclosed.

In a building structure, such as a house, a frame is typically built. An exterior wall of plywood or material of similar function is then placed upon the frame to provide an exterior surface. A weatherproofing layer may cover the exterior wall. An insulation layer can then be placed, and finally a cladding, paneling, veneer, or siding is placed to provide the final exterior view.

Vinyl siding is a popular substitute for wood paneling and aluminum siding. It is easily cleaned, and it is resistant to deterioration. It may also be easily installed around windows and doors. Moreover, it may be produced in a variety of shapes and colors by known extrusion and molding processes at a relatively low cost per sheet or panel.

To enhance the thermal insulation of building structures, one or more layers of insulating material can be placed between the vinyl siding and the exterior wall of the building. For example, a layer of insulation can be placed on a exterior wall, and the vinyl siding then installed over the insulating layer. In other insulated siding systems, an insulated panel is generally attached to a veneer, such as a vinyl siding panel.

Current insulation and exterior finishing products are complex to install and have performance shortcomings. For example, rigid insulating sheathing and siding are installed in two separate steps and function separately from one

another as well. The installation of insulation and siding is a two-step process that is complicated, time-consuming, and requires the installer to put excessive penetrations into the walls of a building, creating areas that are vulnerable to moisture intrusion. Because the fasteners used to attach siding panels to a wall restrict the movement of the panels, visual defects due to thermal expansion can occur as well. Also, when installing plank siding product, there is no natural alignment from course to course integrated into the siding product or the sheathing product. This forces the installer to strike chalk lines or use other secondary alignment devices, increasing the time and cost of the installation.

It would be desirable to produce additional insulated siding panel systems or assemblies that allow for simple production and easy installation.

BRIEF DESCRIPTION

Disclosed in embodiments are insulating siding systems useful on the exterior surfaces or walls of a building. The insulating siding systems contain rigid foam insulation, which provides strength to the insulated siding system, enables a wide variety of design options, and provides increased R-values.

Generally, the insulating siding systems include a foam sheathing product having integral siding receivers or connectors that allow easy, straight alignment and fastening of a siding panel or façade that is equipped with the complementary receiver / connector, without the use of typical fasteners like nails, staples, screws, etc. in the siding panel / façade.

In some embodiments, an insulating siding system comprising a sheathing panel and a siding panel is disclosed. The sheathing panel comprises a front surface and a rear surface, the front surface and rear surface being spaced laterally apart from each other. The front surface comprises a first slot, the first slot extending laterally into the sheathing panel and including an upwardly facing channel spaced laterally from the front surface. The siding panel comprises a front face and a first downwardly facing channel that extends rearwards and has a rear wall. The first slot is sized to receive the rear wall of the first downwardly facing channel.

In some other embodiments, an insulating siding system comprising a sheathing panel and a siding panel is disclosed. The sheathing panel comprises a front surface and a rear surface, which are spaced laterally apart from each other. The front surface comprises a first slot and a second slot. Each slot extends laterally into the sheathing panel and includes an upwardly facing channel spaced laterally from the front surface. The siding panel comprises a front face, an upper downwardly facing channel that extends rearwards and has a rear wall, and a lower downwardly facing channel that extends rearwards and has a rear wall. The first slot is sized to receive the rear wall of the upper downwardly facing channel and the second slot is sized to receive the rear wall of the lower downwardly facing channel.

In other embodiments, an insulating siding system comprising a sheathing panel and a siding panel is disclosed. The sheathing panel comprises a rear surface and a forward surface. The forward surface comprises a first row and a second row. The two rows extend laterally from the forward surface to define a front surface. The second row has a ridge extending upwardly at the front surface between the first row and the second row to define a slot. The siding panel comprises a front face having an upper edge and a lower edge. A lower downwardly facing channel extends rearwards from the lower edge and has a rear wall. The slot is sized to receive the rear wall of the lower downwardly facing channel.

In still other embodiments, an insulating siding system comprises a sheathing panel and a siding panel. The sheathing panel comprises a front surface and a rear surface, which are spaced laterally apart from each other. The front surface comprises a first slot and a second slot. Each slot comprises an upper surface extending laterally into the front surface, a rear surface extending downwards from the upper surface, a lower surface extending from the rear surface laterally towards the front surface for a lower surface width, a forward surface extending upwards from the lower surface for a forward surface height, a medial surface extending from the forward surface to the front surface for a medial surface width, and a slot entry height between the upper surface

and the medial surface. The siding panel comprises a front face and a rear face, an upper channel wall extending rearwards from the rear face and having an upper channel wall width, an upper channel rear wall extending downwards from the upper channel wall and having an upper rear wall height, a bottom wall extending rearwards from the rear face, a lower channel front wall extending upwards from the bottom wall, a lower channel top wall extending rearwards from the lower channel front wall and having a lower top wall width, and a lower channel rear wall extending downwards from the lower channel top wall and having a lower rear wall height. The slot entry height of the first slot is equal to or greater than the upper rear wall height and the slot entry height of the second slot is equal to or greater than the lower rear wall height.

In still other embodiments, an insulating siding system comprises a sheathing panel and a siding panel. The sheathing panel comprises a front surface and a rear surface. The front surface comprises a first slot and a second slot. Each slot extends rearwards into the sheathing panel and includes an upwardly facing channel spaced apart from the front surface. The siding panel comprises a front face, a rear face, an upper connecting wall extending rearwards from an upper portion of the rear face, an upper rear wall extending downwards from the upper connecting wall, and a lower rear wall connected to a lower portion of the rear face by a lower connecting wall and extending downwards from the lower connecting wall. The first slot is sized to receive the upper rear wall and the second slot is sized to receive the lower rear wall.

Disclosed in yet other embodiments are insulating siding systems comprising a sheathing panel and a siding panel. The sheathing panel comprises a front surface and a rear surface. The front surface comprises a first slot and a second slot. Each slot extends rearwards into the sheathing panel and includes (i) an upwardly facing channel spaced from the front surface; (ii) a lip along the front surface having a lip height; and (iii) a slot entry height. The siding panel comprises a front face and a rear face. An upper downwardly facing channel extends rearwards from an upper portion of the rear face. A lower upwardly facing channel extends rearwards from a lower portion of the

rear face, and a lower downwardly facing channel extends rearwards from the lower upwardly facing channel. The first slot entry height is sized to allow the first slot lip to enter the upper downwardly facing channel and the second slot entry height is sized to allow the second slot lip to enter the lower downwardly facing channel.

In some other embodiments, an insulating siding system comprises a sheathing panel and a siding panel. The sheathing panel comprises a front surface and a rear surface. The front surface comprises a slot having a slot entry height and extends rearwards into the sheathing panel to form a cavity having a cavity height. The cavity height is greater than the slot entry height. The siding panel comprises a front face and a rear face, a connecting wall extending from the rear face, and a rear wall extending transversely from the connecting wall. The rear wall has a height that is greater than the slot entry height.

In still more embodiments, an insulating siding system comprises a sheathing panel and a siding panel. The siding panel comprises a front face and a rear face. The rear face comprises a receptacle that has a receptacle entry height and extends into the siding panel to form a cavity having a cavity height. The cavity height is greater than the receptacle entry height. The sheathing panel comprises a front face and a rear face, a connecting wall extending from the front face, and a front wall extending transversely from the connecting wall. The front wall has a height that is greater than the receptacle entry height.

These and other non-limiting characteristics of the disclosure are more particularly disclosed below.

BRIEF DESCRIPTION OF THE DRAWINGS

The following is a brief description of the drawings, which are presented for the purposes of illustrating the exemplary embodiments disclosed herein and not for the purposes of limiting the same.

Figure 1 is a side view of an exemplary embodiment of a sheathing panel used in the present disclosure.

Figure 2 is a side view of an exemplary embodiment of a siding panel used in the present disclosure.

Figure 3 is a side view of an exemplary embodiment of the panels of **Figures 1** and **2** attached to each other.

Figure 4 is a side view of another exemplary embodiment of an insulating siding system of the present disclosure.

Figure 5 is a side view of another exemplary embodiment of a sheathing panel used in the present disclosure.

Figure 6 is a side view of another exemplary embodiment of a siding panel used in the present disclosure.

Figure 7 is a side view of an exemplary embodiment of the panels of **Figures 5** and **6** attached to each other.

Figure 8 is a side view of another exemplary embodiment of a sheathing panel used in the present disclosure.

Figure 9 is a side view of another exemplary embodiment of a siding panel used in the present disclosure.

Figure 10 is a side view of an exemplary embodiment of the panels of **Figures 8** and **9** attached to each other.

Figure 11 is a side view of another exemplary embodiment of a sheathing panel used in the present disclosure.

Figure 12 is a side view of another exemplary embodiment of a siding panel used in the present disclosure.

Figure 13 is a side view of an exemplary embodiment of the panels of **Figures 11** and **12** attached to each other.

Figure 14 is a side view of another exemplary embodiment of a siding panel used in the present disclosure.

Figure 15 is a side view of another exemplary embodiment of a siding panel used in the present disclosure.

Figure 16 is a side view of an exemplary embodiment of the panels of **Figures 11** and **15** attached to each other.

Figure 17 is a front view of another exemplary embodiment of a sheathing panel of the present disclosure.

Figure 18 is a bottom perspective view showing the connection between two sheathing panels of the present disclosure.

Figure 19 is a side view of another exemplary embodiment of a sheathing panel used in the present disclosure.

Figure 20 is a side view of another exemplary embodiment of a siding panel used in the present disclosure.

Figure 21 is a side view of an exemplary embodiment of the panels of **Figures 19** and **20** attached to each other.

Figure 22 is a side view of another exemplary embodiment of a sheathing panel used in the present disclosure.

Figure 23 is a side view of another exemplary embodiment of a siding panel used in the present disclosure.

Figure 24 is a perspective view of another exemplary embodiment of a sheathing panel and a siding panel of the present disclosure.

Figure 25 is a side view of the sheathing panel of **Figure 24**.

Figure 26 is a side view of the siding panel of **Figure 24**.

Figure 27 is a diagram showing one method for constructing a sheathing panel of the present disclosure.

DETAILED DESCRIPTION

A more complete understanding of the components, processes and apparatuses disclosed herein can be obtained by reference to the accompanying drawings. These figures are merely schematic representations based on convenience and the ease of demonstrating the present disclosure, and are, therefore, not intended to indicate relative size and dimensions of the devices or components thereof and/or to define or limit the scope of the exemplary embodiments.

Although specific terms are used in the following description for the sake of clarity, these terms are intended to refer only to the particular structure of the embodiments selected for illustration in the drawings, and are not intended to define or limit the scope of the disclosure. In the drawings and the following description below, it is to be understood that like numeric designations refer to components of like function.

The insulating siding systems of the present disclosure comprise a combination of a sheathing panel and a siding panel. Various embodiments of sheathing panels and siding panels will be described herein. Generally, any sheathing panel can be combined with any siding panel.

In some embodiments, referring to **Figures 1-3**, the insulating siding system **10** comprises a sheathing panel **20** and a siding panel **50**. The sheathing panel **20** comprises a front surface **22** and a rear surface **24** which are spaced laterally apart from each other. The rear surface is generally planar or flat to conform to an exterior wall. The front surface **22** comprises a first slot **30** and a second slot **40**. Each slot extends laterally into the sheathing panel and includes an upwardly facing channel **32**, **42** spaced laterally from the front surface **22**. Alternatively, each slot may be considered has having an upper surface **31**, **41**, and a lower surface **35**, **45**, the upwardly facing channel **32**, **42** being located along the lower surface. The siding panel **50** comprises a front face **52**, a first downwardly facing channel **60** that extends rearwards and has a rear wall **62**, and a second downwardly facing channel **70** that extends rearwards and has a rear wall **72**. The first slot **30** is sized to receive the rear wall **62** of the first downwardly facing channel **60** and the second slot **40** is sized to receive the rear wall **72** of the second downwardly facing channel **70**. The front face **52** may generally be contoured to provide any desired profile.

In some embodiments, the first downwardly facing channel **60** extends rearwards from an upper edge **54** of the siding panel and the second downwardly facing channel **70** extends rearwards from a lower edge **56** of the siding panel.

Generally, the upwardly facing channel **32** of the first slot **30** has a height **34** that is equal to or greater than a height **64** of the first downwardly facing channel rear wall **62**. Similarly, the upwardly facing channel **42** of the second slot **40** may have a height **44** that is equal to or greater than a height **74** of the second downwardly facing channel rear wall **72**.

The siding panel **50** may further comprise a lower upwardly facing channel **80** between the lower edge **56** of the siding panel and the second downwardly facing channel **70**.

If desired, an insulating panel **90** may be included with the insulating siding system. The insulating panel **90** can be located between the siding panel **50** and the sheathing panel **20** when they are assembled. In particular, the insulating panel **90** can have an upper edge **92** and a lower edge **94**. At a minimum, the lower edge **94** of the insulating panel extends into the lower upwardly facing channel **80**. The upper edge **92** of the insulating panel can also extend into the first or upper downwardly facing channel **60**. Depending on the thickness of the insulating panel, the rear face **96** of the insulating panel **90** can abut or contact the front surface **22** of the sheathing panel **20**.

The upper downwardly facing channel **60** should be sized so that it can contain the lip **36** of the first slot **30**. If an insulating panel **90** is also used, then the first or upper downwardly facing channel **60** should be sized to contain the upper edge **92** of the insulating panel and the lip **36** of the first slot.

As seen in **Figure 4**, as siding panels are integrated or connected to the sheathing panel **120**, the second or lower downwardly facing channel **170** of a siding panel **110** will contain the first or upper downwardly facing channel **260** of the siding panel **210** below it. Put another way, the first or upper downwardly facing channel **260** of the siding panel is generally sized to fit within the second or lower downwardly facing channel **270**.

However, this should not be construed as requiring the entire upper downwardly facing channel to fit within the lower downwardly facing channel. For example, the heights of the rear walls generally can vary. Thus, the height **74** of the lower downwardly facing channel rear wall **72** and the height **64** of the

upper downwardly facing channel rear wall **62** can be the same or different. In addition, the thicknesses of the various walls of the channels may vary, as shown in later embodiments.

Again referring to **Figure 4**, the two downwardly facing channels **260**, **270** of the siding panel are not necessarily placed in two adjacent or consecutive slots. A third slot **150** may be located between the first slot **130** and the second slot **140**.

Generally, the siding panel **210** is integrated with the sheathing panel **120** by inserting the rear wall **62** of the upper downwardly facing channel **60** into the first slot **30** and inserting the rear wall **72** of the lower downwardly facing channel **70** into the second slot **40**. The siding panel **210** is then pushed downwards so that rear wall **62** enters upwardly facing channel **32** and rear wall **72** enters upwardly facing channel **42**.

The first slot and the second slot need not have the same dimensions. As mentioned above, all that is required is that the first slot be sized to receive the rear wall of the upper downwardly facing channel and the second slot be sized to receive the rear wall of the lower downwardly facing channel. This feature may be helpful, for example, in specifying locations on the sheathing panel in which the siding panel(s) can and cannot be placed. However, in specific embodiments, the first slot and the second slot have the same dimensions to promote interchangeability and allow the installer to fit the panels as needed. In addition, the spacing between adjacent slots and the size of the channels, both in height and width, can vary in the various embodiments of the sheathing panel.

Referring to **Figures 5-7**, the insulating siding system **310** may be considered as comprising a sheathing panel **320** and a siding panel **350**. The sheathing panel **320** comprises a rear surface **324** and a forward surface **326**. The forward surface **326** comprises a first row **330** and a second row **340**. The two rows extend laterally from the forward surface **326** to define a front surface **322**. The second row **340** has a ridge **342** extending upwardly at the front surface **322** between the first row **330** and the second row **340** to define a slot

345. The siding panel **350** comprises a front face **352** having an upper edge **354** and a lower edge **356**. A lower downwardly facing channel **370** extends rearwards from the lower edge **356** and has a rear wall **372**. The slot **345** on the sheathing panel is sized to receive the rear wall **372** of the lower downwardly facing channel. The ridge **342** may have a height **344** that is equal to or greater than a height **374** of the lower downwardly facing channel rear wall **372**.

