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(54) Title: HIGH-DENSITY FIBER OPTIC MODULES AND MODULE HOUSINGS AND RELATED EQUIPMENT

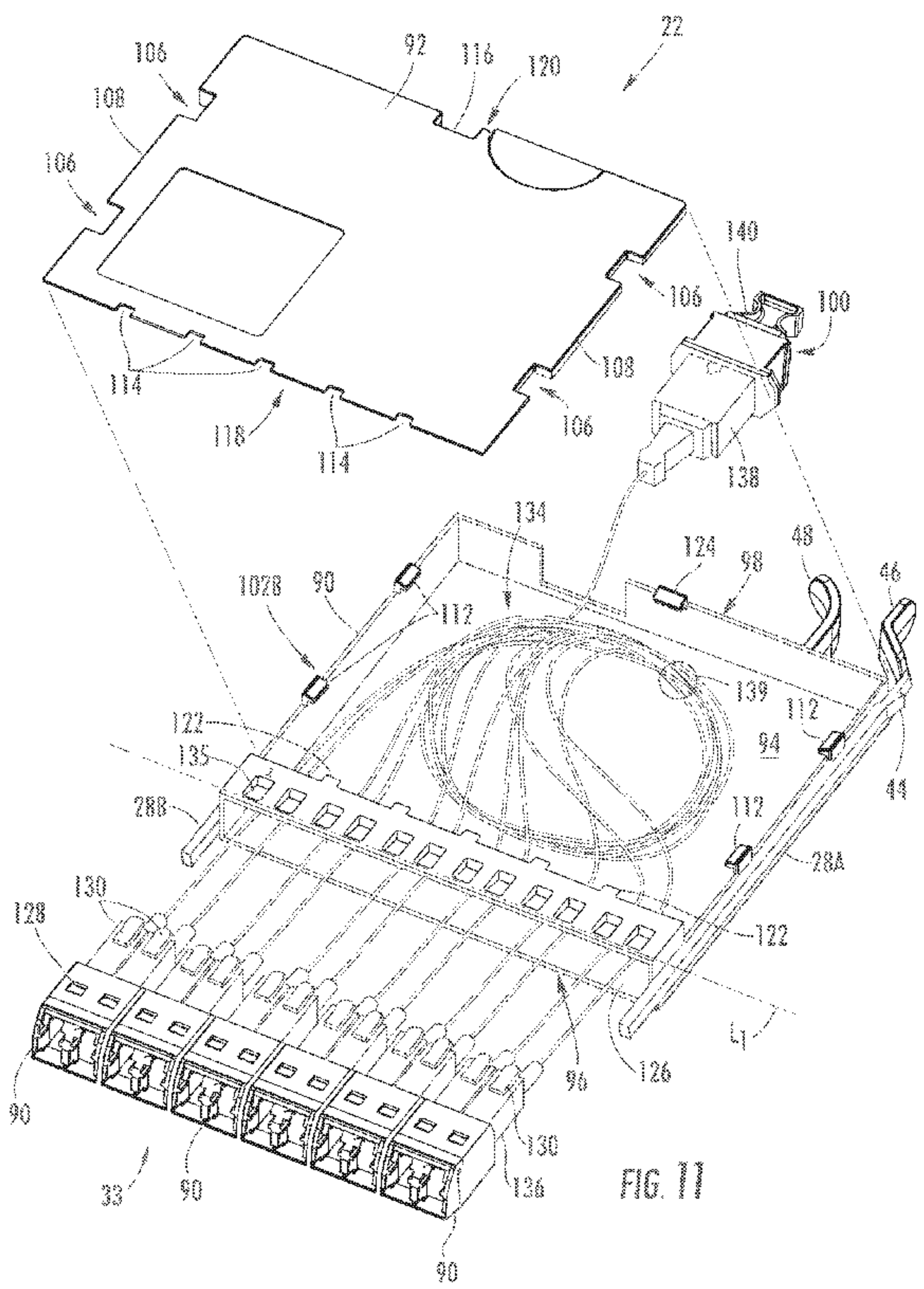

FIG. 11

(57) Abrégé/Abstract:
High-density fiber optic modules and fiber optic module housings and related equipment are disclosed. In certain embodiments, a front opening of a fiber optic module and/or fiber optic module housing is configured to receive fiber optic components. The width

(57) Abrégé(suite)/Abstract(continued):

and/or height of the front opening can be provided according to a designed relationship to a width and/or height, respectively, of a front side of a main body of the fiber optic module and/or fiber optic module housing. In this manner, a high density of fiber optic components and/or connections for a given space of the front side of the fiber optic module can be supported by the fiber optic module and/or fiber optic module housing. The fiber optic modules and fiber optic module housings disclosed herein can be disposed in fiber optic equipment including but not limited to a fiber optic chassis and a fiber optic equipment drawer.

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(54) Title: HIGH-DENSITY FIBER OPTIC MODULES AND MODULE HOUSINGS AND RELATED EQUIPMENT

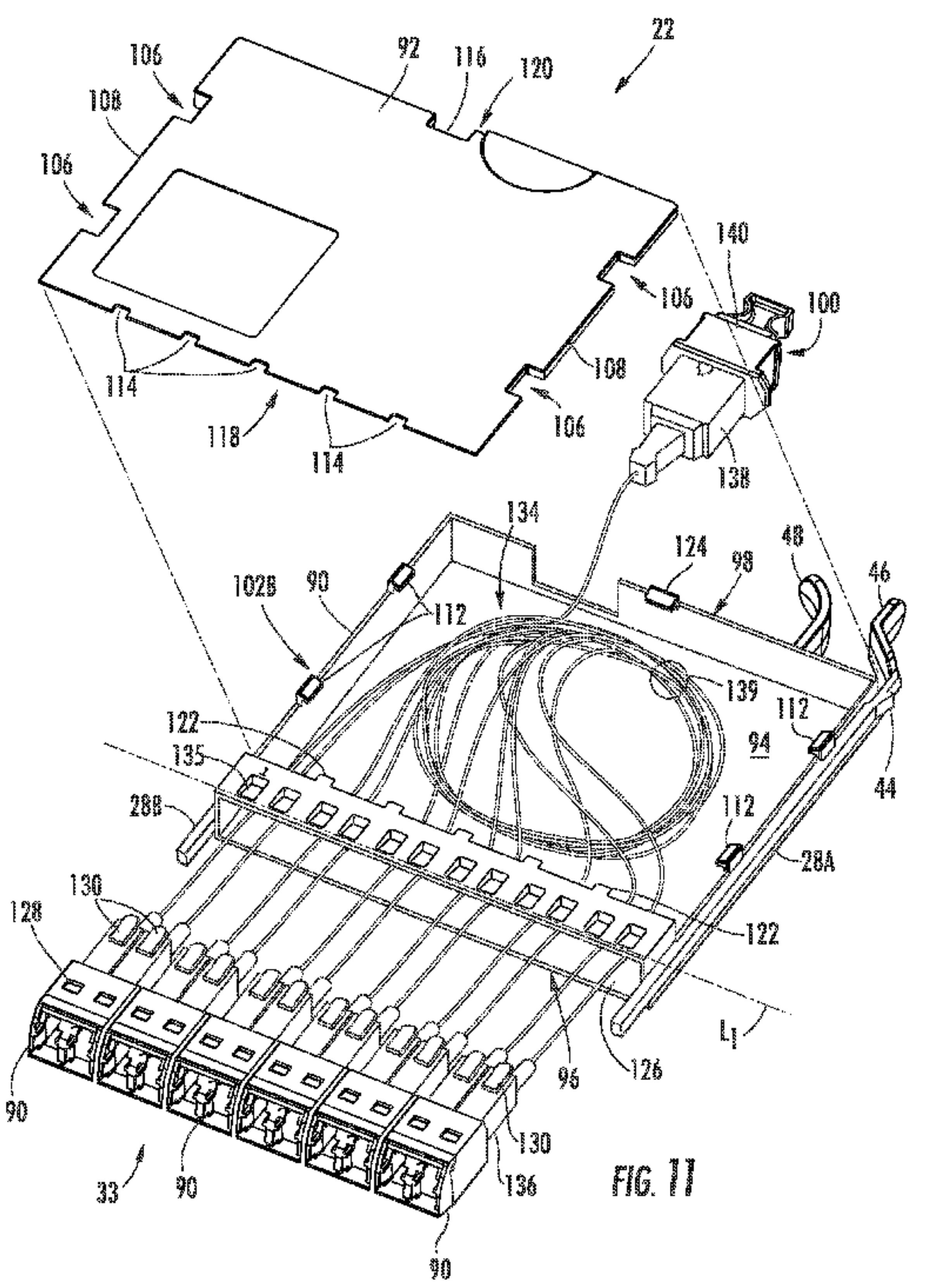

FIG. 11

(57) Abstract: High-density fiber optic modules and fiber optic module housings and related equipment are disclosed. In certain embodiments, a front opening of a fiber optic module and/or fiber optic module housing is configured to receive fiber optic components. The width and/or height of the front opening can be provided according to a designed relationship to a width and/or height, respectively, of a front side of a main body of the fiber optic module and/or fiber optic module housing. In this manner, a high density of fiber optic components and/or connections for a given space of the front side of the fiber optic module can be supported by the fiber optic module and/or fiber optic module housing. The fiber optic modules and fiber optic module housings disclosed herein can be disposed in fiber optic equipment including but not limited to a fiber optic chassis and a fiber optic equipment drawer.