The siding panel **350** may further comprise an upper downwardly facing channel **360** that extends rearwards from the upper edge **354** and has a rear wall **362** as well. Again, an insulating panel **390** could be placed between the siding panel **350** and the sheathing panel **320**. Again, the downwardly facing channels of the siding panel do not need to be placed in adjacent or consecutive slots on the sheathing panel. The sheathing panel **320** can further comprise a third row **380** that extends laterally from the forward surface **326** so that the first row **330** is between the third row **380** and the second row **340**. The third row **380** has a ridge **382** extending upwardly at the front surface away from the first row **330** to define a third row slot **385**, and the third row slot **385** is sized to receive the rear wall **362** of the upper downwardly facing channel **360**.

Each ridge **342** can extend from about one-third to about two-thirds of the distance between two adjacent rows. Put in different terms, the ridge **342** has a height **344**, and the slot **345** has a height **347**, wherein the ratio of the slot height **347** to the ridge height **344** is from about 1:2 to about 2:1.

Referring to the embodiments shown in **Figures 8-10**, the sheathing panel **420** comprises a front surface **422** and a rear surface **424** which are spaced laterally apart from each other. The front surface **422** comprises a first slot **430** and a second slot **460**. Each slot **430**, **460** comprises an upper surface **432**, **462** extending laterally into the front surface **422**, a rear surface **434**, **464** extending downwards from the upper surface and having a rear surface height **436**, **466**, a lower surface **438**, **468** extending from the rear surface laterally towards the front surface **422** for a lower surface width **440**, **470**, a forward surface **442**, **472** extending upwards from the lower surface for a forward

surface height **444**, **474**, a medial surface **446**, **476** extending from the forward surface to the front surface for a medial surface width **448**, **478**, and a slot entry height **450**, **480** between the upper surface **432**, **462** and the medial surface **446**, **476**. The siding panel **500** comprises a front face **502** and a rear face **504**, an upper channel wall **510** extending rearwards from the rear face and having an upper channel wall width **512**, an upper channel rear wall **514** extending downwards from the upper channel wall and having an upper rear wall height **516**, a bottom wall **520** extending rearwards from the rear face, a lower channel front wall **522** extending upwards from the bottom wall, a lower channel top wall **524** extending rearwards from the lower channel front wall and having a lower top wall width **526**, and a lower channel rear wall **528** extending downwards from the lower channel top wall and having a lower rear wall height **530**. The slot entry height **450** of the first slot **430** is equal to or greater than the upper rear wall height **516** and the slot entry height **480** of the second slot **460** is equal to or greater than the lower rear wall height **530**.

In some embodiments, the upper channel wall **510** extends rearwards at an upper edge **506** of the siding panel, and the bottom wall **520** extends rearwards at a lower edge **508** of the siding panel.

The first slot forward surface height **444** can be equal to or greater than the upper rear wall height **516**. Similarly, the second slot forward surface height **474** can be equal to or greater than the lower rear wall height **530**.

When an insulating panel **550** is used, the lower edge **552** of the insulating panel can extend into a channel formed by the lower channel front wall **522**, the bottom wall **520**, and the front face **502**. If desired, the upper edge **554** of the insulating panel can extend past an edge **518** of the upper channel rear wall **514**. The upper channel wall width **512** should be equal to or greater than the sum of the insulating panel upper edge width **556** and the medial surface width **448**.

Again, when the siding panels overlap, it is clear that the lower top wall width **526** is equal to or greater than the upper channel wall width **512**. The upper rear wall height **516** and the lower rear wall height **530** can be different or

the same (i.e. equal or unequal to each other). Again, the first slot **430** and second slot **460** can have the same dimensions or different dimensions. A third slot **570** can also be located between the first slot **430** and the second slot **460**.

The ratio of the slot entry height **450**, **480** to the forward surface height **444**, **474** for each slot can be independently from about 1:2 to about 2:1. Alternatively, the forward surface height **444**, **474** can be about one-third to about two-thirds of the rear surface height **436**, **466**.

Referring to embodiments shown in **Figures 11-13**, the sheathing panel **620** comprises a front surface **622** and a rear surface **624**. The front surface **622** comprises a first slot **630** and a second slot **640**. Each slot **630**, **640** extends rearwards into the sheathing panel and includes an upwardly facing channel **650**, **660** spaced apart from the front surface. The siding panel **670** comprises a front face **672**, a rear face **674**, an upper connecting wall **680** extending rearwards from an upper portion **676** of the rear face, an upper rear wall **682** extending downwards from the upper connecting wall, and a lower rear wall **692** connected to a lower portion **678** of the rear face by a lower connecting wall **690** and extending downwards from the lower connecting wall. The first slot **630** is sized to receive the upper rear wall **682** and the second slot **640** is sized to receive the lower rear wall **692**. The upper connecting wall **680** can extend rearward from the upper edge **673** of the siding panel and the lower connecting wall **690** can extend rearward from the lower edge **675** of the siding panel if desired.

The height **652** of the upwardly facing channel **650** of the first slot **630** is equal to or greater than the height **684** of the upper rear wall **682**. Similarly, the height **662** of the upwardly facing channel **680** of the second slot **640** is equal to or greater than the height **694** of the lower rear wall **692**.

The lower connecting wall **690** can be shaped to provide a lower upwardly facing channel **695** between the front face **672** and the lower rear wall **692**. An insulating panel **700** can be inserted there. A portion **697** of the lower connecting wall **690** adjacent to the lower rear wall **692** can also have a width **696** that is equal to or greater than a width **686** of the upper connecting wall

680. The upper connecting wall has a width **686** that is greater than the sum of the upper edge width **702** of the insulating panel and the lip width **634** of the first slot **630**.

Referring to embodiments shown in **Figures 11**, **13**, and **14**, the sheathing panel **620** comprises a front surface **622** and a rear surface **624**. The front surface **622** comprises a first slot **630** and a second slot **640**. Each slot extends rearwards into the sheathing panel and includes an upwardly facing channel **650**, **660** spaced from the front surface, a lip **632**, **642** along the front surface having a lip height **636**, **646**, and a slot entry height **638**, **648**. The siding panel **820** comprises a front face **822** and a rear face **824**, an upper downwardly facing channel **830** extending rearwards from an upper portion **826** of the rear face, a lower upwardly facing channel **840** extending rearwards from a lower portion **828** of the rear face, and a lower downwardly facing channel **850** extending rearwards from the lower upwardly facing channel **840**. The first slot entry height **638** is sized to allow the first slot lip **632** to enter the upper downwardly facing channel **830** and the second slot entry height **648** is sized to allow the second slot lip **642** to enter the lower downwardly facing channel **850**. The upper downwardly facing channel **830** may extend rearward from the upper edge **823** of the siding panel and the lower upwardly facing channel **840** may extend rearward from the lower edge **825** of the siding panel.

Figure 15 shows another embodiment of a siding panel. The siding panel **900** has a front face **902** and a rear face **904**. An upper channel wall **910** extends rearward from an upper portion **906** of the rear face and an upper channel rear wall **912** extends downwards from the upper channel wall. A lower channel wall **920** extends rearward from a lower portion **908** of the rear face and a lower channel rear wall **922** extends downwards from the lower channel wall. Here, the siding panel has a veneer panel **930** attached to the front face. The veneer panel **930** can extend below the lower edge **916** of the siding panel, but generally does not extend above the upper edge **918** of the siding panel. **Figure 16** shows a plurality of such siding panels **950**, **960**, **970**, **980** when they are attached to the sheathing panel **990**. Note that the cross-section of the

channels **995** is different compared to that of **Figure 11**. Instead of being a straight line, the bottom of the channel is rounded. Also note that the thicknesses of the walls **910**, **912**, **920**, **922** are different compared to those of, for example, **Figure 9**. Such differences are contemplated as being within the scope of the present disclosure.

Figure 17 is a front view of another exemplary embodiment of a sheathing panel **1000**. A plurality of slots **1010** and rows **1020** can be seen in this view. Holes **130** are shown here at intervals to serve as attachment sites for the sheathing panel. Nails, staples, and other similar fasteners may be used at the attachment site to connect the sheet to the exterior wall. Alternatively, the sheathing panel may be adhered to the exterior wall with an adhesive material spread on the wall. Grooves **1040** are also located in the sheathing panel at intervals to manage the flow of water that gets into the sheathing panel. The grooves are shown as being cut along the front surface of the sheathing panel, though they could be placed along the rear surface of the sheathing panel as well. Along the right and left edges **1002**, **1004** of the sheathing panel are complementary connecting members **1050** for connecting adjacent sheathing panels. **Figure 18** shows two sheathing panels **1100**, **1200** being connected. Here, a tongue and groove relationship is shown.

Other exemplary embodiments of various sheathing panels and siding panels are also within the scope of this disclosure. Referring to embodiments shown in **Figures 19-21**, the sheathing panel **1320** comprises a front surface **1322** and a rear surface **1324**. The front surface **1322** comprises a slot **1330**. The slot **1330** has a slot entry height **1335** and extends rearwards into the sheathing panel **1320** to form a cavity **1340**. The height **1345** of the cavity is greater than the slot entry height **1335**. The cavity **1340** may also be described as including a downwardly extending channel **1342** located along an upper surface **1332** of the slot **1330** and an upwardly extending channel **1344** located along a lower surface **1334** of the slot.

The siding panel **1350** comprises a front face **1352** and a rear face **1354**. A connecting wall **1360** extends from the rear face **1354** to a rear wall **1362**

extending transversely from the connecting wall. The rear wall has a height **1365** that is greater than the slot entry height **1335**. The connecting wall **1360** may have a width **1368** that is equal to or greater than the width **1358** of the upper edge **1356** of the siding panel **1330**.

As shown here, the rear wall **1362** of the siding panel **1330** is sized to substantially fill the cavity **1340**. In some embodiments, the connecting wall **1360** and the rear wall **1362** of the siding panel are sized to substantially fill the slot **1330**. The rear wall **1362** may extend substantially perpendicularly from the connecting wall. The rear wall **1362** may comprise an upper portion **1364** extending transversely above the connecting wall **1360** and a lower portion **1366** extending transversely below the connecting wall.

The siding panel **1330** may also comprise an upper connecting wall **1370** extending from the rear face **1354**, an upper rear wall **1372** extending downwards from the upper connecting wall, an lower connecting wall **1380** extending from the rear face, and a lower rear wall **1382** extending upwards from the lower connecting wall. As seen in **Figure 21**, the upper connecting wall **1370**, upper rear wall **1372**, lower connecting wall **1380**, and lower rear wall **1382** can be used to further secure the siding panel by fitting into parts of two other slots **1390**, **1395**. Put another way, these additional connecting walls and rear walls are sized to collectively fill the cavity of one slot.

Referring to **Figures 22** and **23**, the siding panel **1450** may alternatively be described as comprising a front face **1452** and a rear face **1454**. The rear face comprises at least one receptacle **1460**, including at least two receptacles. The receptacle has a receptacle entry height **1465** and extends into the siding panel to form a cavity **1470**. The cavity has a cavity height **1475** which is greater than the receptacle entry height **1465**. Though not shown here, if desired, a veneer panel, similar to that shown in **Figure 15**, may be attached to the front face **1452**. The sheathing panel **1420** may alternatively be described as comprising a front face **1422** and a rear face **1424**. A connecting wall **1430** extends from the front face to a front wall **1432** extending transversely from the connecting wall. The height **1435** of the front wall **1432** is greater than the

receptacle entry height **1465**. The cavity **1470** may also be described as including a downwardly extending channel **1472** located along an upper surface **1462** of the receptacle **1460** and an upwardly extending channel **1474** located along a lower surface **1464** of the receptacle.

The front wall **1432** of the sheathing panel is sized to substantially fill the cavity **1470**. In other embodiments, the connecting wall **1430** and the front wall **1432** of the sheathing panel are sized to substantially fill the receptacle **1460**. The front wall **1432** may extend substantially perpendicularly from the connecting wall. The front wall **1432** may also comprise an upper portion **1434** extending transversely above the connecting wall **1430** and a lower portion **1436** extending transversely below the connecting wall.

The siding panel **1450** also has an upper edge **1456** and a lower edge **1458**. In some embodiments, the lower edge **1458** includes a recess **1480** having a width **1482** that is equal to or greater than the width **1457** of the upper edge **1456**.

In these insulated siding systems shown in **Figures 19-23**, the siding panel is integrated with the sheathing panel by sliding the siding panel from the side into the sheathing panel. Unlike the siding panels shown in **Figures 1-18**, these siding panels cannot be inserted into the sheathing panel from the front. However, if desired, the siding panels of **Figures 1-18** could be used with the sheathing panel of **Figures 19** and **22**.

Figures 24-26 show yet another exemplary embodiment of an insulated siding system **1510**. Again, the sheathing panel **1520** has a front face **1522** and a rear face **1524**. Here, rather than continuous slots running the length of the sheathing panel along the front face, the front face **1522** comprises a plurality of sockets **1530**. The siding panel **1550** comprises a front face **1552** and a rear face **1552**. Instead of channels, a plurality of plugs **1560** extend from the rear face. At least two plugs are generally required to prevent the siding panel from rotating; here, the siding panel is depicted as having six plugs. Again, the lower edge **1556** of the siding panel **1550** may include a recess **1570** having a width **1572** that is equal to or greater than the width **1555** of the upper edge **1554** of

the siding panel. The siding panel is attached to the sheathing panel by pushing the plugs **1560** of the siding panel into the sockets **1530** on the front of the sheathing panel. Of course, not all sockets must receive a plug. As depicted in **Figure 24**, the sheathing panel **1520** and siding panel **1550** are joined together by a ball-and-socket arrangement. Of course, the roles may be reversed if desired, so that the rear face of the siding panel comprises a plurality of sockets and the front face of the sheathing panel comprises a plurality of plugs. The plug can be shaped, if desired, with a tapered surface that makes inserting the plug into the socket easy, but removing the plug difficult, such as with a snap-fit mechanism.

Interestingly, in this embodiment, the cross-section of the sheathing panel **1520** shown in **Figure 25** is very similar to the sheathing panel **1320** of **Figure 19** and the cross-section of the siding panel **1550** shown in **Figure 26** is very similar to the siding panel **1350** of **Figure 20**. For example, the socket **1530** could be considered a cavity **1340** and the plug **1560** could be considered a combination of the connecting wall **1360** and rear wall **1362**. However, unlike the combination of **Figures 19** and **20**, the siding panel of **Figure 25** must be inserted from the front, not the side.

If desired, the insulating panel (reference numeral **90** in **Figure 2**) can be attached to the siding panel (reference numeral **50** in **Figure 2**) in a variety of ways including, but not limited to, adhesive, chemical bonding, interlocking complementary surfaces, and/or fasteners. Typically, however, adhesives are used. The adhesive may be used over the entire surface of the siding panel or in discrete locations instead. Suitable adhesives may include, but are not limited to, UV curable adhesives and hot melt adhesives, such as polyamines and urethanes, glue, thermosetting or thermoplastic adhesives, pressure sensitive adhesives or solvent-based adhesives.

The sheathing panel and/or the insulating panel, when present, may be shape molded. Such molding operations will generally impart the desired contours and/or design to the sheathing panel. Typically, pellets of a polymeric precursor material are placed in a suitably configured die mold, then reacted in

the presence of water and heat to expand during the reaction process. The polymeric precursor material expands and presses against the die surface to form compressed elongated closed cells that form a characteristic tough smooth skin. The shape molded process produces a panel that is essentially straight, free of camber, and/or self-supporting. The various grooves, slots, and channels of the sheathing panel may be obtained by any combination of computer numerical control (CNC) cutting, milling, wire-cutting, or during the shape molding process as well.

The sheathing panel and/or insulating panel is generally made from a cellular foam product, i.e. a plastic or polymeric material with numerous cells of trapped air distributed throughout its mass. For example, expanded polystyrene (EPS) is a cellular foam plastic made from beads of polystyrene beads that are first pre-expanded and allowed to rest for a suitable interval, then molded in closed steam-heated shaped molds to produce closed-cell molded foams. The size and density of the closed cells can be controlled and may vary depending upon the application. Suitable materials for the sheathing panel can include expandable polystyrene (XPS), expanded polystyrene (EPS), polyurethane, polyisocyanurate, polyethylene, polypropylene, or combinations thereof.