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HIGH-DENSITY FIBER OPTIC MODULES AND MODULE HOUSINGS AND RELATED EQUIPMENT

PRIORITY APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 61/218,870 filed on June 19, 2009, the contents of which are incorporated by reference herein.

[0002] This application also claims the benefit of U.S. Patent Application Serial No. 12/771,473 filed on April 30, 2010, the contents of which are incorporated by reference herein.

BACKGROUND

Field of the Disclosure

[0003] The technology of the disclosure relates to fiber optic modules and fiber optic modules housings provided in fiber optic equipment to support fiber optic connections.

Technical Background

[0004] Benefits of optical fiber include extremely wide bandwidth and low noise operation. Because of these advantages, optical fiber is increasingly being used for a variety of applications, including but not limited to broadband voice, video, and data transmission. Fiber optic networks employing optical fiber are being developed and used to deliver voice, video, and data transmissions to subscribers over both private and public networks. These fiber optic networks often include separated connection points linking optical fibers to provide "live fiber" from one connection point to another connection point. In this regard, fiber optic equipment is located in data distribution centers or central offices to support interconnections.

[0005] The fiber optic equipment is customized based on application need. The fiber optic equipment is typically included in housings that are mounted in equipment racks to optimize use of space. One example of such fiber optic equipment is a fiber optic module. A fiber optic module is designed to provide cable-to-cable fiber optic connections and/or manage the polarity of fiber optic cable connections. A fiber optic module is typically mounted to a chassis or housing which is then mounted inside an equipment rack or cabinet. A technician establishes fiber optic connections to the fiber optic modules mounted in the equipment rack. Due to increasing bandwidth needs and the need to provide a larger number of connections in data centers for increased revenue generating opportunities, a need exists to provide fiber optic modules that can facilitate larger numbers of fiber optic connections in a given space.

SUMMARY OF THE DETAILED DESCRIPTION

[0006] Embodiments disclosed in the detailed description include high-density fiber optic modules and fiber optic module housings and related equipment. In certain embodiments, the fiber optic modules and fiber optic module housings comprise a main body defining an internal chamber disposed between a front side and a rear side. A front opening is disposed along a longitudinal axis in the front side of the main body. A plurality of fiber optic components is disposed through the front opening. In certain embodiments, the width and/or height of the front opening can be provided according to a designed relationship to the width and/or height, respectively, of the front side of the main body to support fiber optic components or connections within the fiber optic module and/or fiber optic module housing. In this manner, fiber optic components can be installed in a given percentage or area of the front side of the fiber optic module to provide a high density of fiber optic connections for a given fiber optic component type(s). In other embodiments, the front opening can be provided to support a designed connection density capacity of fiber optic components or connections for a given width and/or height of the front opening of the fiber optic module and/or fiber optic module housing. The fiber optic components and connections can be provided by fiber optic adapters and/or fiber optic connectors as examples. The fiber optic modules and fiber optic module housings disclosed herein can be disposed in fiber optic equipment including but not limited to a chassis and fiber optic equipment drawer.

[0007] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the invention as described herein, including the detailed description that follows, the claims, as well as the appended drawings.

[0008] It is to be understood that both the foregoing general description and the following detailed description present embodiments, and are intended to provide an overview or framework for understanding the nature and character of the disclosure. The accompanying drawings are included to provide a further understanding, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments, and together with the description serve to explain the principles and operation of the concepts disclosed.

BRIEF DESCRIPTION OF THE FIGURES

[0009] **FIG. 1** is a front perspective view of an exemplary fiber optic equipment rack with an installed exemplary 1-U size chassis supporting high-density fiber optic modules to provide a given fiber optic connection density and bandwidth capability, according to one embodiment;

[0010] **FIG. 2** is a rear perspective close-up view of the chassis of **FIG. 1** with fiber optic modules installed in fiber optic equipment trays installed in the fiber optic equipment;

[0011] **FIG. 3** is a front perspective view of one fiber optic equipment tray with installed fiber optic modules configured to be installed in the chassis of **FIG. 1**;

[0012] **FIG. 4** is a close-up view of the fiber optic equipment tray of **FIG. 3** without fiber optic modules installed;

[0013] **FIG. 5** is a close-up view of the fiber optic equipment tray of **FIG. 3** with fiber optic modules installed;

[0014] **FIG. 6** is a front perspective view of the fiber optic equipment tray of **FIG. 3** without fiber optic modules installed;

[0015] **FIG. 7** is a front perspective view of fiber optic equipment trays supporting fiber optic modules with one fiber optic equipment tray extended out from the chassis of **FIG. 1**;

[0016] **FIGS. 8A and 8B** are left perspective views of an exemplary tray guides that can be disposed in the chassis of **FIG. 1** and can be configured to receive fiber optic equipment trays of **FIG. 6** capable of supporting one or more fiber optic modules;

[0017] **FIGS. 9A and 9B** are perspective and top views, respectively, of an exemplary tray rail disposed on each side of the fiber optic equipment tray of **FIG. 3** and configured to be received in the chassis of **FIG. 1** by the tray guide of **FIG. 8A or 8B**;

[0018] **FIGS. 10A and 10B** are front right and left perspective views, respectively, of an exemplary fiber optic module that can be disposed in the fiber optic equipment trays of **FIG. 3;**

[0019] **FIG. 11** is a perspective, exploded view of the fiber optic module in **FIGS. 10A and 10B**;

[0020] **FIG. 12** is a perspective top view of the fiber optic module of **FIG. 11** with the cover removed and showing a fiber optic harness installed therein;

[0021] **FIG. 12A** is a perspective top view of another fiber optic module with the cover removed showing the fiber optic harness installed within guides;

[0022] **FIG. 13** is a front view of the fiber optic module of **FIG. 11** without fiber optic components installed;

[0023] **FIG. 14** is a front right perspective view of another alternate fiber optic module that supports twelve (12) fiber MPO fiber optic components and which can be installed in the fiber optic equipment tray of **FIG. 3**;

[0024] **FIG. 15** is front right perspective view of another alternate fiber optic module that supports twenty-four (24) fiber MPO fiber optic components and which can be installed in the fiber optic equipment tray of **FIG. 3**;

[0025] **FIG. 16** is a front perspective view of an alternate fiber optic module being installed in the fiber optic equipment tray of **FIG. 3**;

[0026] **FIG. 17** is front right perspective view of the fiber optic module of **FIG. 16**;

[0027] **FIG. 18** is a front view of the fiber optic module of **FIGS. 16 and 17**;

[0028] **FIG. 19** is a front perspective view of another alternate fiber optic module being installed in the fiber optic equipment tray of **FIG. 3**;

[0029] **FIG. 20** is front right perspective view of the fiber optic module of **FIG. 19**;

[0030] **FIG. 21** is a front view of the fiber optic module of **FIGS. 19 and 20**;

[0031] **FIG. 22** is a front perspective view of another alternate fiber optic module being installed in an alternate fiber optic equipment tray that can be installed in the chassis of **FIG. 1**;

[0032] **FIGS. 23** is front right perspective view of the fiber optic module of **FIG. 22**;

[0033] **FIG. 24** is a front view of the fiber optic module of **FIGS. 22 and 23**; and

[0034] **FIG. 25** is a front perspective view of alternate exemplary 4-U size fiber optic chassis that can support the fiber optic equipment trays and fiber optic modules according to the fiber optic equipment tray and fiber optic modules disclosed.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0035] Reference will now be made in detail to certain embodiments, examples of which are illustrated in the accompanying drawings, in which some, but not all features are shown. Indeed, embodiments disclosed herein may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Whenever possible, like reference numbers will be used to refer to like components or parts.