The sheathing panel and/or insulating panel can be of any density desired, or be tuned to provide different densities depending on the location. For example, it may be desirable to have higher densities where the sheathing panel is thin, and lower densities where the panel is thicker. Similarly, it may be desirable to have higher densities near the edges of the insulating panel, and lower densities near the center of the insulating panel (where it is covered by the siding panel).

Expanded or expandable polystyrene are particularly desirable materials for the sheathing panel and/or insulating panel because they provide a solid feel; improve the R-value; deaden noise transmitted through the siding; and channel heat and water away into the external environment, protecting the exterior wall behind the sheathing panel and reducing mold growth.

The various slots, grooves, and channels could also be made out of different materials, such as plastics or metals, instead of being milled or wire-cut from a foamed sheet. For example, the rows, ridges, and lips could be inserted into a flat foamed sheet and fastened with adhesive, tape, screws, or other mechanical fasteners. Alternatively, the rows, ridges, and lips may be inserted into the foamed sheet and fastened mechanically during the shape molding process. The plastic or metal piece could be inserted and the foam would be expanded and fused around it. No secondary fasteners or additional fastening step would be required. **Figure 27** illustrates this method of making the slots in the sheathing panel. Here, a foam sheet **1600** is partially foamed to include holes **1610** into which plastic or metal pieces **1620** are inserted. The foam sheet is then expanded around the piece **1620** to form the final sheathing panel **1630** and fix the piece **1620** in place. For example, the piece **1620** has a lip **1625** which is filled with foam in the sheathing panel **1630**.

The siding panel can generally be formed from any suitable polymeric, metallic, cementious or composite material. Exemplary materials include vinyl, polypropylene, fiber-cement material, polyolefins, polyvinyls, polycarbonates, polyacetals, polysulfones, polyesters, polyamides, multilayer films, polyethylene (HDPE), polypropylene, low density polyethylene (LDPE), CPVC ABS, ethyl-vinyl acetate, various extruded ionomeric films, polyethylene based films, or combinations thereof. Other siding materials suitable for the siding layer include wood, aluminum, and steel.

Generally, siding must be thick to resist sagging and retain the desired shape. However, the insulating panel allows the siding panel to be thinner than otherwise necessary. The siding panel only has to provide weatherability to the siding panel assembly. Whereas traditional vinyl veneer sidings have a minimum material thickness of 0.040 inches, the siding panels of the present disclosure may have a thickness from 0.020 to 0.036 inches.

The downwardly facing channels or connectors can be made integral with the front face of the siding panel, or as separate pieces attached to the front face.

In embodiments such as that shown in **Figure 15**, the siding panel is generally made from a cellular foam product, as described above with respect to the insulating panel. The veneer panel can be made from suitable materials as described with respect to the siding panel.

The sheathing panel can have a length of between 12 and 240 inches and will typically have lengths of 48 to 96 inches, as desired or required. The sheathing panel's height may be between 12 and 240 inches, and the sheathing panel may have a width (from rear surface to front surface) of 0.1875 to 36 inches. The siding panel or veneer panel can have a total thickness of from about 0.2 to about 4 inches.

The sheathing panels and siding panels are used in suitable combinations as insulating siding systems of the present disclosure to be affixed to or attached to exterior walls of a building. The foam sheathing with integral receivers/connectors allow easy, straight alignment and fastening of the siding panels without the use of fasteners that must go through the siding panel. The combination of the slots / channels of the sheathing panel with the siding panels above and below generally restrict the movement of a siding panel in any direction. Installation and alignment of the siding panels is made easier. Because the siding panels present a solid, unpenetrated façade, there are fewer places through which moisture can penetrate into the exterior wall. Defects related to the expansion of the siding panels is also minimized.

While particular embodiments have been described, alternatives, modifications, variations, improvements, and substantial equivalents that are or may be presently unforeseen may arise to applicants or others skilled in the art. Accordingly, the appended claims as filed and as they may be amended are intended to embrace all such alternatives, modifications variations, improvements, and substantial equivalents.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An insulating siding system comprising a foam sheathing panel, a foam insulating panel, and a siding panel;

the sheathing panel comprising a front surface and a rear surface, the front surface and rear surface being spaced laterally apart from each other, the front surface comprising a first slot, the first slot extending laterally into the sheathing panel and including an upwardly facing channel spaced laterally from the front surface; and

the siding panel comprising a front face and a first downwardly facing channel that extends rearwards and has a rear wall;

wherein the first slot is sized to receive the rear wall of the first downwardly facing channel; and

wherein the insulating panel is sized and shaped to fit between the rear face of the rear wall of the first downwardly facing channel.

2. The insulating siding system of claim 1, wherein the upwardly facing channel of the first slot has a height that is equal to or greater than a height of the first downwardly facing channel rear wall.

3. The insulating siding system of claim 1, wherein the first downwardly facing channel extends rearwards from an upper edge of the siding panel.

4. The insulating siding system of claim 1, wherein the siding panel further comprises a second downwardly facing channel extending rearwards from a lower edge of the siding panel

5. The insulating siding system of claim 4, wherein the siding panel further comprises a lower upwardly facing channel located between the lower edge of the siding panel and the second downwardly facing channel.

6. The insulating siding system of claim 5, wherein the insulating panel has an upper edge and a lower edge, the upper edge of the insulating panel extending into the first downwardly facing channel and the lower edge of the insulating panel extending into the lower upwardly facing channel.

7. The insulating siding system of claim 6, wherein the first downwardly facing channel is sized so as to contain the upper edge of the insulating panel and a lip of the first slot.

8. The insulating siding system of claim 4, wherein the second downwardly facing channel comprises a rear wall which is sized so as to be received by the first slot of the sheathing panel.

9. An insulating siding system comprising a foam sheathing panel, a foam insulating panel, and a siding panel;

the sheathing panel comprising a front surface and a rear surface, the front surface and rear surface being spaced laterally apart from each other, the front surface comprising a first slot and a second slot,

each slot comprising an upper surface extending laterally into the front surface, a rear surface extending downwards from the upper surface, a lower surface extending from the rear surface laterally towards the front surface for a lower surface width, a forward surface extending upwards from the lower surface for a forward surface height, a medial surface extending from the forward surface to the front surface for a medial surface width, and a slot entry height between the upper surface and the medial surface; and

the siding panel comprising a front face and a rear face, an upper channel wall extending rearwards from the rear face and having an upper

channel wall width, an upper channel rear wall extending downwards from the upper channel wall and having an upper rear wall height, a bottom wall extending rearwards from the rear face, a lower channel front wall extending upwards from the bottom wall, a lower channel top wall extending rearwards from the lower channel front wall and having a lower top wall width, and a lower channel rear wall extending downwards from the lower channel top wall and having a lower rear wall height;

wherein the slot entry height of the first slot is equal to or greater than the upper rear wall height and the slot entry height of the second slot is equal to or greater than the lower rear wall height; and

wherein the insulating panel is sized and shaped to fit between the rear face of the siding panel and the front surface of the sheathing panel.

10. The insulating siding system of claim 9, wherein the insulating panel has an upper edge and a lower edge, the upper edge of the insulating panel extending past an edge of the upper channel rear wall and the lower edge of the insulating panel extending into a channel formed by the lower channel front wall, the bottom wall, and the front face.

11. The insulating siding system of claim 9, wherein the insulating panel has an upper edge width, and the upper channel wall width is equal to or greater than the sum of the insulating panel upper edge width and the medial surface width.

12. The insulating siding system of claim 9, wherein the lower top wall width is equal to or greater than the upper channel wall width.

13. The insulating siding system of claim 9, wherein the ratio of the slot entry height to the forward surface height for each slot is independently from about 1:2 to about 2:1.

14. The insulating siding system of claim 9, wherein the upper channel wall extends rearwards at an upper edge of the siding panel, and the bottom wall extends rearwards at a lower edge of the siding panel.

15. An insulating siding system comprising a foam sheathing panel, a foam insulating panel, and a siding panel;

the sheathing panel comprising a front surface and a rear surface, the front surface and rear surface being spaced laterally apart from each other, the front surface comprising a first slot, the first slot extending laterally into the sheathing panel and including an upwardly facing channel spaced laterally from the front surface; and

the siding panel comprising a front face, a rear face, and a first downwardly facing channel that extends rearwards, wherein the channel is defined by the rear face, a planar upper channel wall, and a rear wall;

wherein the first slot is sized to receive the rear wall of the first downwardly facing channel; and

wherein the insulating panel extends up to the upper channel wall and is sized and shaped to fit between the rear face of the siding panel, the rear wall, and the front surface of the sheathing panel when the first slot receives the rear wall of the first downwardly facing channel.

16. The insulating siding system of claim 15, wherein the upwardly facing channel of the first slot has a height that is equal to or greater than a height of the first downwardly facing channel rear wall.

17. The insulating siding system of claim 15, wherein the first downwardly facing channel extends rearwards from an upper edge of the siding panel.

18. The insulating siding system of claim 15, wherein the siding panel further comprises a second downwardly facing channel extending rearwards from a lower edge of the siding panel.

19. The insulating siding system of claim 18, wherein the siding panel further comprises a lower upwardly facing channel located between the lower edge of the siding panel and the second downwardly facing channel.

20. The insulating siding system of claim 19, wherein the insulating panel has an upper edge and a lower edge, the upper edge of the insulating panel extending into the first downwardly facing channel and the lower edge of the insulating panel extending into the lower upwardly facing channel.

21. The insulating siding system of claim 20, wherein the first downwardly facing channel is sized so as to contain the upper edge of the insulating panel and a lip of the first slot.

22. The insulating siding system of claim 18, wherein the second downwardly facing channel comprises a rear wall which is sized so as to be received by the first slot of the sheathing panel.

23. An insulating siding system comprising a foam sheathing panel, a foam insulating panel, and a siding panel;

the sheathing panel comprising a front surface and a rear surface, the front surface and rear surface being spaced laterally apart from each other, the front surface comprising a first slot and a second slot,

each slot comprising an upper surface extending laterally into the front surface, a rear surface extending downwards from the upper surface, a lower surface extending from the rear surface laterally towards the front surface for a lower surface width, a forward surface extending upwards from the lower surface for a forward surface height, a medial surface extending from the forward surface to the front surface for a medial surface width, and a slot entry height between the upper surface and the medial surface; and

the siding panel comprising a front face and a rear face, an upper channel wall extending rearwards from the rear face and having an upper channel wall width, an upper channel rear wall extending downwards from the upper channel wall and having an upper rear wall height, a bottom wall extending rearwards from the rear face, a lower channel front wall extending upwards from the bottom wall, a lower channel top wall extending rearwards from the lower channel front wall and having a lower top wall width, and a lower channel rear wall extending downwards from the lower channel top wall and having a lower rear wall height;

wherein the slot entry height of the first slot is equal to or greater than the upper rear wall height and the slot entry height of the second slot is equal to or greater than the lower rear wall height;

wherein the insulating panel is sized and shaped to fit between the rear face of the siding panel and the front surface of the sheathing panel; and

wherein the insulating panel has an upper edge and a lower edge, the upper edge of the insulating panel extending upwardly past an edge of the upper channel rear wall and the lower edge of the insulating panel extending into a channel formed by the lower channel front wall, the bottom wall, and the front face.

24. The insulating siding system of claim 23, wherein the insulating panel has an upper edge width, and the upper channel wall width is equal to or greater than the sum of the insulating panel upper edge width and the medial surface width.

25. The insulating siding system of claim 23, wherein the lower top wall width is equal to or greater than the upper channel wall width.

26. The insulating siding system of claim 23, wherein the ratio of the slot entry height to the forward surface height for each slot is independently from about 1:2 to about 2:1.

27. The insulating siding system of claim 23, wherein the upper channel wall extends rearwards at an upper edge of the siding panel, and the bottom wall extends rearwards at a lower edge of the siding panel.

28. An insulating siding system comprising a sheathing panel, an insulating panel, and a siding panel;

the sheathing panel comprising a front surface and a rear surface, the front surface and rear surface being spaced laterally apart from each other, the front surface comprising a first slot, the first slot extending laterally into the sheathing panel and including an upwardly facing channel spaced laterally from the front surface; and

the siding panel comprising a front face, a rear face, a first downwardly facing channel that extends rearwards from an upper edge of the siding panel, wherein the channel is defined by the rear face, a planar upper channel wall, and a rear wall, a second downwardly facing channel extending rearwards from a lower edge of the siding panel, and a lower upwardly facing channel located between the lower edge of the siding panel and the second downwardly facing channel;

wherein the first slot is sized to receive the rear wall of the first downwardly facing channel;

wherein the insulating panel extends up to the upper channel wall and is sized and shaped to fit between the rear face of the siding panel, the rear wall, and the front surface of the sheathing panel when the first slot receives the rear wall of the first downwardly facing channel;

wherein the insulating panel has an upper edge and a lower edge, the upper edge of the insulating panel extending into the first downwardly facing channel and the lower edge of the insulating panel extending into the lower upwardly facing channel; and

wherein the first downwardly facing channel is sized so as to contain the upper edge of the insulating panel and a lip of the first slot.