[0036] Embodiments disclosed in the detailed description include high-density fiber optic modules and fiber optic module housings and related equipment. In certain embodiments, the width and/or height of the front opening of fiber optic modules and/or fiber optic module housings can be provided according to a designed relationship to the width and/or height, respectively, of a front side of the main body of the fiber optic modules and fiber optic module housings to support fiber optic components or connections. In this manner, fiber optic components can be installed in a given percentage or area of the front side of the fiber optic module to provide a high density of fiber optic connections for a given fiber optic component type(s). In another embodiment, the front openings of the fiber optic modules and/or fiber optic module housings can be provided to support a designed connection density of fiber optic components or connections for a given width and/or height of the front opening of the fiber optic module and/or fiber optic module housing. Embodiments disclosed in the detailed description also include high connection density and bandwidth fiber optic apparatuses and related equipment. In certain embodiments, fiber optic apparatuses are provided and comprise a chassis defining one or more U space fiber optic equipment units, wherein at least one of the one or more U space fiber optic equipment units is configured to support a given fiber optic connection density or bandwidth in a 1-U space, and for a given fiber optic component type(s).

[0037] In this regard, **FIG. 1** illustrates exemplary 1-U size fiber optic equipment **10** from a front perspective view. The fiber optic equipment **10** supports high-density fiber optic modules that support a high fiber optic connection density and bandwidth in a 1-U space, as will be described in greater detail below. The fiber optic equipment **10** may be provided at a data distribution center or central office to support cable-to-cable fiber optic connections and to manage a plurality of fiber optic cable connections. As will be described in greater detail below, the fiber optic equipment **10** has one or more fiber optic equipment trays that each support one or more fiber optic modules. However, the fiber optic equipment **10** could also be adapted to support one or more fiber optic patch panels or other fiber optic equipment that supports fiber optic components and connectivity.

[0038] The fiber optic equipment **10** includes a fiber optic equipment chassis **12** ("chassis **12**"). The chassis **12** is shown as being installed in a fiber optic equipment rack **14**. The fiber optic equipment rack **14** contains two vertical rails **16A**, **16B** that extend vertically and include a series of apertures **18** for facilitating attachment of the chassis **12** inside the fiber optic equipment rack **14**. The chassis **12** is attached and supported by the fiber optic equipment rack **14** in the form of shelves that are stacked on top of each other within the vertical rails **16A**, **16B**. As illustrated, the chassis **12** is attached to the vertical rails **16A**, **16B**. The fiber optic equipment rack **14** may support 1-U-sized shelves, with "U" equal to a standard 1.75 inches in height and seventeen (19) inches in width. In certain applications, the width of "U" may be twenty-three (23) inches. In this embodiment, the chassis **12** is 1-U in size; however, the chassis **12** could be provided in a size greater than 1-U as well.

[0039] As will be discussed in greater detail later below, the fiber optic equipment **10** includes a plurality of extendable fiber optic equipment trays **20** that each carries one or more fiber optic modules **22**. The chassis **12** and fiber optic equipment trays **20** support fiber optic modules **22** that support high-density fiber optic modules and a fiber optic connection density and bandwidth connections in a given space, including in a 1-U space. **FIG. 1** shows exemplary fiber optic components **23** disposed in the fiber optic modules **22** that support fiber optic connections. For example, the fiber optic components **23** may be fiber optic adapters or fiber optic connectors. As will also be discussed in greater detail later below, the fiber optic modules **22** in this embodiment can be provided such that the fiber optic components **23** can be disposed through at least eighty-five percent (85%) of the width of the front side or face of the fiber optic module **22**, as an example. This fiber optic module **22** configuration may provide a front opening of approximately 90 millimeters (mm) or less wherein fiber optic components can be disposed through the front opening and at a fiber optic connection density of at least one fiber optic connection per 7.0 mm of width of the front opening of the fiber optic modules **22** for simplex or duplex fiber optic components **23**. In this example, six (6) duplex or twelve (12) simplex fiber optic components may be installed in each fiber optic module **22**. The fiber optic equipment trays **20** in this embodiment support up to four (4) of the fiber optic modules **22** in approximately the width of a 1-U space, and three (3) fiber optic equipment trays **20** in the height of a 1-U space for a total of twelve (12) fiber optic modules **22** in a 1-U space. Thus, for example, if six (6) duplex fiber optic components were disposed in each of the twelve (12) fiber optic modules **22** installed in fiber optic equipment trays **20** of the chassis **12** as illustrated in **FIG. 1**, a total of one hundred forty-four (144) fiber optic connections, or seventy-two (72) duplex channels (i.e., transmit and receive channels), would be supported by the chassis **12** in a 1-U space. If five (5) duplex fiber optic adapters are disposed in each of the twelve (12) fiber optic modules **22** installed in fiber optic equipment trays **20** of the chassis **12**, a total of one hundred twenty (120) fiber optic connections, or sixty (60) duplex channels, would be supported by the chassis **12** in a 1-U space. The chassis **12** also supports at least ninety-eight (98) fiber optic components in a 1-U space wherein at least one of the fiber optic components is a simplex or duplex fiber optic component.

[0040] If multi-fiber fiber optic components were installed in the fiber optic modules **22**, such as MPO components for example, higher fiber optic connection density and bandwidths would be possible over other chassis **12** that use similar fiber optic components. For example, if up to four (4) twelve (12) fiber MPO fiber optic components were disposed in each fiber optic module **22**, and twelve (12) of the fiber optic modules **22** were disposed in the chassis **12** in a 1-U space, the chassis **12** would support up to five hundred seventy-six (576) fiber optic connections in a 1-U space. If up to four (4) twenty-four (24) fiber MPO fiber optic components were disposed in each fiber optic module **22**, and twelve (12) of the fiber optic modules **22** were disposed in the chassis **12**, up to one thousand one hundred fifty-two (1152) fiber optic connections in a 1-U space.

[0041] **FIG. 2** is a rear perspective close-up view of the chassis **12** of **FIG. 1** with fiber optic modules **22** loaded with fiber optic components **23** and installed in fiber optic equipment trays **20** installed in the chassis **12**. Module rails **28A**, **28B** are disposed on each side of each fiber optic module **22**. The module rails **28A**, **28B** are configured to be inserted within tray channels **30** of module rail guides **32** disposed in the fiber optic equipment tray **20**, as illustrated in more detail in **FIGS. 3-5**. Note that any number of module rail guides **32** can be provided. The fiber optic module **22** can be installed from both a front end **34** and a rear end **36** of the fiber optic equipment tray **20** in this embodiment. If it is desired to install the fiber optic module **22** in the fiber optic equipment tray **20** from the rear end **36**, a front end **33** of the fiber optic module **22** can be inserted from the rear end **36** of the fiber optic equipment tray **20**. More specifically, the front end **33** of the fiber optic module **22** is inserted into the tray channels **30** of the module rail guides **32**. The fiber optic module **22** can then be pushed forward within the tray channels **30** until the fiber optic module **22** reaches the front end **34** of the module rail guides **32**. The fiber optic modules **22** can be moved towards the front end **34** until the fiber optic modules **22** reach a stop or locking feature disposed in the front end **34** as will described later in this application. **FIG. 6** also illustrates the fiber optic equipment tray **20** without installed fiber optic modules **22** to illustrate the tray channels **30** and other features of the fiber optic equipment tray **20**.

[0042] The fiber optic module **22** can be locked into place in the fiber optic equipment tray **20** by pushing the fiber optic module **22** forward to the front end **33** of the fiber optic equipment tray **20**. A locking feature in the form of a front stop **38** is disposed in the module rail guides **32**, as illustrated in **FIG. 3** and in more detail in the close-up view in **FIG. 4**. The front stop **38** prevents the fiber optic module **22** from extending beyond the front end **34**, as illustrated in the close-up view of the fiber optic equipment tray **20** with installed fiber optic modules **22** in **FIG. 5**. When it is desired to remove a fiber optic module **22** from the fiber optic equipment tray **20**, a front module tab **40** also disposed in the module rail guides **32** and coupled to the front stop **38** can be pushed downward to engage the front stop **38**. As a result, the front stop **38** will move outward away from the fiber optic module **22** such that the fiber optic module **22** is not obstructed from being pulled forward. The fiber optic module **22**, and in particular its module rails **28A, 28B (FIG. 2)**, can be pulled forward along the module rail guides **32** to remove the fiber optic module **22** from the fiber optic equipment tray **20**.