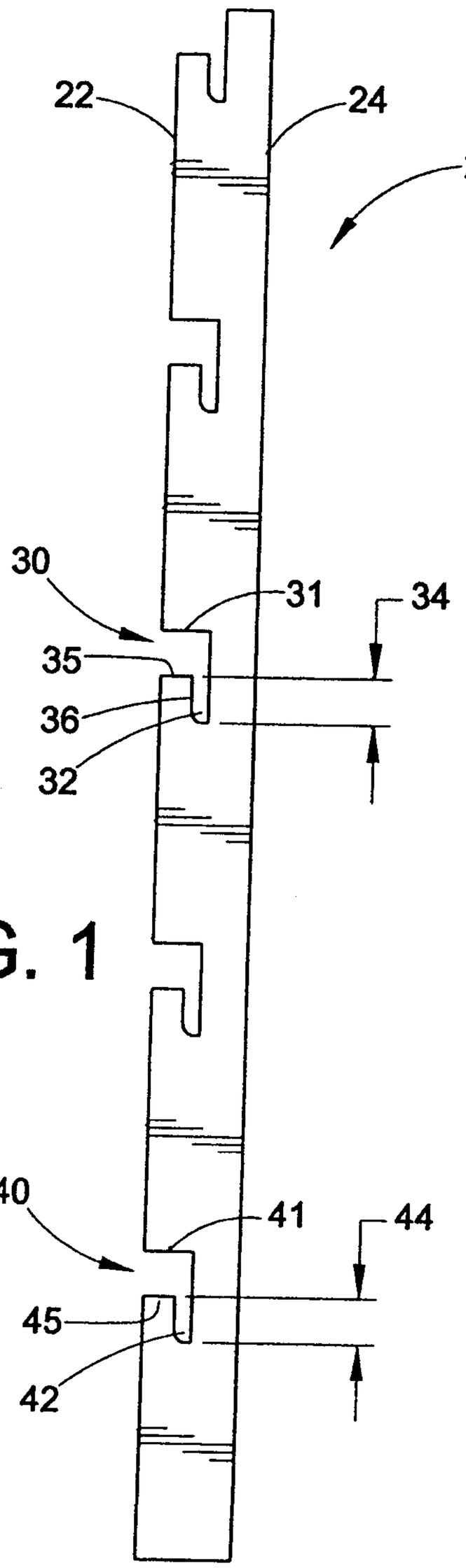

22
24
20
30
31
34
35
36
32
40
41
44
45
42

FIG. 1

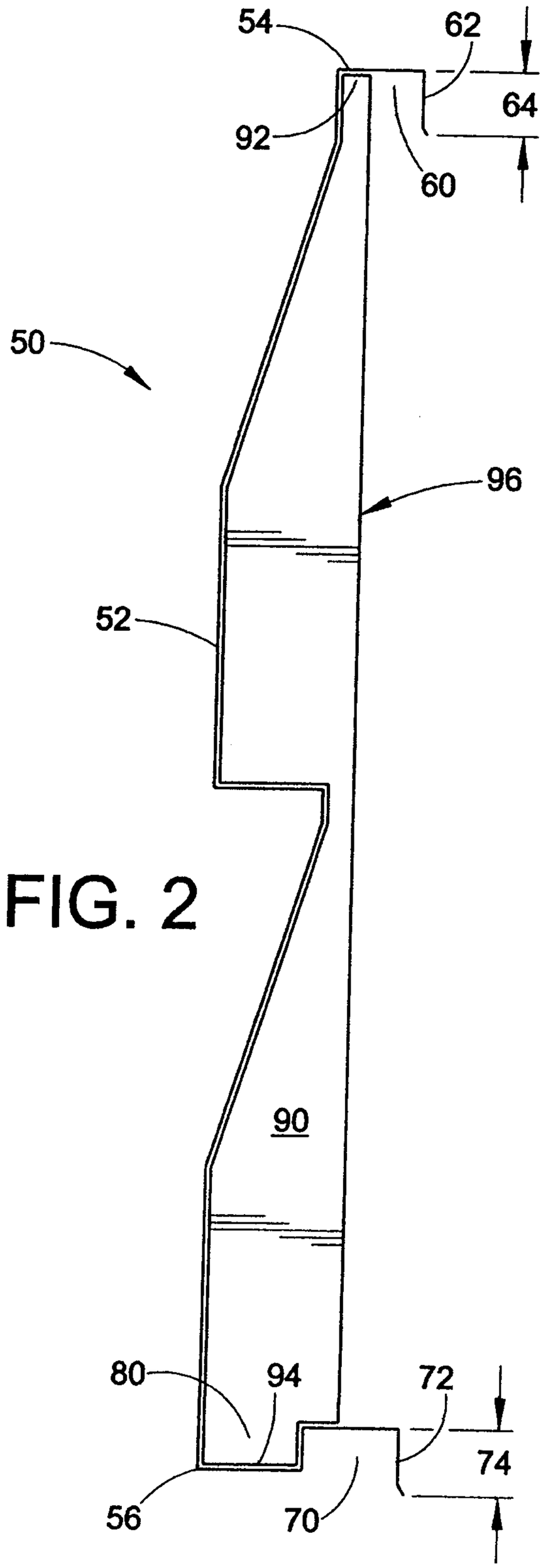

54
62
64
92
60
50
96
52
90
80
94
72
74
56
70

FIG. 2

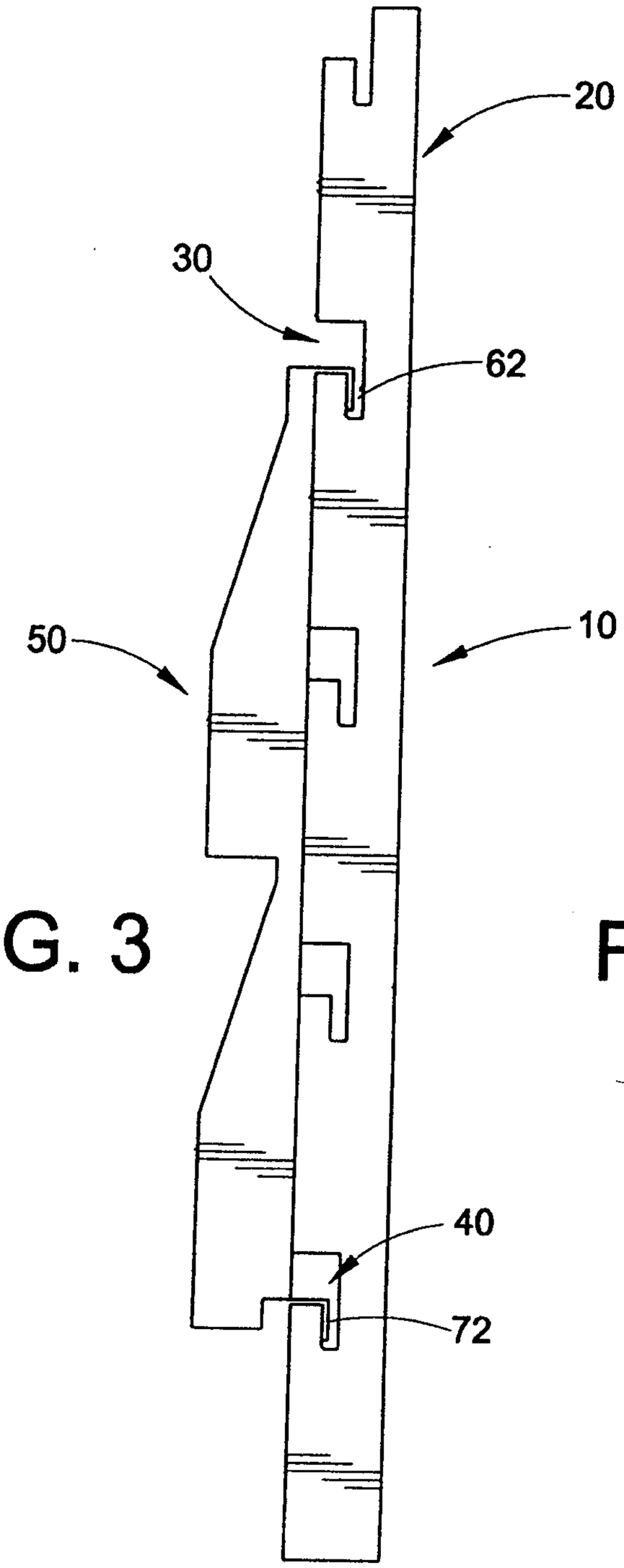


FIG. 3

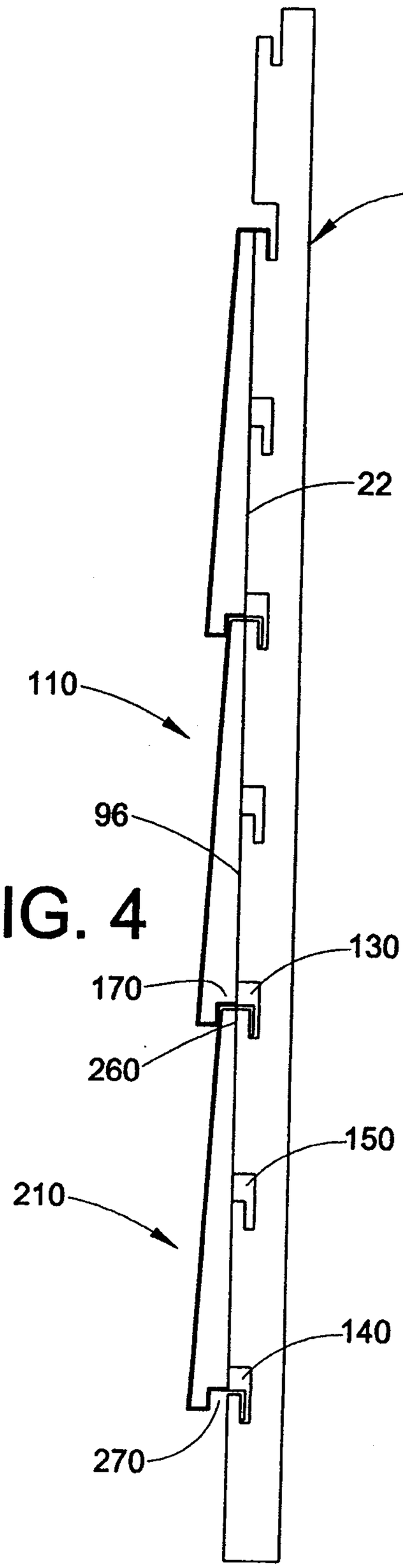


FIG. 4

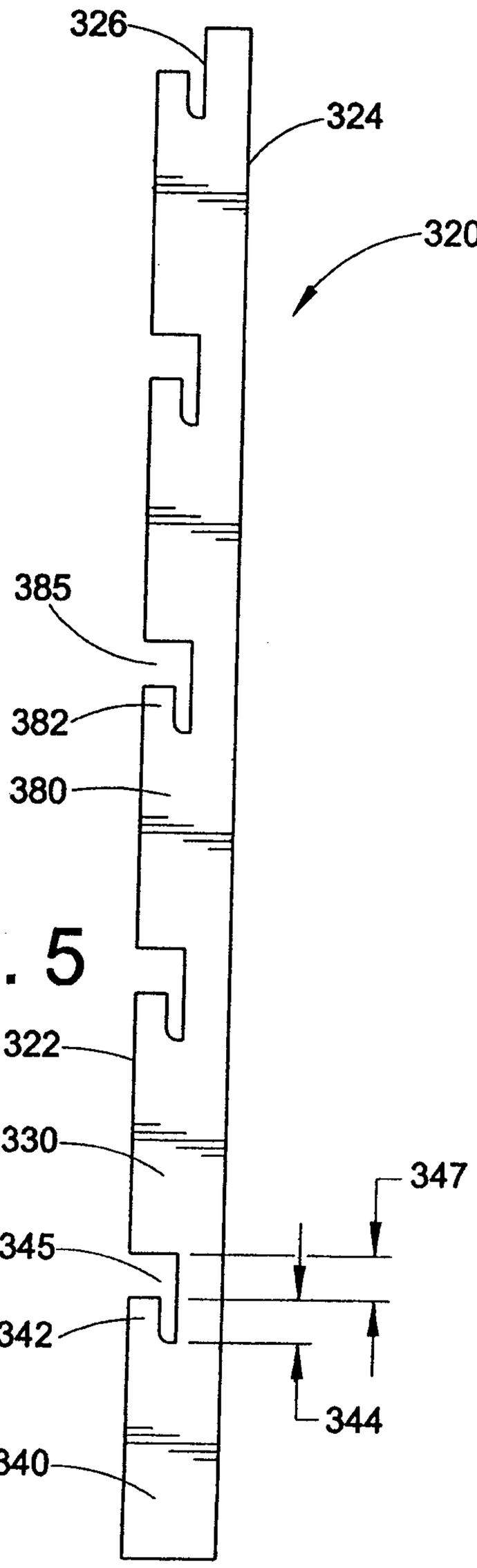

326
324
320
385
382
380
322
330
347
345
342
344
340

FIG. 5

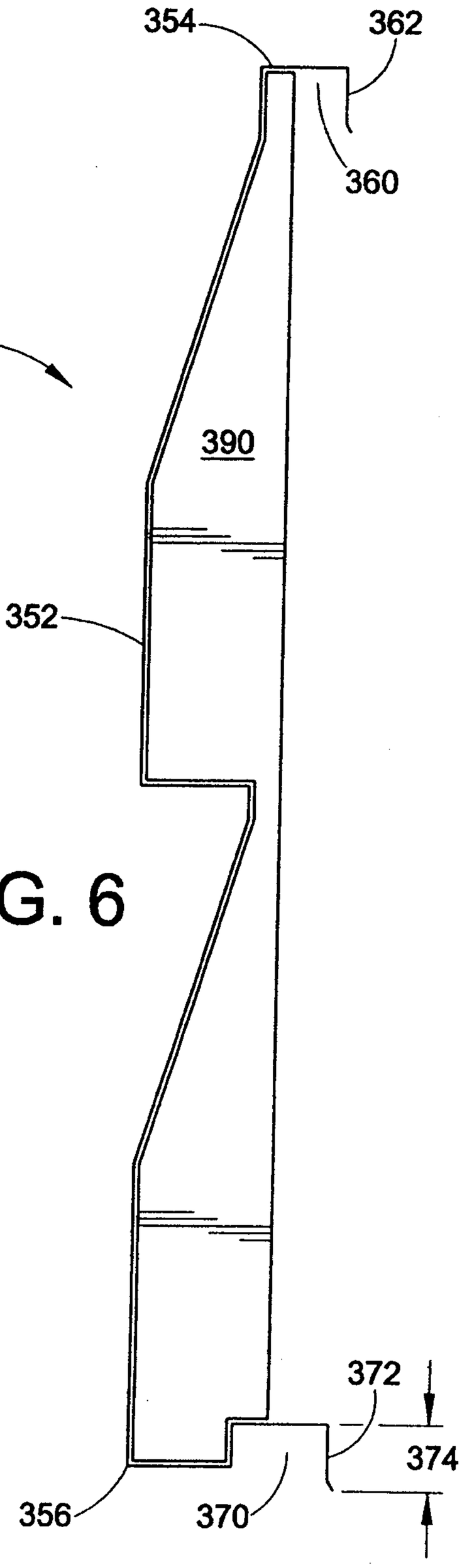

354
362
360
350
390
352
372
374
356
370

FIG. 6

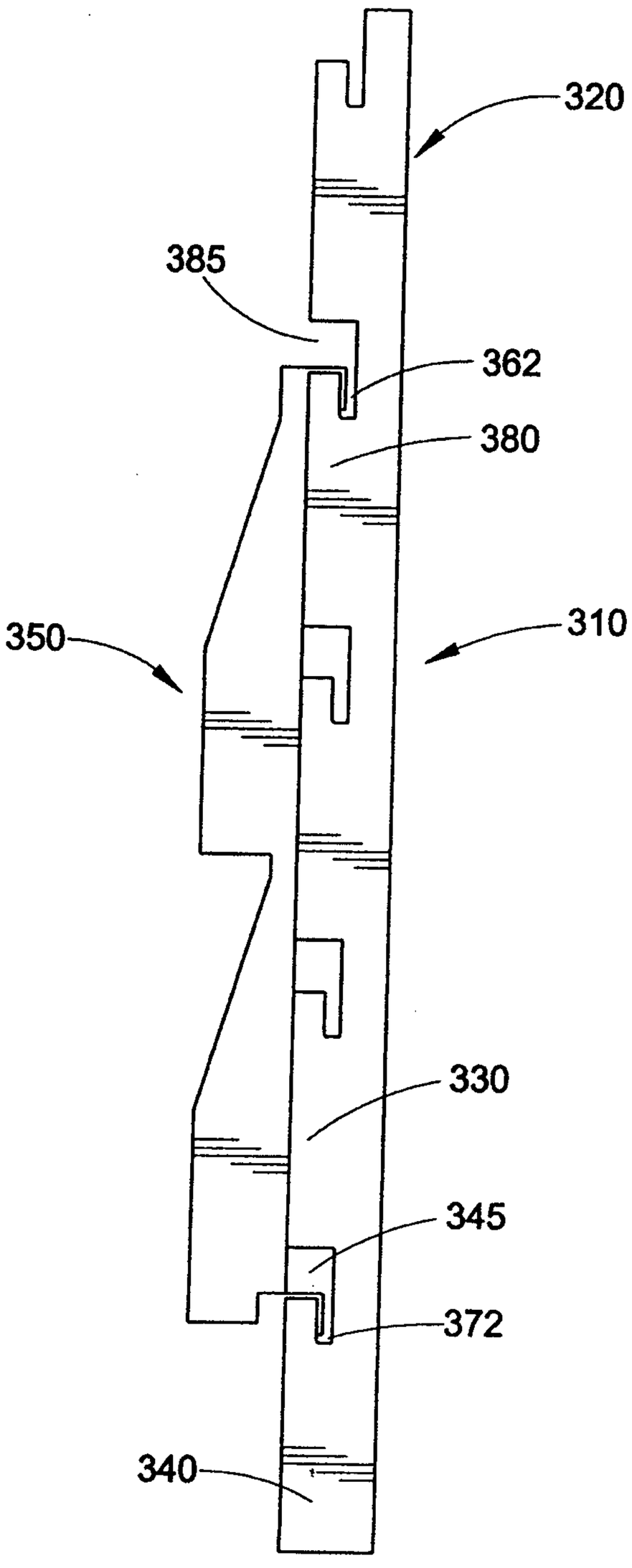

320
385
362
380
350
310
330
345
372
340

FIG. 7

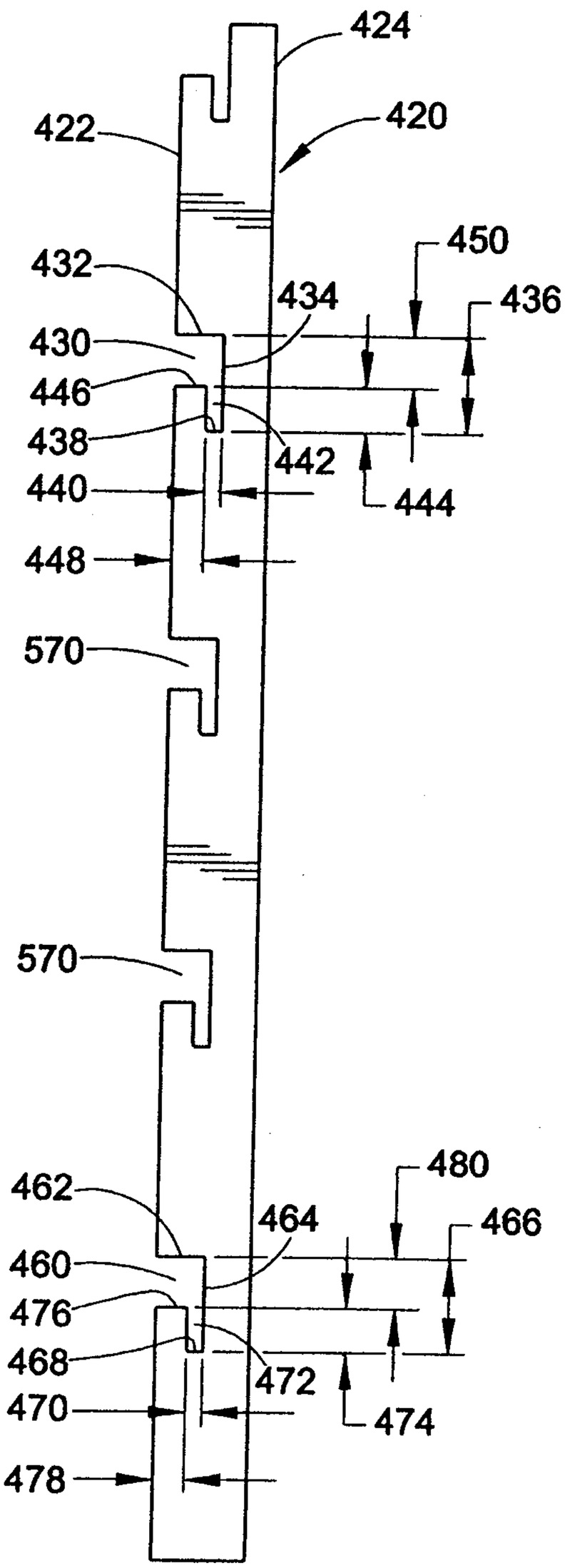

424
422
420
432
450
434
436
430
446
438
442
440
444
448
570
570
480
462
464
466
460
476
468
472
470
474
478

FIG. 8

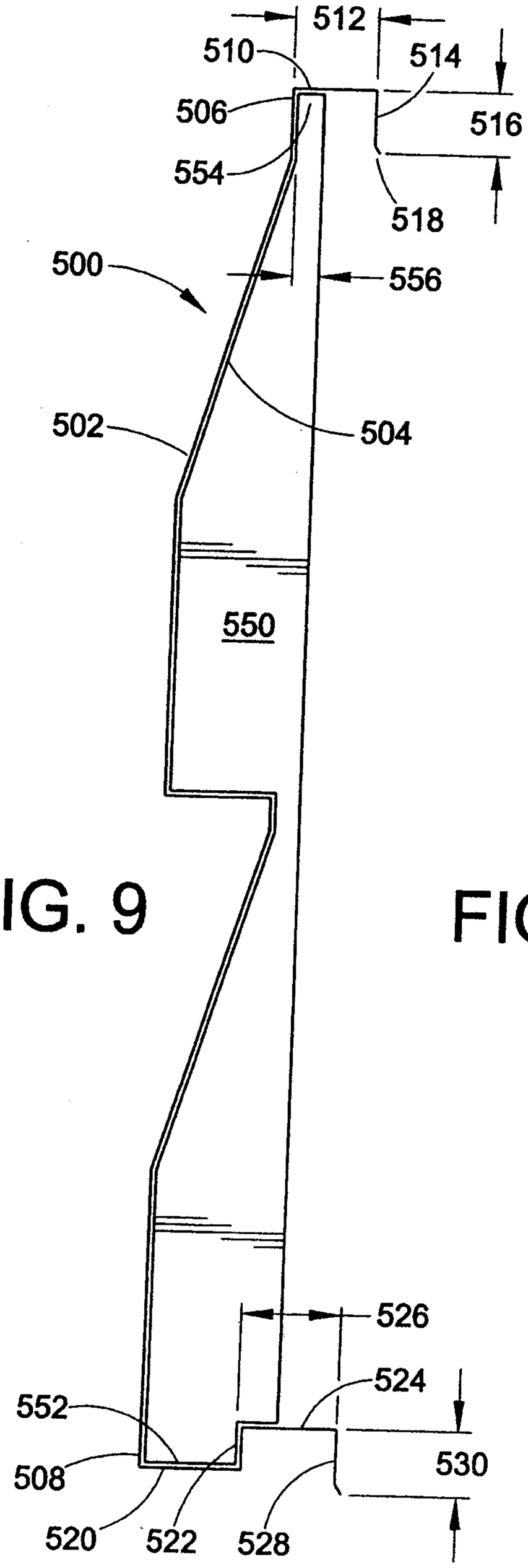

512
510
514
506
516
554
518
500
556
502
504
550
526
552
524
530
508
520
522
528

FIG. 9

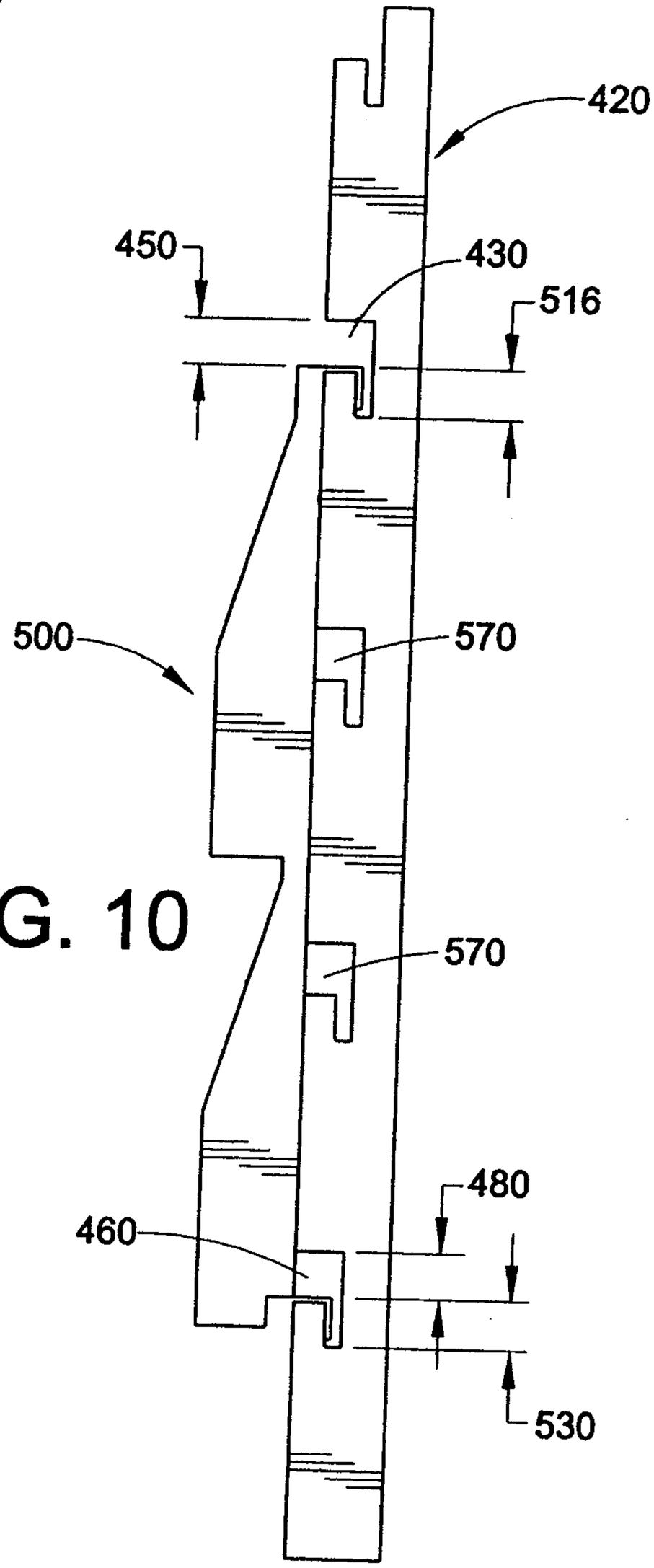

420
450
430
516
500
570
570
460
480
530

FIG. 10

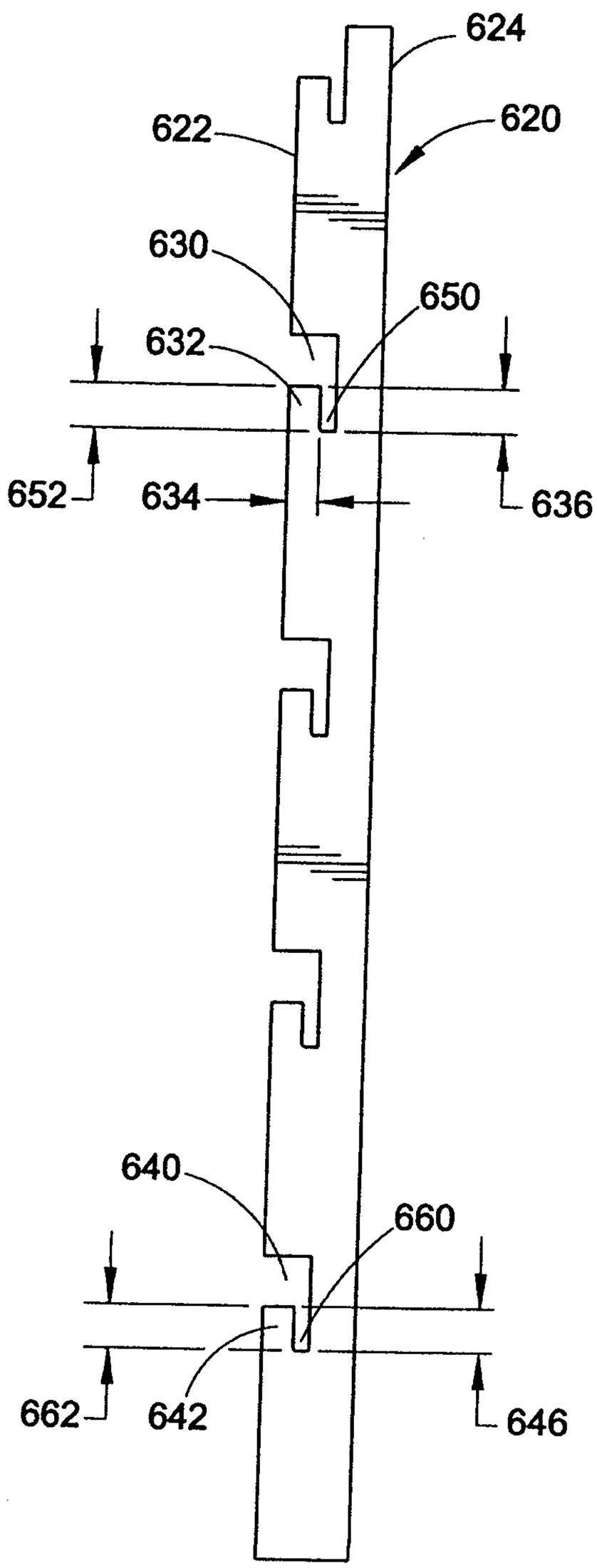

624
622
620
630
650
632
652
634
636
640
660
662
642
646

FIG. 11

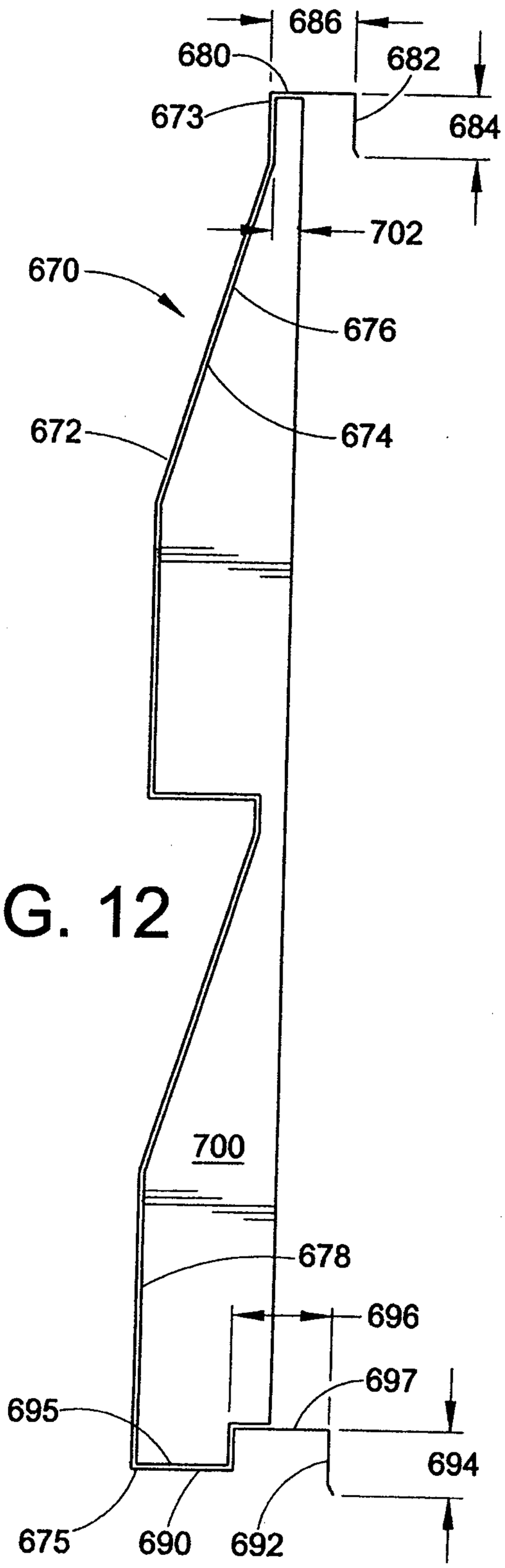

686
680
682
673
684
702
670
676
672
674
700
678
696
697
695
694
675
690
692

FIG. 12

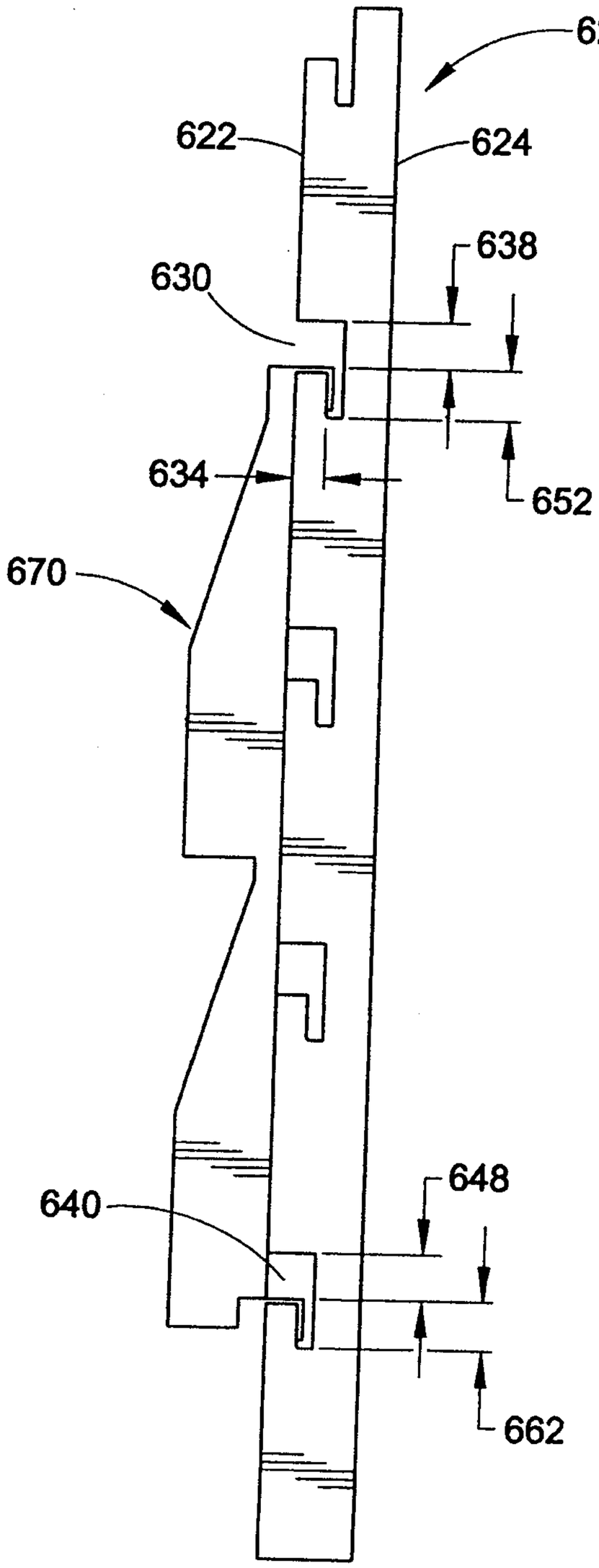

620