[0043] The fiber optic module **22** can also be removed from the rear end **36** of the fiber optic equipment tray **20**. To remove the fiber optic module **22** from the rear end **36** of the fiber optic equipment tray **20**, a latch **44** is disengaged by pushing a lever **46** (see **FIGS. 2 and 3**; see also, **FIGS. 10A and 10B**) inward towards the fiber optic module **22** to release the latch **44** from the module rail guide **32**. To facilitate pushing the lever **46** inward towards the fiber optic module **22**, a finger hook **48** is provided adjacent to the lever **46** so the lever **46** can easily be squeezed into the finger hook **48** by a thumb and index finger.

[0044] With continuing reference to **FIG. 3-6**, the fiber optic equipment tray **20** may also contain extension members **50**. Routing guides **52** may be conveniently disposed on the extension members **50** to provide routing for optical fibers or fiber optic cables connected to fiber optic components **23** disposed in the fiber optic modules **22 (FIG. 3)**. The routing guides **52'** on the ends of the fiber optic equipment tray **20** may be angled with respect to the module rail guides **32** to route optical fibers or fiber optic cables at an angle to the sides of the fiber optic equipment tray **20**. Pull tabs **54** may also be connected to the extension members **50** to provide a means to allow the fiber optic equipment tray **20** to easily be pulled out from and pushed into the chassis **12**.

[0045] As illustrated in **FIGS. 3 and 6**, the fiber optic equipment tray **20** also contains tray rails **56**. The tray rails **56** are configured to be received in tray guides **58** disposed in the chassis **12** to retain and allow the fiber optic equipment trays **20** to move in and out of the chassis **12**, as illustrated in **FIG. 7.** More detail regarding the tray rails **56** and their coupling to the tray guides **58** in the chassis **12** is discussed below with regard to **FIGS. 8 and 9A-9B**. The fiber optic equipment trays **20** can be moved in and out of the chassis **12** by their tray rails **56** moving within the tray guides **58**. In this manner, the fiber optic equipment trays **20** can be independently movable about the tray guides **58** in the chassis **12**. **FIG. 7** illustrates a front perspective view of one fiber optic equipment tray **20** pulled out from the chassis **12** among three (3) fiber optic equipment trays **20** disposed within the tray guides **58** of the chassis **12**. The tray guides **58** may be disposed on both a left side end **60** and a right side end **62** of the fiber optic equipment tray **20**. The tray guides **58** are installed opposite and facing each other in the chassis **12** to provide complementary tray guides **58** for the tray rails **56** of the fiber optic equipment trays **20** received therein. If it is desired to access a particular fiber optic equipment tray **20** and/or a particular fiber optic module **22** in a fiber optic equipment tray **20**, the pull tab **54** of the desired fiber optic equipment tray **20** can be pulled forward to cause the fiber optic equipment tray **20** to extend forward out from the chassis **12**, as illustrated in **FIG. 7**. The fiber optic module **22** can be removed from the fiber optic equipment tray **20** as previously discussed. When access is completed, the fiber optic equipment tray **20** can be pushed back into the chassis **12** wherein the tray rails **56** move within the tray guides **58** disposed in the chassis **12**.

[0046] **FIGS. 8A and 8B** are left perspective views of an exemplary tray guides **58,58'** that can be disposed in the chassis **12** of **FIG. 1**. The tray guide **58** of **FIG. 8A** is configured to support up to two (2) tray rails **56** in a 1-U space. The tray guide **58'** of **FIG. 8B** is configured to support up to three (3) tray rails **56** per 1-U space, as illustrated in **FIG. 1**. The tray guides **58,58'** contain like features and thus the description below with regard to tray guide **58** in **FIG. 8A** is equally applicable to the tray guide **58'** of **FIG. 8B**. Like features or elements between tray guides **58,58'** are illustrated with common element numbers, except that such features in tray guide **58'** will be appended with an apostrophe (').

[0047] As discussed above, the tray guides **58,58'** are configured to receive fiber optic equipment trays **20** supporting one or more fiber optic modules **22** in the chassis **12**. The tray guides **58,58'** allow the fiber optic equipment trays **20** to be pulled out from the chassis **12**, as illustrated in **FIG. 7**. The tray guide **58** in **FIG. 8A** is comprised of a guide panel **64**. The guide panel **64** is comprised of an elongated member **65**. The guide panel **64** may be constructed out of any material desired, including but not limited to a polymer or metal. The guide panel **64** contains a series of apertures **66** to facilitate attachment of the guide panel **64** to the chassis **12**, as illustrated in **FIG. 8A**. Guide members **68** are disposed in the guide panel **64** and are configured to receive the tray rail **56** of the fiber optic equipment tray **20**. Two (2) guide members **68** are disposed in the guide panel **64** in the embodiment of **FIG. 8A** to be capable of receiving up to two (2) tray rails **56** of three (3) fiber optic equipment trays **20** in a 1-U space. Three (3) guide members **68'** are disposed in the guide panel **64'** in the embodiment of **FIG. 8B** to be capable of receiving up to three (3) tray rails **56** of three (3) fiber optic equipment trays **20** in a 1-U space. However, any number of guide members **68,68'** desired may be provided in the tray guides **58,58'** to cover sizes less than or greater than a 1-U space. As illustrated in **FIG. 8A**, the guide members **68** each include guide channels **70** configured to receive and allow tray rails **56** to move along the guide channels **70** for translation of the fiber optic equipment trays **20** about the chassis **12**.

[0048] With reference to **FIG. 8A**, leaf springs **72** are disposed in each of the guide members **68** of the tray guide **58** and are each configured to provide stopping positions for the tray rails **56** during movement of the fiber optic equipment tray **20** in the guide members **68**. The leaf springs **72** are disposed between ends **73** disposed in the guide member **68** to give leaf springs **72** spring action. The leaf springs **72** each contain protrusions **74** that are configured to receive detents **76** (**FIG. 9A and 9B**) disposed in the tray rails **56** to provide stopping or resting positions. The tray rails **56** contain mounting platforms **75** that are used to attach the tray rails **56** to the fiber optic equipment trays **20**. It may be desirable to provide stopping positions in the tray guide **56** to allow the fiber optic equipment trays **20** to have stopping positions when moved in and out of the chassis **12**. Stopping positions allow the technician to impart a certain force to pull or push the fiber optic tray **20** about the guide panel **64** so that the fiber optic equipment tray **20** is retained in place when not pulled or pushed. However, the force can also be designated to allow a technician to easily push in or pull out the fiber optic equipment tray **20** into and from the guide panel **64** when desired, especially when the fiber optic equipment tray **20** is located above the technician. In this regard and by example, two (2) detents **76** in the tray rail **56** are disposed in two (2) protrusions **74** in the tray guide **58** at any given time. When the fiber optic equipment tray **20** is fully retracted into the chassis **12** in a first stopping position, the two (2) detents **76** of the tray rail **56** are disposed in the one protrusion **74** adjacent a rear end **77** of the guide channel **70** and the middle protrusion **74**

disposed between the rear end **77** and a front end **78** of the guide channel **70**. When the fiber optic equipment tray **20** is pulled out from the chassis **12**, the two (2) detents **76** of the tray rail **56** are disposed in the one protrusion **74** adjacent the front end **78** of the guide channel **70** and the middle protrusion **74** disposed between the rear end **77** and the front end **78** of the guide channel **70**. Thus, the stopping or resting positions provided by the engagement of the detents **76** of the leaf springs **72** with the protrusions **74** of the tray rail **56** in this embodiment are provided to require force on the guide panel **64** to overcome the stopping position to translate the tray rail **56** of a fiber optic equipment tray **20** disposed within the guide member **68**.