622
624
638
630
634
652
670
648
640
662

FIG. 13

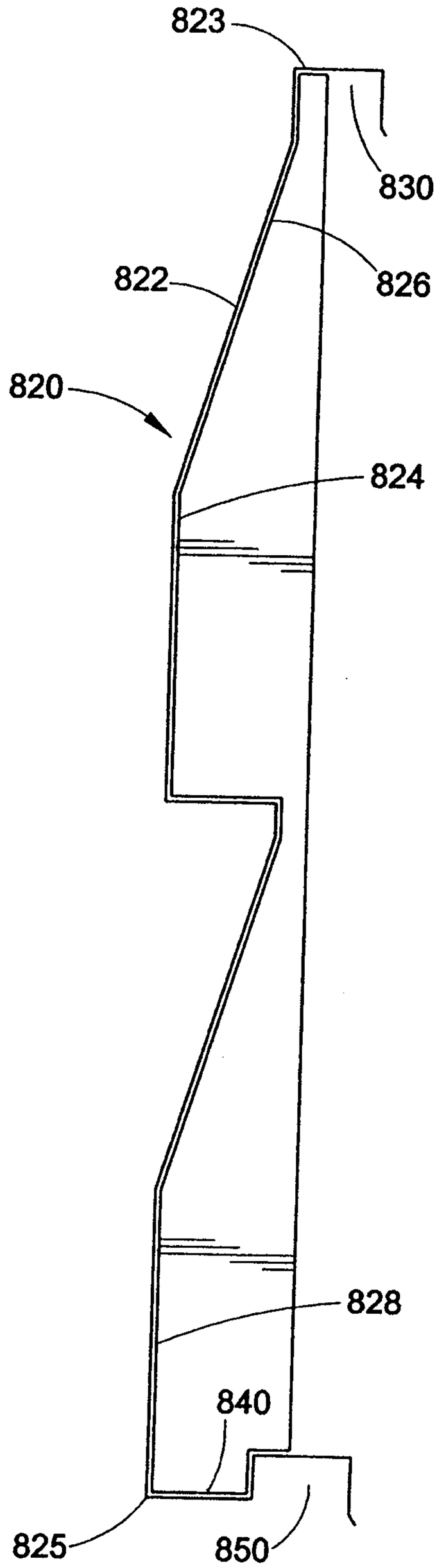

823
830
826
822
820
824
828
840
825
850

FIG. 14

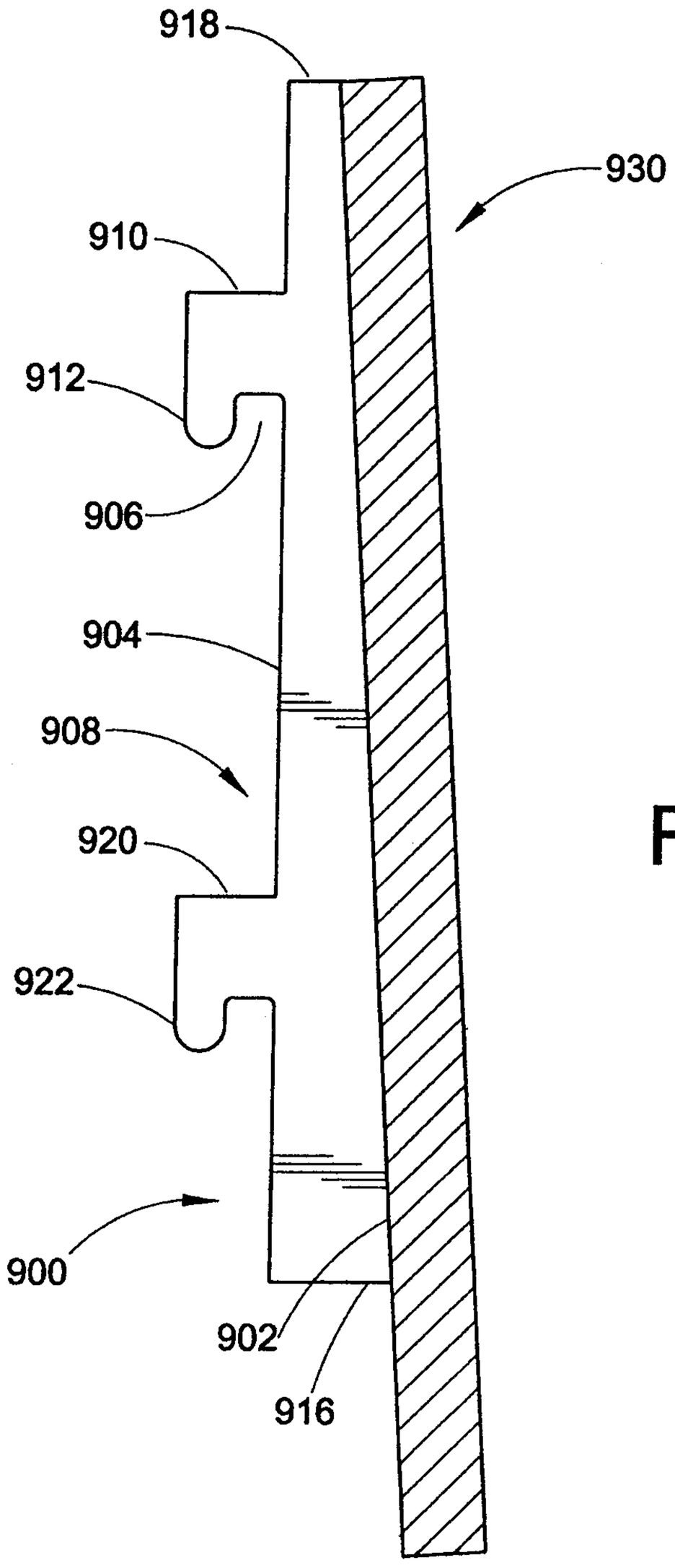

918
930
910
912
906
904
908
920
922
900
902
916

FIG. 15

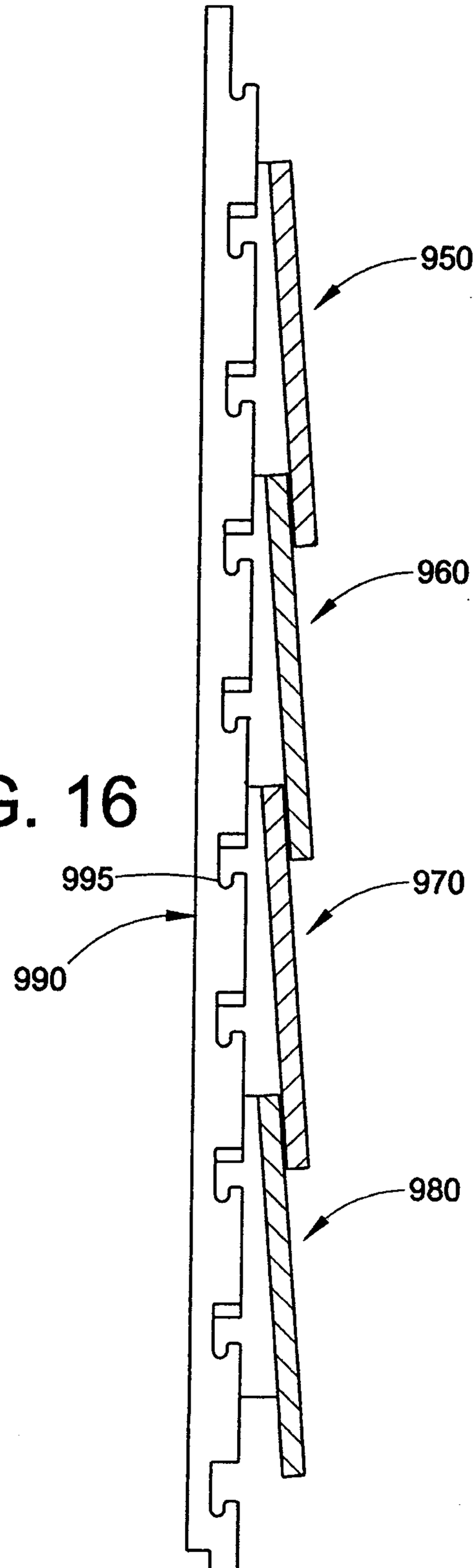

950
960
995
970
990
980

FIG. 16

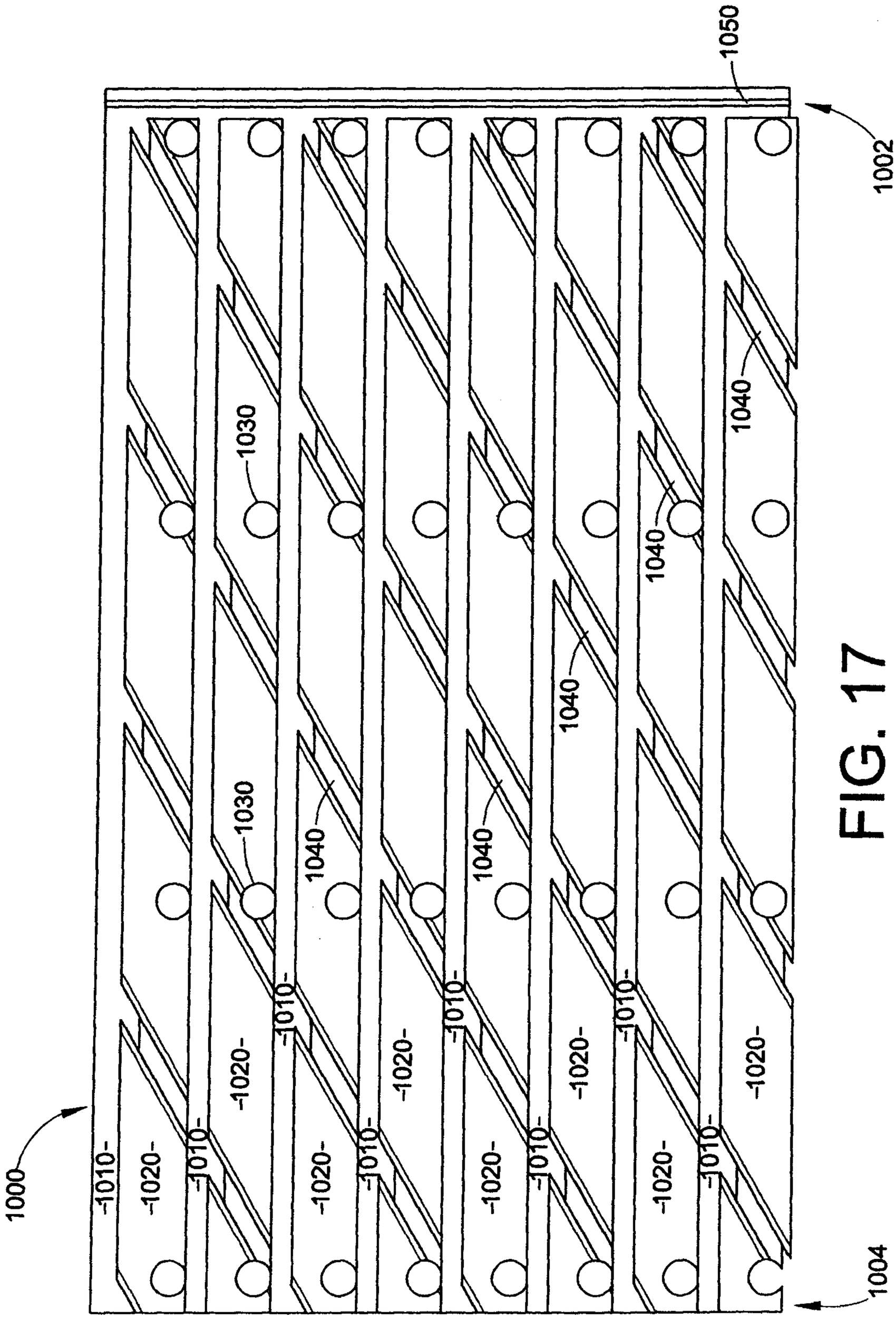

1050
1002
1030
1040
1040
1040
1030
1040
1040
1000
1004
-1010-
-1020-
-1010-
-1020-
-1010-
-1020-
-1010-
-1020-
-1010-
-1020-
-1010-
-1020-
-1010-
-1020-

FIG. 17

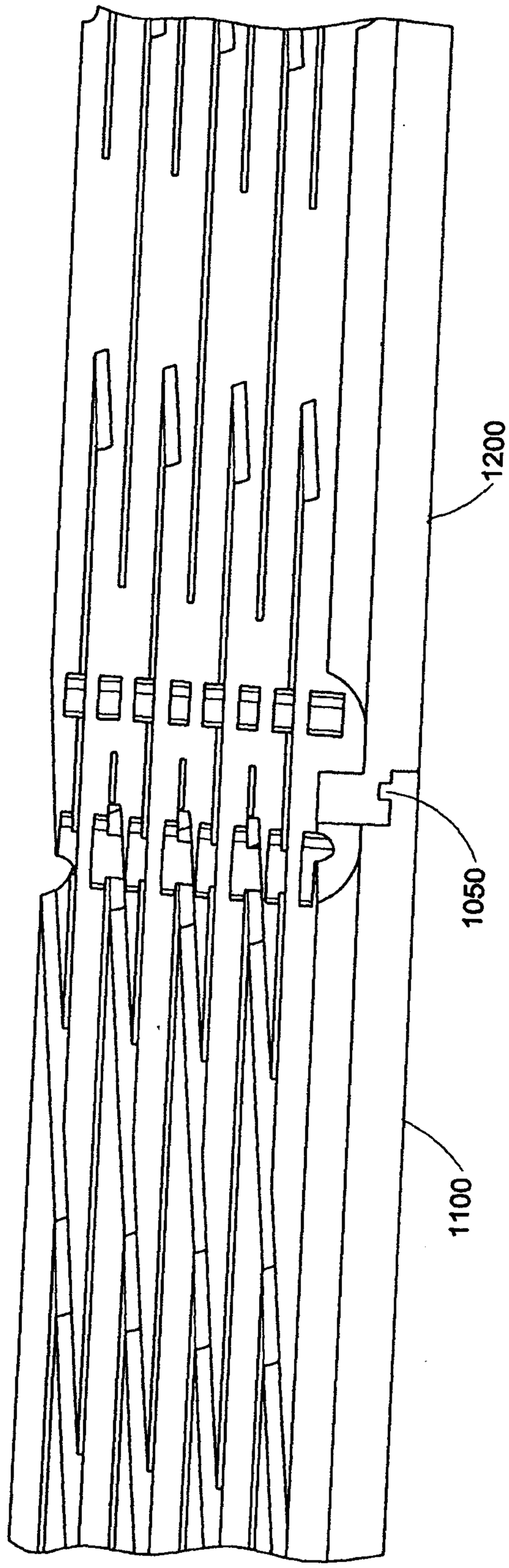


FIG. 18

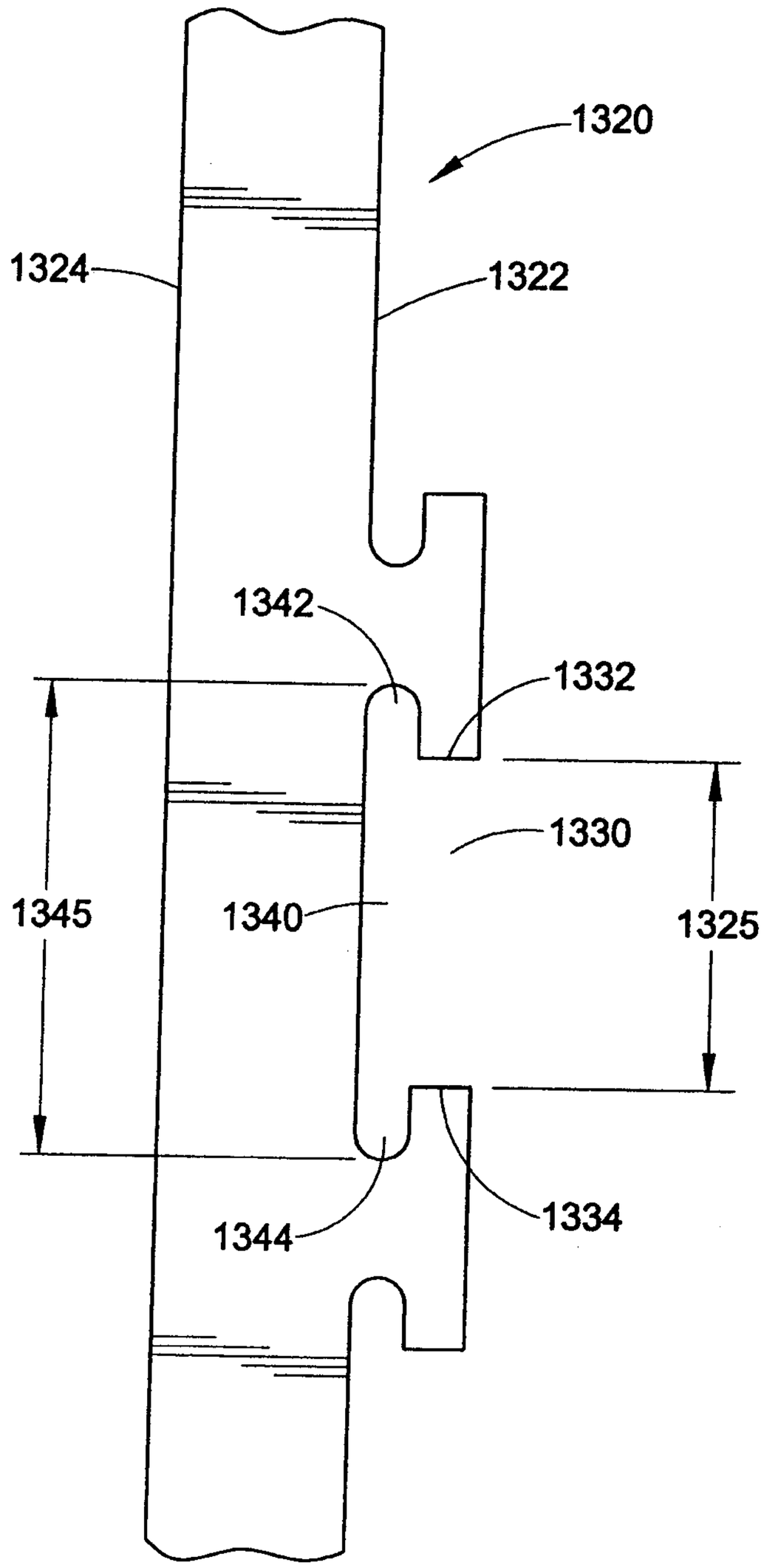


FIG. 19

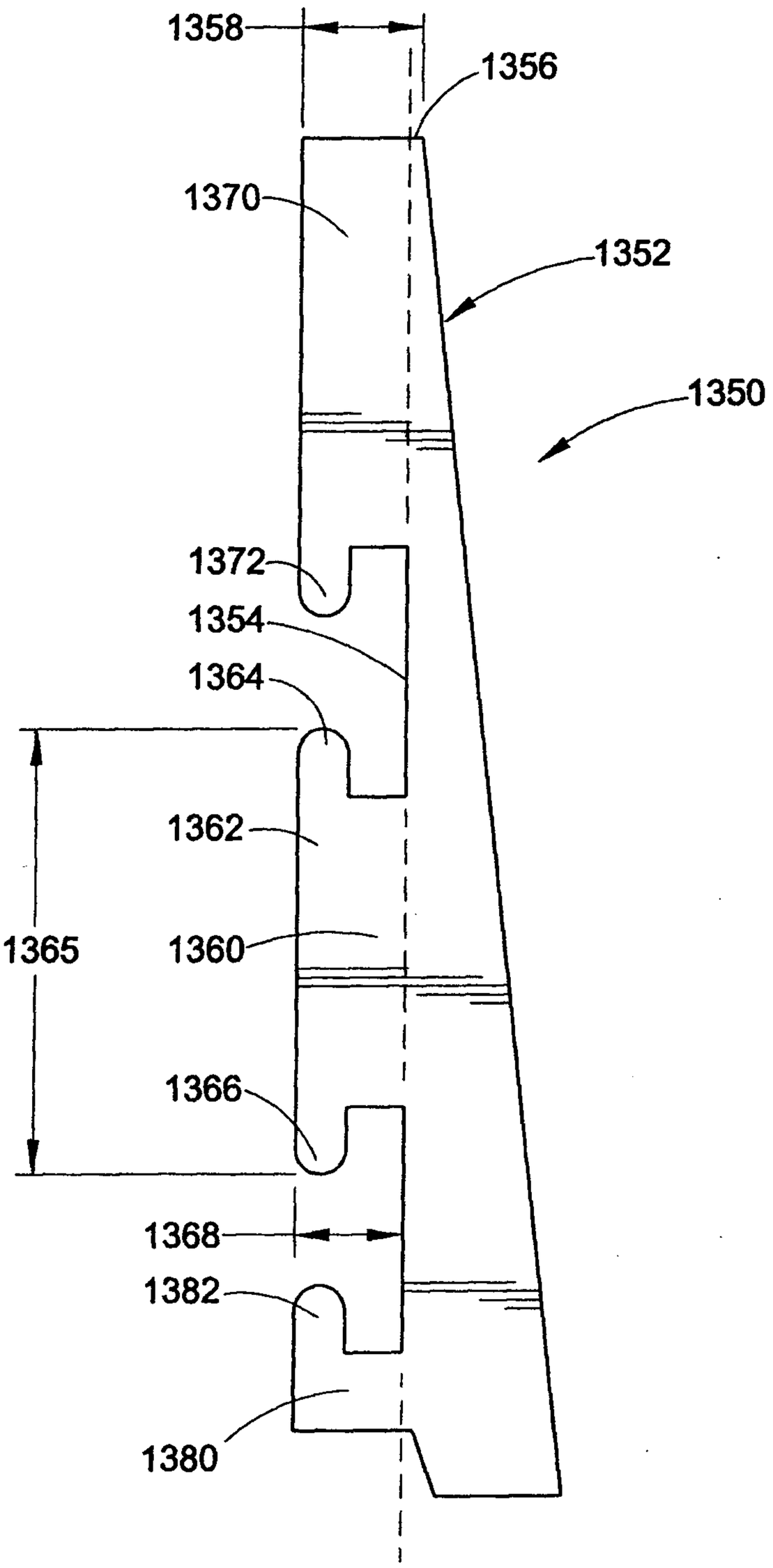

1358
1356
1370
1352
1350
1372
1354
1364
1362
1365
1360
1366
1368
1382
1380

FIG. 20

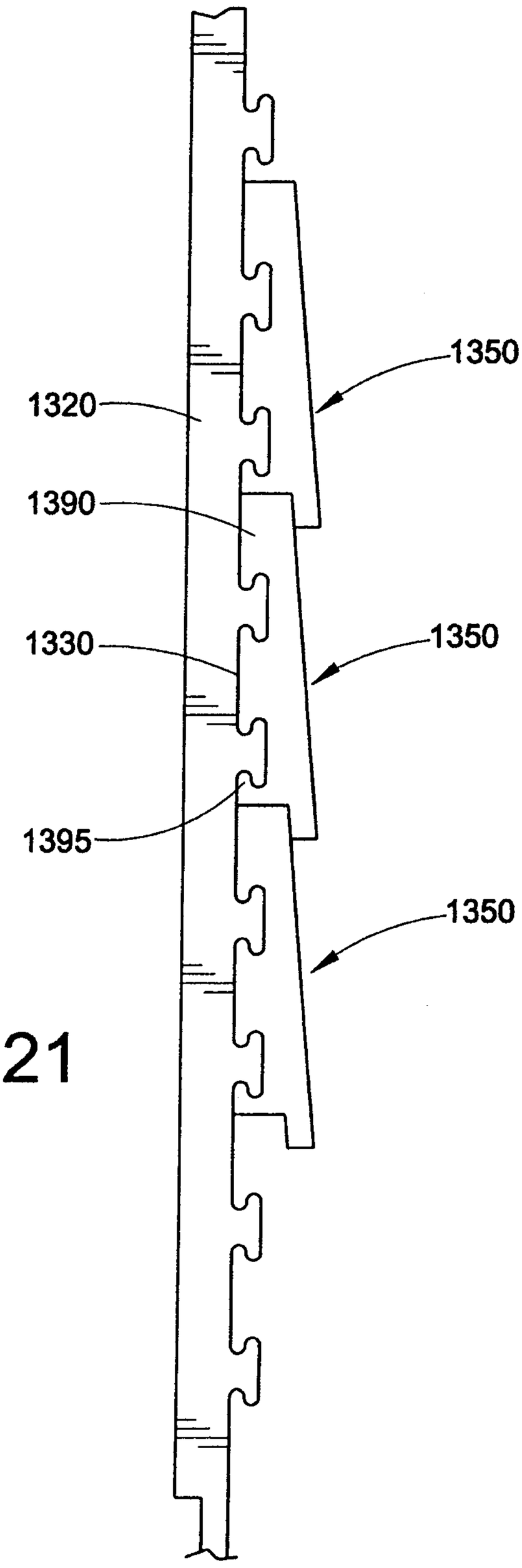


FIG. 21

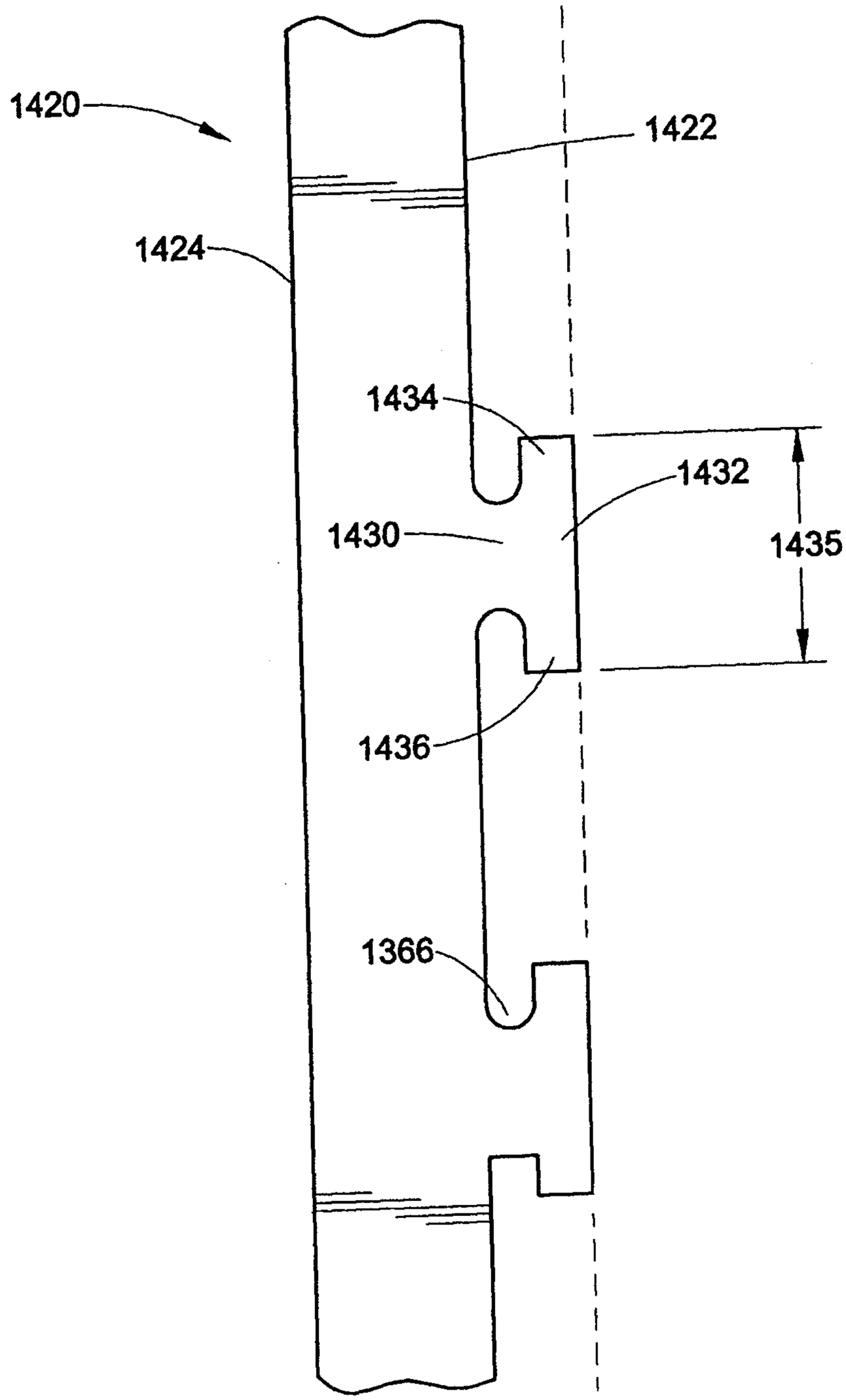


FIG. 22

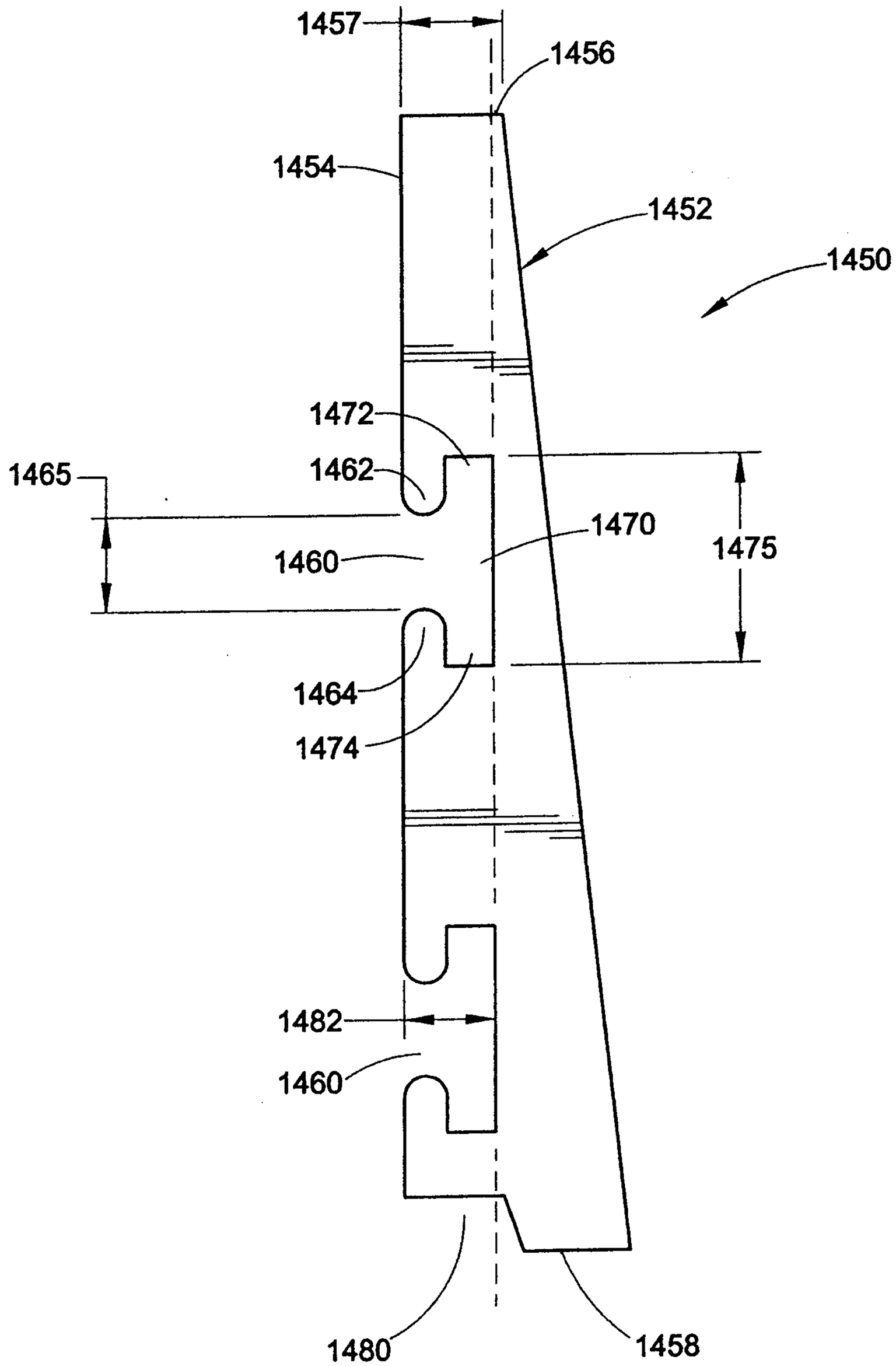

1457
1456
1454
1452
1450
1472
1462
1465
1470
1460
1475
1464
1474
1482
1460
1480
1458