[0049] In this embodiment, each leaf spring **72** is designed to require approximately two (2) pounds (lbs.) of pulling force to allow protrusion **74** in the leaf spring **72** to overcome the protrusion **74** disposed in the tray rail **56** for a total of four (4) lbs. pulling force (i.e., two (2) detents **76** in the tray rail **56** are engaged with two (2) protrusions **74** disposed in two (2) leaf springs **72**). The pulling force required to overcome the engagement of the protrusion **74** in the detents **76** could be designed to be any pulling force desired. For example, the pulling force required to overcome the engagement of the protrusion **74** in the detents **76** could be designated to be greater than the pulling force required to engage or disengage a fiber optic connector from a fiber optic module **22** supported by the fiber optic equipment tray **20**. The leaf springs 72 in this embodiment are designed to each provide the same force, but such does not have to be the case. Further, the guide panel **64** and tray rail **56** could be designed to provide fewer stopping positions or only provide one protrusion **74** that is engaged with one detent **76** in each stopping or resting position.

[0050] When the tray rail **56** is in a stopped position, two (2) protrusions **74** disposed in two (2) leaf springs **72** are engaged with two (2) detents **76** in the tray rail **56**, as previously discussed. In this embodiment, when the tray rail **56** is in a stopping position, the leaf springs **72** and their protrusions **74** and complimentary detents **76** in the tray rail **56** are designed cooperatively such that the detents **76** do not impart a force on the protrusion **74**. Thus, the leaf springs **72** are in an unstressed state when the tray rail **56** is in a stopped position. This may be advantageous if the leaf springs **72** are made out of a material, such as a polymer material for example, where creep can occur over time, thus reducing the effectiveness of the leaf spring **72** over time. However, this feature is not a requirement for the design. The tray guide **58'** in **FIG. 8B** can also be employed as described above with regard to the tray guide **58** of **FIG. 8A** to support and allow movement of three (3) tray rails **56**.

[0051] As the tray rail **56** is pulled within the guide channel **70**, a protrusion **80** disposed in the tray rail **56** and illustrated in **FIGS. 9A and 9B** is biased to pass over transition members **82** disposed between the leaf springs **72**, as illustrated in **FIG. 8**. The protrusion **80** is provided in a leaf spring **81** disposed in the tray rail **56**, as illustrated in **FIGS. 9A and 9B**. The transition members **82** have inclined surfaces **84** that allow the protrusion **80** to pass over the transition members **82** as the fiber optic equipment tray **20** is being translated with the guide channel **70**. As the protrusion **80** contains the transition members **82**, the force imparted onto the protrusion **80** causes the leaf spring **81** to bend inward to allow the protrusion **80** to pass over the transition member **82**. To prevent the tray rail **56** and thus the fiber optic equipment tray **20** from being extended beyond the front end **78** and rear end **77** of the guide channel **70**, stopping members **86** are disposed at the front end **78** and rear end **77** of the guide channel **70**. The stopping members **86** do not have an inclined surface; thus the protrusion **80** in the tray rail **56** abuts against the stopping member **86** and is prevented from extending over the stopping member **86** and outside of the front end **78** of the guide channel **70**.

[0052] Against the background of the above disclosed embodiment of a 1-U chassis **12** and fiber optic equipment trays **20** and fiber optic modules **22** that can installed therein, the form factor of the fiber optic module **22** will now be described. The form factor of the fiber optic module **22** allows a high density of fiber optic components **23** to be disposed within a certain percentage area of the front of the fiber optic module **22** thus supporting a particular fiber optic connection density and bandwidth for a given type of fiber optic component **23**. When this fiber optic module **22** form factor is combined with the ability to support up to twelve (12) fiber optic modules **22** in a 1-U space, as described by the exemplary chassis **12** example above, a higher fiber optic connection density and bandwidth is supported and possible.

[0053] In this regard, **FIGS. 10A and 10B** are right and left perspective views of the exemplary fiber optic module **22**. As discussed above, the fiber optic module **22** can be installed in the fiber optic equipment trays **20** to provide fiber optic connections in the chassis **12**. The fiber optic module **22** is comprised of a main body **90** receiving a cover **92**. An internal chamber **94** (**FIG. 11**) disposed inside the main body **90** and the cover **92** and is configured to receive or retain optical fibers or a fiber optic cable harness, as will be described in more detail below. The main body **90** is disposed between a front side **96** and a rear side **98** of the main body **90**. Fiber optic components **23** can be disposed through the front side **96** of the main body **90** and configured to receive fiber optic connectors connected to fiber optic cables (not shown). In this example, the fiber optic components **23** are duplex LC fiber optic adapters that are configured to receive and support connections with duplex LC fiber optic connectors. However, any fiber optic connection type desired can be provided in the fiber optic module **22**. The fiber optic components **23** are connected to a fiber optic component **100** disposed through the rear side **98** of the main body **90.** In this manner, a connection to the fiber optic component **23** creates a fiber optic connection to the fiber optic component **100**. In this example, the fiber optic component **100** is a multi-fiber MPO fiber optic adapter equipped to establish connections to multiple optical fibers (e.g., either twelve (12) or twenty-four (24) optical fibers). The fiber optic module **22** may also manage polarity between the fiber optic components **23, 100**.

[0054] The module rails **28A, 28B** are disposed on each side **102A, 102B** of the fiber optic module **22**. As previously discussed, the module rails **28A, 28B** are configured to be inserted within the module rail guides **32** in the fiber optic equipment tray **20**, as illustrated in **FIG. 3**. In this manner, when it is desired to install a fiber optic module **22** in the fiber optic equipment tray **20**, the front side **96** of the fiber optic module **22** can be inserted from either the front end **33** or the rear end **36** of the fiber optic equipment tray **20**, as previously discussed.

[0055] **FIG. 11** illustrates the fiber optic module **22** in an exploded view with the cover **92** of the fiber optic module **22** removed to illustrate the internal chamber **94** and other internal components of the fiber optic module **22**. **FIG. 12** illustrates the fiber optic module **22** assembled, but without the cover **92** installed on the main body **90**. The cover **92** includes notches **106** disposed in sides **108, 110** that are configured to interlock with protrusions **112** disposed on the sides **102A, 102B** of the main body **90** of the fiber optic modules **22** when the cover **92** is attached to the main body **90** to secure the cover **92** to the main body **90**. The cover **92** also contains notches **114, 116** disposed on a front side **118** and rear side **120**, respectively, of the cover **92**. The notches **114**, **116** are configured to interlock with protrusions **122, 124** disposed in the front side **96** and the rear end **98**, respectively, of the main body **90** when the cover **92** is attached to the main body **90** to also secure the cover **92** to the main body **90**. **FIG. 12** does not show protrusions **122, 124**.

[0056] With continuing reference to **FIG. 11**, the fiber optic components **23** are disposed through a front opening **126** disposed along a longitudinal axis $\mathbf{L_1}$ in the front side **96** of the main body **90**. In this embodiment, the fiber optic components **23** are duplex LC adapters **128**, which support single or duplex fiber connections and connectors. The duplex LC adapters **128** in this embodiment contain protrusions **130** that are configured to engage with orifices **135** disposed on the main body **90** to secure the duplex LC adapters **128** in the main body **90** in this embodiment. A cable harness **134** is disposed in the internal chamber **94** with fiber optic connectors **136, 138** disposed on each end of optical fibers **139** connected to the duplex LC adapters **128** and the fiber optic component **100** disposed in the rear side **98** of the main body **90**. The fiber optic component 100 in this embodiment is a twelve (12) fiber MPO fiber optic adapter **140** in this embodiment. Two vertical members **142A, 142B** (i.e., fiber guides) are disposed in the internal chamber **94** of the main body **90**, as illustrated in **FIG. 12**, to retain the looping of the optical fibers **139** of the cable harness **134**. The vertical members **142A, 142B** and the distance therebetween are designed to provide a bend radius **R** in the optical fibers **139** no greater than forty (40) millimeters and preferably twenty-five (25) millimeters or less, thereby aiding in maintaining a high fiber optic connector density.

[0057] Other structures besides vertical members **142A,142B** of **FIG. 12** are possible for fiber guides that retain and/or route the cable harness **134** within the module to inhibit damage, organize, maintain a bend radius and/or make the device easier to assemble. The fiber guide structure is also useful for maintaining a bend radius **R** for the optical fibers. By way of example, **FIG. 12A** shows a perspective top view of another fiber optic module **22** with the cover removed showing the fiber optic harness **134** installed within a plurality of fiber guides **143,144** for retaining and routing the optical fibers of fiber optic harness **134**. Any suitable shape for the fiber guides are possible along with a suitable number of fiber guides in the module. Moreover, one or more of the fiber guides can be shaped to accommodate a furcation body for the ribbon to individual fiber transition or the like. In this embodiment, fiber guides **143,144** have two different shapes and have three different locations. Specifically, fiber guides **143** are configured as L-guides and are located at a suitably spaced apart locations and fiber guide **144** is a J-guide spaced apart from fiber guides **143**. Consequently, the assembler can easily and quickly install the cable harness **134** into the internal chamber **94** of main body **90** using fiber guides **143,144**. Moreover, the fiber guides **143,144** ensure an adequate bend radius for the optical fibers of the fiber optic harness **134** and inhibits pinching of the optical fibers when installing the cover. Fiber guides **143,144** may be configured in any suitable arrangement such molded with main body **90** or configured separate components. For instance, other arrangements may have retention pins molded into main body **90** for receiving and securing discrete fiber guides using a friction fit and/or adhesive; however, this adds manufacturing complexity.

[0058] **FIG. 13** illustrates a front view of the fiber optic module **22** without loaded fiber optic components **23** in the front side **96** to further illustrate the form factor of the fiber optic module **22**. As previously discussed, the front opening **126** is disposed through the front side **96** of the main body **90** to receive the fiber optic components **23**. The greater the width $\mathbf{W_1}$ of the front opening **126**, the greater the number of fiber optic components **23** that may be disposed in the fiber optic module **22**. Greater numbers of fiber optic components **23** equates to more fiber optic connections, which supports higher fiber optic connectivity and bandwidth. However, the larger the width $\mathbf{W_1}$ of the front opening **126**, the greater the area required to be provided in the chassis **12** for the fiber optic module **22**. Thus, in this embodiment, the width $\mathbf{W_1}$ of the front opening **126** is design to be at least eighty-five percent (85%) of the width $\mathbf{W_2}$ of the front side **96** of the main body **90** of the fiber optic module **22**. The greater the percentage of the width $\mathbf{W_1}$ to width $\mathbf{W_2}$, the larger the area provided in the front opening **126** to receive fiber optic components **23** without increasing width $\mathbf{W_2}$. Width $\mathbf{W_3}$, the overall width of the fiber optic module **22**, may be 86.6 mm or 3.5 inches in this embodiment. The overall depth $\mathbf{D_1}$ of the fiber optic module **22** is 113.9 mm or 4.5 inches in this embodiment (**FIG. 12**).

As previously discussed, the fiber optic module **22** is designed such that four (4) fiber optic modules **22** can be disposed in a 1-U width space in the fiber optic equipment tray **20** in the chassis **12**. The width of the chassis **12** is designed to accommodate a 1-U space width in this embodiment.

[0059] With three (3) fiber optic equipment trays **20** disposed in the 1-U height of the chassis **12**, a total of twelve (12) fiber optic modules **22** can be supported in a given 1-U space. Supporting up to twelve (12) fiber optic connections per fiber optic module **22** as illustrated in the chassis **12** in **FIG. 1** equates to the chassis **12** supporting up to one hundred forty-four (144) fiber optic connections, or seventy-two (72) duplex channels, in a 1-U space in the chassis **12** (i.e., twelve (12) fiber optic connections X twelve (12) fiber optic modules **22** in a 1-U space). Thus, the chassis **12** is capable of supporting up to one hundred forty-four (144) fiber optic connections in a 1-U space by twelve (12) simplex or six (6) duplex fiber optic adapters being disposed in the fiber optic modules **22**. Supporting up to ten (10) fiber optic connections per fiber optic module **22** equates to the chassis **12** supporting one hundred twenty (120) fiber optic connections, or sixty (60) duplex channels, in a 1-U space in the chassis **12** (i.e., ten (10) fiber optic connections X twelve (12) fiber optic modules **22** in a 1-U space). Thus, the chassis **12** is also capable of supporting up to one hundred twenty (120) fiber optic connections in a 1-U space by ten (10) simplex or five (5) duplex fiber optic adapters being disposed in the fiber optic modules **22**.

[0060] This embodiment of the chassis **12** and fiber optic module **22** disclosed herein can support a fiber optic connection density within a 1-U space wherein the area occupied by the fiber optic component **23** in twelve (12) fiber optic modules **22** in a 1-U space represents at least fifty percent (50%) of the total fiber optic equipment rack **14** area in a 1-U space (see **FIG. 1**). In the case of twelve (12) fiber optic modules **22** provided in a 1-U space in the chassis **12**, the 1-U space is comprised of the fiber optic components **23** occupying at least seventy-five percent (75%) of the area of the front side **96** of the fiber optic module **22**.

[0061] Two (2) duplexed optical fibers to provide one (1) transmission/reception pair can allow for a data rate of ten (10) Gigabits per second in half-duplex mode or twenty (20) Gigabits per second in full-duplex mode. Thus, with the above-described embodiment, providing at least seventy-two (72) duplex transmission and reception pairs in a 1-U space employing at least one duplex or simplex fiber optic component can support a data rate of at least seven hundred twenty (720) Gigabits per second in half-duplex mode in a 1-U space or at least one thousand four hundred forty (1440) Gigabits per second in a 1-U space in full-duplex mode if employing a ten (10) Gigabit transceiver. This configuration can also support at least six hundred (600) Gigabits per second in half-duplex mode in a 1-U space and at least one thousand two hundred (1200) Gigabits per second in full-duplex mode in a 1-U space, respectively, if employing a one hundred (100) Gigabit transceiver. This configuration can also support at least four hundred eighty (480) Gigabits per second in half-duplex mode in a 1-U space and nine hundred sixty (960) Gigabits per second in full duplex mode in a 1-U space, respectively, if employing a forty (40) Gigabit transceiver. At least sixty (60) duplex transmission and reception pairs in a 1-U space can allow for a data rate of at least six hundred (600) Gigabits per second in a 1-U space in half-duplex mode or at least one thousand two hundred (1200) Gigabits per second in a 1-U space in full-duplex mode when employing a ten (10) Gigabit transceiver. At least forty nine (49) duplex transmission and reception pairs in a 1-U space can allow for a data rate of at least four hundred eighty-one (481) Gigabits per second in half-duplex mode or at least nine hundred sixty-two (962) Gigabits per second in a 1-U space in full-duplex mode when employing a ten (10) Gigabit transceiver.

[0062] The width $\mathbf{W_1}$ of front opening **126** could be designed to be greater than eighty-five percent (85%) of the width $\mathbf{W_2}$ of the front side **96** of the main body **90** of the fiber optic module **22**. For example, the width $\mathbf{W_1}$ could be designed to be between ninety percent (90%) and ninety-nine percent (99%) of the width $\mathbf{W_2}$. As an example, the width $\mathbf{W_1}$ could be less than ninety (90) mm. As another example, the width $\mathbf{W_1}$ could be less than eighty-five (85) mm or less than eighty (80) mm. For example, the width $\mathbf{W_1}$ may be eighty-three (83) mm and width $\mathbf{W_2}$ may be eighty-five (85) mm, for a ratio of width $\mathbf{W_1}$ to width $\mathbf{W_2}$ of 97.6%. In this example, the front opening **126** may support twelve (12) fiber optic connections in the width $\mathbf{W_1}$ to support a fiber optic connection density of at least one fiber optic connection per 7.0 mm of width $\mathbf{W_1}$ of the front opening **126**. Further, the front opening **126** of the fiber optic module **22** may support twelve (12) fiber optic connections in the width $\mathbf{W_1}$ to support a fiber optic connection density of at least one fiber optic connection per 6.9 mm of width $\mathbf{W_1}$ of the front opening **126**.

[0063] Further as illustrated in **FIG. 13**, height $\mathbf{H_1}$ of front opening **126** could be designed to be at least ninety percent (90%) of height $\mathbf{H_2}$ of the front side **96** of the main body **90** of the fiber optic module **22**. In this manner, the front opening **126** has sufficient height to receive the fiber optic components **23**, and such that three (3) fiber optic modules **22** can be disposed in a 1-U space height. As an example, height $\mathbf{H_1}$ could be twelve (12) mm or less or ten (10) mm or less. As an example, height $\mathbf{H_1}$ could be ten (10) mm and height $\mathbf{H_2}$ could be eleven (11) mm (or 7/16 inches), for a ratio of height $\mathbf{H_1}$ to width $\mathbf{H_2}$ of 90.9%.