FIG. 23

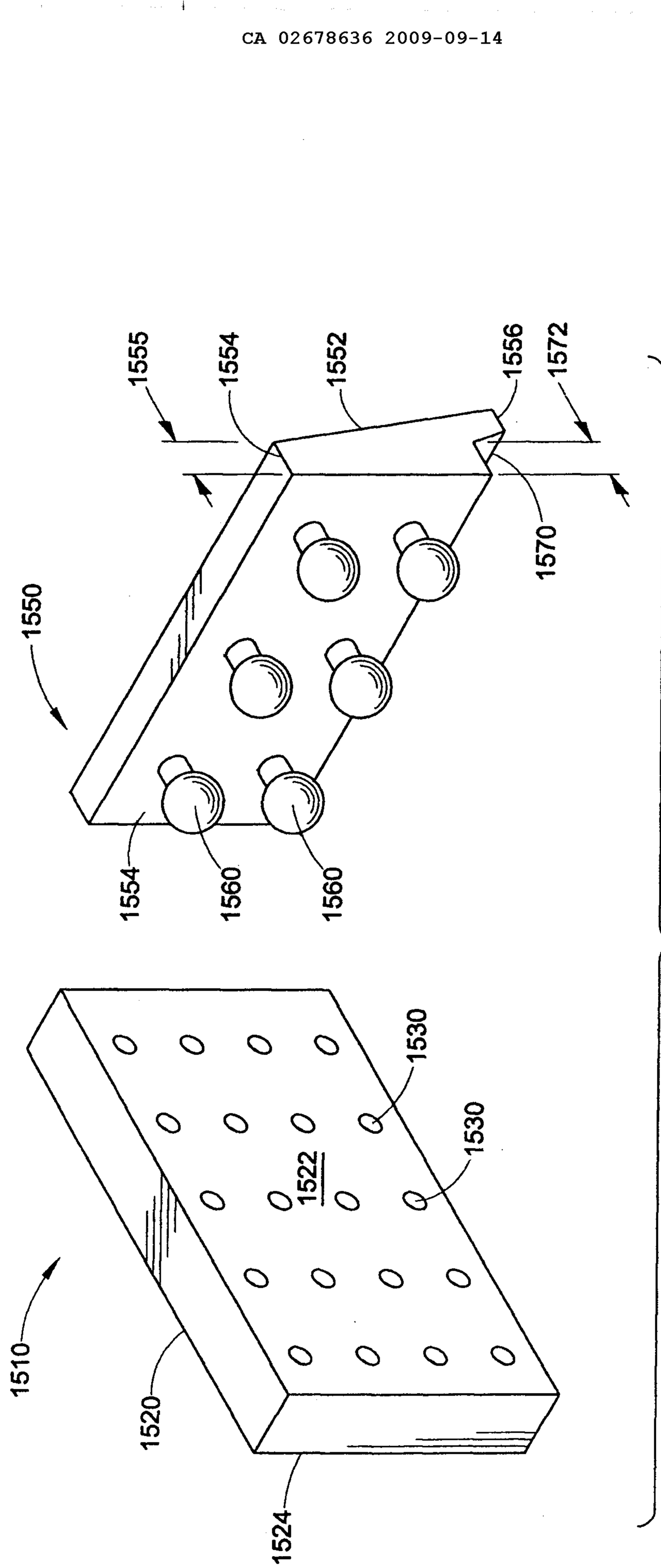

1555
1554
1552
1556
1572
1550
1570
1554
1560
1560
1530
1530
1522
1510
1520
1524

FIG. 24

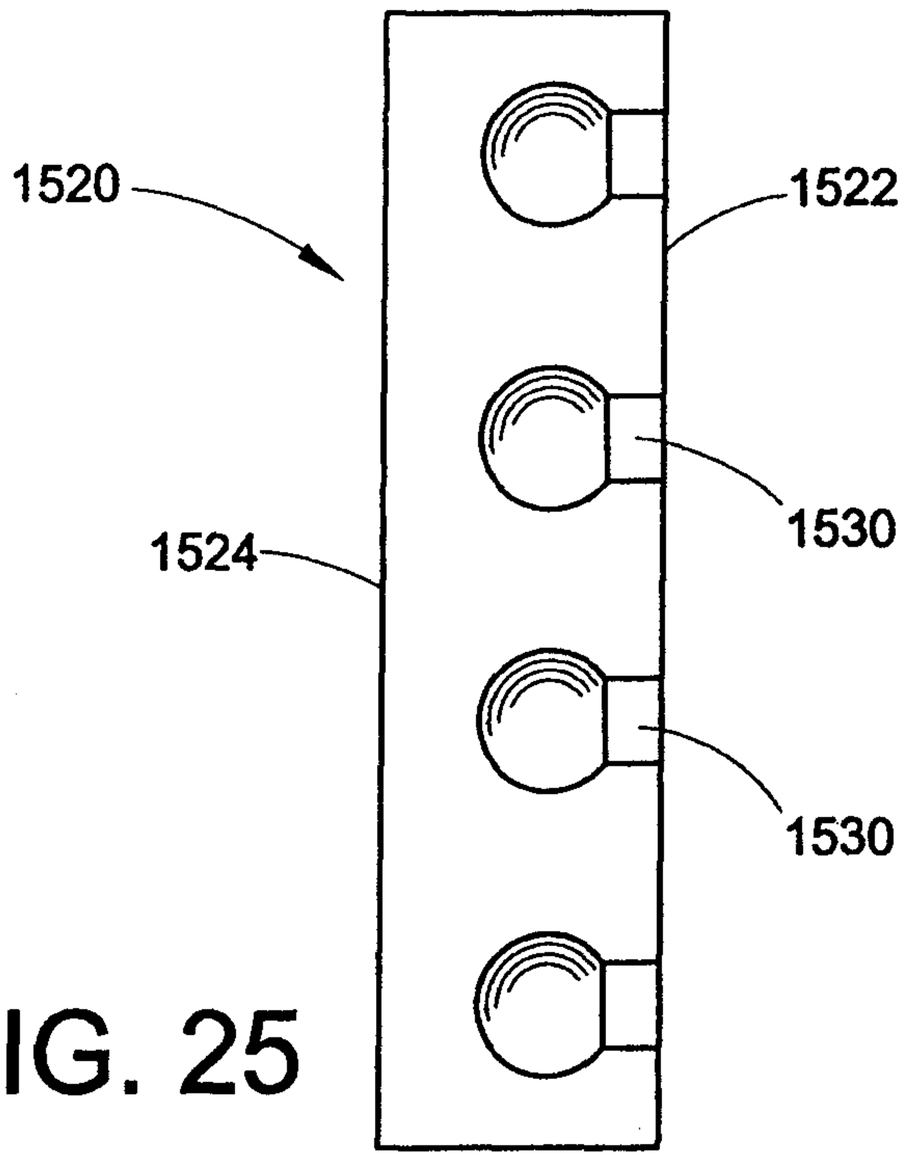


FIG. 25

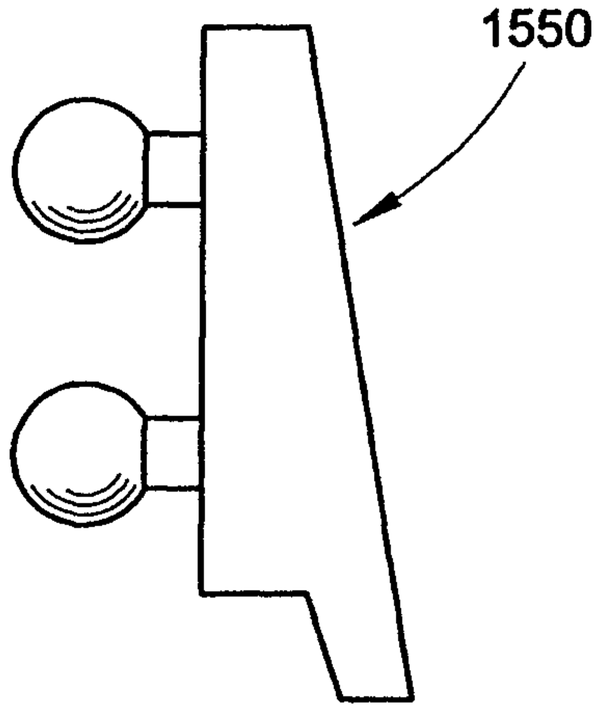


FIG. 26

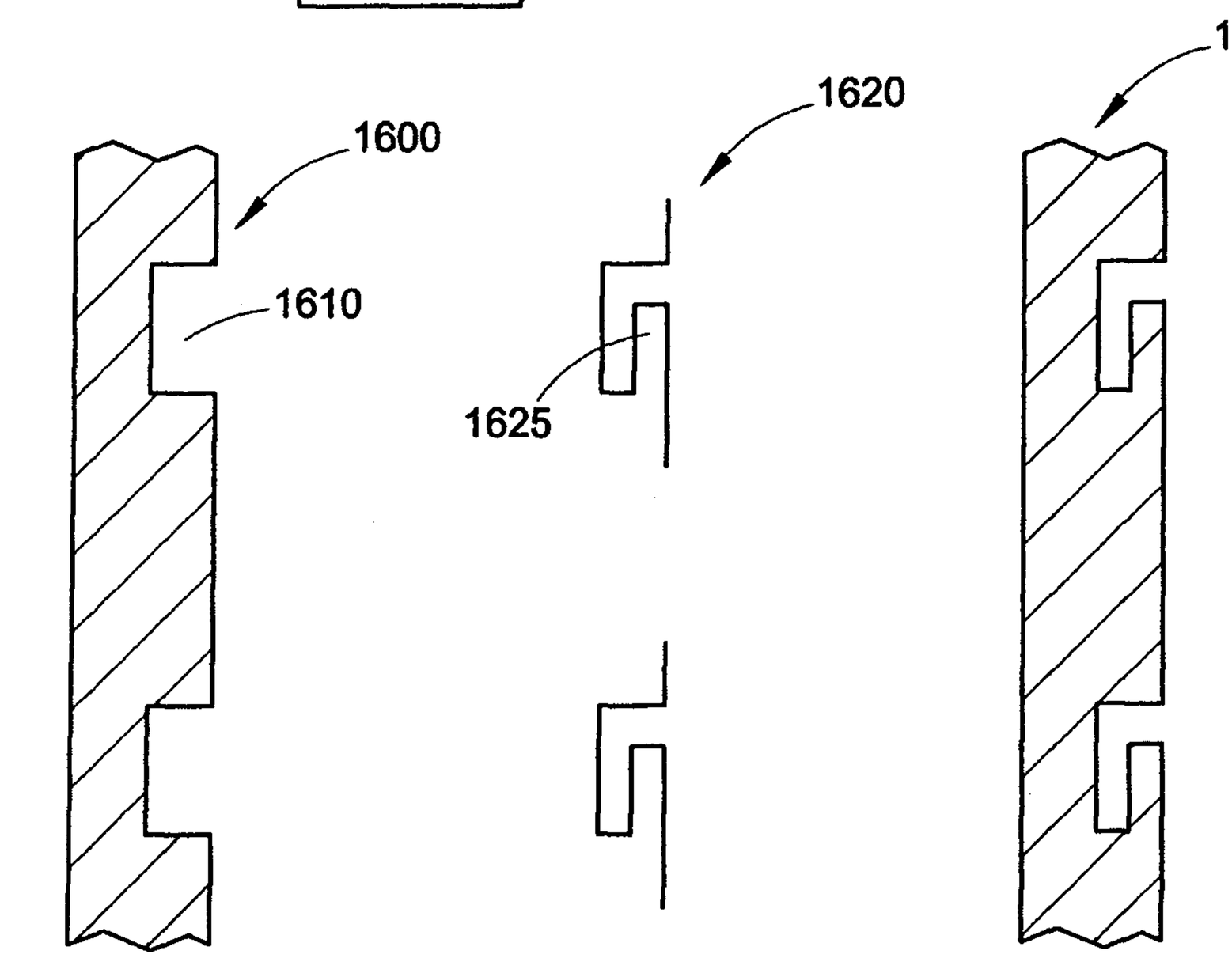
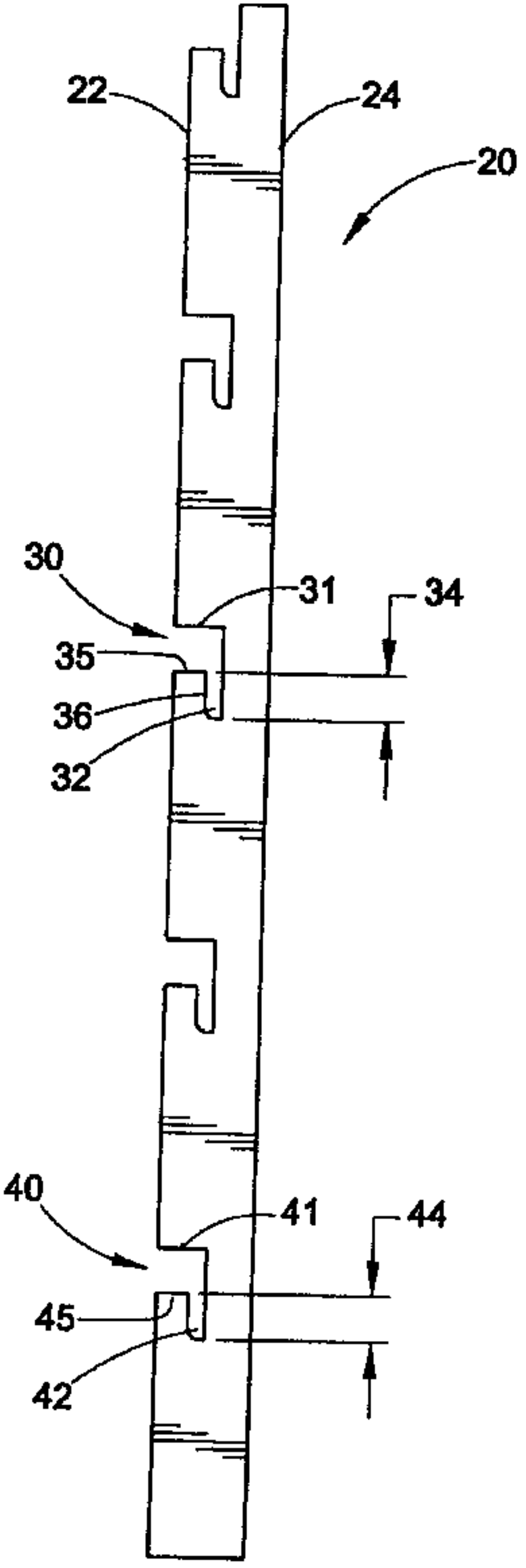


FIG. 27


22
24
20
30
31
34
35
36
32
40
41
44
45
42