[0064] Alternate fiber optic modules with alternative fiber optic connection densities are possible. **FIG. 14** is a front perspective view of an alternate fiber optic module **22'** that can be installed in the fiber optic equipment tray **20** of **FIG. 1**. The form factor of the fiber optic module **22'** is the same as the form factor of the fiber optic module **22** illustrated in **FIGS. 1-13**. However, in the fiber optic module **22'** of **FIG. 14**, two (2) MPO fiber optic adapters **150** are disposed through the front opening **126** of the fiber optic module **22'**. The MPO fiber optic adapters **150** are connected to two (2) MPO fiber optic adapters **152** disposed in the rear side **98** of the main body **90** of the fiber optic module **22'**. Thus, if the MPO fiber optic adapters **150** each support twelve (12) fibers, the fiber optic module **22'** can support up to twenty-four (24) fiber optic connections. Thus, in this example, if up to twelve (12) fiber optic modules **22'** are provided in the fiber optic equipment trays **20** of the chassis **12**, up to two hundred eighty-eight (288) fiber optic connections can be supported by the chassis **12** in a 1-U space. Further in this example, the front opening **126** of the fiber optic module **22'** may support twenty-four (24) fiber optic connections in the width $\mathbf{W_1}$ (**FIG. 13**) to support a fiber optic connection density of at least one fiber optic connection per 3.4-3.5 mm of width $\mathbf{W_1}$ of the front opening **126**. It should be understood that the discussion with regard to modules may also apply to a panel. For purposes of this disclosure, a panel may have one or more adapters on one side and no adapters on the opposite side.

[0065] Thus, with the above-described embodiment, providing at least two-hundred eighty-eight (288) duplex transmission and reception pairs in a 1-U space employing at least one twelve (12) fiber MPO fiber optic components can support a data rate of at least two thousand eight hundred eighty (2880) Gigabits per second in half-duplex mode in a 1-U space or at least five thousand seven hundred sixty (5760) Gigabits per second in a 1-U space in full-duplex mode if employing a ten (10) Gigabit transceiver. This configuration can also support at least four thousand eight hundred (4800) Gigabits per second in half-duplex mode in a 1-U space and nine thousand six hundred (9600) Gigabits per second in full-duplex mode in a 1-U space, respectively, if employing a one hundred (100) Gigabit transceiver. This configuration can also support at least one thousand nine hundred twenty (1920) Gigabits per second in half-duplex mode in a 1-U space and three thousand eight hundred forty (3840) Gigabits per second in full-duplex mode in a 1-U space, respectively, if employing a forty (40) Gigabit transceiver. This configuration also supports a data rate of at least four thousand three hundred twenty-two (4322) Gigabits per second in full-duplex mode in a 1-U space when employing a ten (10) Gigabit transceiver employing at least one twelve (12) fiber MPO fiber optic component, or two thousand one hundred sixty-one (2161) Gigabits per second in full-duplex mode in a 1-U space when employing a ten (10) Gigabit transceiver employing at least one twenty-four (24) fiber MPO fiber optic component.

[0066] If the MPO fiber optic adapters **150** in the fiber optic module **22'** support twenty-four (24) fibers, the fiber optic module **22'** can support up to forty-eight (48) fiber optic connections. Thus, in this example, if up to twelve (12) fiber optic modules **22'** are provided in the fiber optic equipment trays **20** of the chassis **12**, up to five hundred seventy-six (576) fiber optic connections can be supported by the chassis **12** in a 1-U space if the fiber optic modules **22'** are disposed in the fiber optic equipment trays **20**. Further, in this example, the front opening **126** of the fiber optic module **22'** may support up to forty-eight (48) fiber optic connections in the width $\mathbf{W_1}$ to support a fiber optic connection density of at least one fiber optic connection per 1.7 mm of width $\mathbf{W_1}$ of the front opening **126**.

[0067] **FIG. 15** is a front perspective view of another alternate fiber optic module **22''** that can be installed in the fiber optic equipment tray **20** of **FIG. 1**. The form factor of the fiber optic module **22''** is the same as the form factor of the fiber optic module **22** illustrated in **FIGS. 1-13**. However, in the fiber optic module **22''**, four (4) MPO fiber optic adapters **154** are disposed through the front opening **126** of the fiber optic module **22''**. The MPO fiber optic adapters **154** are connected to four (4) MPO fiber optic adapters **156** disposed in the rear end **98** of the main body **90** of the fiber optic module **22'**. Thus, if the MPO fiber optic adapters **150** support twelve (12) fibers, the fiber optic module **22''** can support up to forty-eight (48) fiber optic connections. Thus, in this example, if up to twelve (12) fiber optic modules **22''** are provided in the fiber optic equipment trays **20** of the chassis **12**, up to five hundred seventy-six (756) fiber optic connections can be supported by the chassis **12** in a 1-U space. Further in this example, the front opening **126** of the fiber optic module **22''** may support twenty-four (24) fiber optic connections in the width $\mathbf{W_1}$ to support a fiber optic connection density of at least one fiber optic connection per 1.7 mm of width $\mathbf{W_1}$ of the front opening **126**.

[0068] If the four (4) MPO fiber optic adapters **154** disposed in the fiber optic module **22''** support twenty-four (24) fibers, the fiber optic module **22''** can support up to ninety-six (96) fiber optic connections. Thus, in this example, if up to twelve (12) fiber optic modules **22''** are provided in the fiber optic equipment trays **20** of the chassis **12**, up to one thousand one hundred fifty-two (1152) fiber optic connections can be supported by the chassis **12** in a 1-U space. Further, in this example, the front opening **126** of the fiber optic module **22''** may support up to ninety-six (96) fiber optic connections in the width $\mathbf{W_1}$ to support a fiber optic connection density of at least one fiber optic connection per 0.85 mm of width $\mathbf{W_1}$ of the front opening **126**.

[0069] Further, with the above-described embodiment, providing at least five hundred seventy-six (576) duplex transmission and reception pairs in a 1-U space employing at least one twenty-four (24) fiber MPO fiber optic component can support a data rate of at least five thousand seven hundred sixty (5760) Gigabits per second in half-duplex mode in a 1-U space or at least eleven thousand five hundred twenty (11520) Gigabits per second in a 1-U space in full-duplex mode if employing a ten (10) Gigabit transceiver. This configuration can also support at least four thousand eight hundred (4800) Gigabits per second in half-duplex mode in a 1-U space and at least nine thousand six hundred (9600) Gigabits per second in full-duplex mode in a 1-U space, respectively, if employing a one hundred (100) Gigabit transceiver. This configuration can also support at least three thousand eight hundred forty (3840) Gigabits per second in half-duplex mode in a 1-U space and at least seven thousand six hundred eighty (7680) Gigabits per second in full-duplex mode in a 1-U space, respectively, if employing a forty (40) Gigabit transceiver. This configuration also supports a data rate of at least eight thousand six hundred forty two (8642) Gigabits per second in full-duplex mode in a 1-U space when employing a ten (10) Gigabit transceiver employing at least one twenty-four (24) fiber MPO fiber optic component, or four thousand three hundred twenty one (4321) Gigabits per second in full-duplex mode in a 1-U space when employing a ten (10) Gigabit transceiver employing at least one twenty-four (24) fiber MPO fiber optic component.

[0070] **FIG. 16** illustrates an alternate fiber optic module **160** that may be provided in the fiber optic equipment trays **20** to support fiber optic connections and connection densities and bandwidths. **FIG. 17** is a right front perspective view of the fiber optic module **160** of **FIG. 16**. In this embodiment, the fiber optic module **160** is designed to fit across two sets of module rail guides **32**. A channel **162** is disposed through a center axis **164** of the fiber optic module **160** to receive a module rail guide **32** in the fiber optic equipment tray **20**. Module rails **165A, 165B**, similar to the module rails **28A, 28B** of the fiber optic module **22** of **FIGS. 1-13**, are disposed on the inside the channel **162** of the fiber optic module **160** and configured to engage with tray channels **30** in the fiber optic equipment tray **20**. Module rails **166A, 166B**, similar to the module rails **28A, 28B** of the fiber optic module **22** of **FIGS. 1-13**, are disposed on each side **168, 170** of the fiber optic module **160** that are configured to engage with tray channels **30** in the fiber optic equipment tray **20**. The module rails **166A, 166B** are configured to engage with tray channels **30** in a module rail guide **32** disposed between module rail guides **32** engaged with the module rail guides **32** disposed on the sides **168, 170** of the fiber optic module **160**.

[0071] Up to twenty-four (24) fiber optic components **23** can be disposed in a front side **172** of the fiber optic module **160**. In this embodiment, the fiber optic components **23** are comprised of up to twelve (12) duplex LC fiber optic adapters, which are connected to one twenty-four (24) fiber MPO fiber optic connector **174** disposed in a rear end **176** of the fiber optic module **160**. Thus, with three (3) fiber optic equipment trays **20** disposed in the height of the chassis **12**, a total of six (6) fiber optic modules **160** can be supported in a given 1-U space. Supporting up to twenty-four (24) fiber optic connections per fiber optic module **160** equates to the chassis **12** supporting up to one hundred forty-four (144) fiber optic connections, or seventy-two (72) duplex channels, in a 1-U space in the chassis **12** (i.e., twenty-four (24) fiber optic connections X six (6) fiber optic modules **160** in a 1-U space). Thus, the chassis **12** is capable of supporting up to one hundred forty-four (144) fiber optic connections in a 1-U space by twenty-four (24) simplex or twelve (12) duplex fiber optic adapters being disposed in the fiber optic modules **160**. Supporting up to twenty (20) fiber optic connections per fiber optic module **160** equates to the chassis **12** supporting one hundred twenty (120) fiber optic connections, or sixty (60) duplex channels, in a 1-U space in the chassis **12** (i.e., twenty (20) fiber optic connections X six (6) fiber optic modules **160** in a 1-U space). Thus, the chassis **12** is also capable of supporting up to one hundred twenty (120) fiber optic connections in a 1-U space by twenty (20) simplex or ten (10) duplex fiber optic adapters being disposed in the fiber optic modules **160**.

[0072] **FIG. 18** illustrates a front view of the fiber optic module **160** of **FIGS. 16-17** without loaded fiber optic components **23** in the front side **172** to further illustrate the form factor of the fiber optic module **160** in this embodiment. Front openings **178A, 178B** disposed on each side of the channel **162** are disposed through the front side **172** of a main body **180** of the fiber optic module **160** to receive the fiber optic components **23**. The widths $\mathbf{W_1}$ and $\mathbf{W_2}$ and the heights $\mathbf{H_1}$ and $\mathbf{H_2}$ are the same as in the fiber optic module **22** illustrated in **FIG. 13**. Thus, in this embodiment, the widths $\mathbf{W_1}$ of front openings **178A, 178B** are designed to be at least eighty-five percent (85%) of the width $\mathbf{W_2}$ of the front side **172** of the main body **180** of the fiber optic module **160**. The greater the percentage of the width $\mathbf{W_1}$ to width $\mathbf{W_2}$, the larger the area provided in the front openings **178A, 178B** to receive fiber optic components **23** without increasing width $\mathbf{W_2}$.

[0073] The width $\mathbf{W_1}$ of the front openings **178A, 178B** could each be designed to be greater than eighty-five percent (85%) of the width $\mathbf{W_2}$ of the front side **172** of the main body **180** of the fiber optic module **160**. For example, the width $\mathbf{W_1}$ could be designed to be between ninety percent (90%) and ninety-nine percent (99%) of the width $\mathbf{W_2}$. As an example, the width $\mathbf{W_1}$ could be less than ninety (90) mm. As another example, the width $\mathbf{W_1}$ could be less than eighty-five (85) mm or less than eighty (80) mm. For example, width W_1 may be eighty-three (83) mm and width W_2 may be eighty-five (85) mm, for a ratio of width W_1 to width W_2 of 97.6%. In this example, the front openings **178A, 178B** may support twelve (12) fiber optic connections in the widths W_1 to support a fiber optic connection density of at least one fiber optic connection per 7.0 mm of width W_1 of the front openings **178A, 178B**. Further, each of the front openings **178A, 178B** may support twelve (12) fiber optic connections in the widths W_1 to support a fiber optic connection density of at least one fiber optic connection per 6.9 mm of width W_1 of the front openings **178A, 178B**.

[0074] Further as illustrated in **FIG. 18**, the height H_1 of front openings **178A, 178B** could be designed to be at least ninety percent (90%) of the height H_2 of the front side **172** of the main body **180** of the fiber optic module **160**. In this manner, the front openings **178A, 178B** have sufficient height to receive the fiber optic components **23**, while three (3) fiber optic modules **160** can be disposed in the height of a 1-U space. As an example, the height H_1 could be twelve (12) mm or less or ten (10) mm or less. As an example, the height H_1 could be ten (10) mm and height H_2 could be eleven (11) mm, for a ratio of height H_1 to height H_2 of 90.9%.

[0075] **FIG. 19** illustrates another alternate fiber optic module **190** that may be provided in the fiber optic equipment trays **20** to support fiber optic connections and connection densities and bandwidths. **FIG. 20** is a right front perspective view of the fiber optic module **190** of **FIG. 19**. In this embodiment, the fiber optic module **190** is designed to fit across two sets of module rail guides **32**. A longitudinal receiver **192** is disposed through a center axis **194** and is configured to receive a module rail guide **32** in the fiber optic equipment tray **20** through an opening **193** in the receiver **192**. Module rails **195A, 195B**, similar to the module rails **28A, 28B** of the fiber optic module **22** of **FIGS. 1-13**, are disposed on each side **198, 200** of the fiber optic module **190** that are configured to engage with tray channels **30** in the fiber optic equipment tray **20**.

[0076] Up to twenty-four (24) fiber optic components **23** can be disposed in a front side **202** of the fiber optic module **190**. In this embodiment, the fiber optic components **23** are comprised of up to twelve (12) duplex LC fiber optic adapters, which are connected to one twenty-four (24) fiber MPO fiber optic connector **204** disposed in a rear end **206** of the fiber optic module **190**. Thus, with three (3) fiber optic equipment trays

20 disposed in the height of the chassis **12**, a total of six (6) fiber optic modules **190** can be supported in a given 1-U space. Supporting up to twenty-four (24) fiber optic connections per fiber optic module **190** equates to the chassis **12** supporting up to one hundred forty-four (144) fiber optic connections, or seventy-two (72) duplex channels, in a 1-U space in the chassis **12** (i.e., twenty-four (24) fiber optic connections X six (6) fiber optic modules **190** in a 1-U space). Thus, the chassis **12** is capable of supporting up to one hundred forty-four (144) fiber optic connections in a 1-U space by twenty (24) simplex or twelve (12) duplex fiber optic adapters being disposed in the fiber optic modules **190**. Supporting up to twenty-four (20) fiber optic connections per fiber optic module **190** equates to the chassis **12** supporting one hundred twenty (120) fiber optic connections, or sixty (60) duplex channels, in a 1-U space in the chassis **12** (i.e., twenty (20) fiber optic connections X six (6) fiber optic modules **190** in a 1-U space). Thus, the chassis **12** is also capable of supporting up to one hundred twenty (120) fiber optic connections in a 1-U space by twenty (20) simplex or ten (10) duplex fiber optic adapters being disposed in the fiber optic modules **190**.

[0077] **FIG. 21** illustrates a front view of the fiber optic module **190** of **FIGS. 19-20** without loaded fiber optic components **23** in the front side **202** to further illustrate the form factor of the fiber optic module **190**. Front openings **208A, 208B** are disposed on each side of the receiver **192** and through the front side **202** of a main body **210** of the fiber optic module **190** to receive the fiber optic components **23**. The widths $\mathbf{W_1}$ and $\mathbf{W_2}$ and the heights $\mathbf{H_1}$ and $\mathbf{H_2}$ are the same as in the fiber optic module **22** as illustrated in **FIG. 13**. Thus, in this embodiment, the width $\mathbf{W_1}$ of front openings **208A, 208B** is designed to be at least eighty-five percent (85%) of the width $\mathbf{W_2}$ of the front side **202** of the main body **210** of the fiber optic module **190**. The greater the percentage of the width $\mathbf{W_1}$ to width $\mathbf{W_2}$, the larger the area provided in the front openings **208A, 208B** to receive fiber optic components **23** without increasing the width $\mathbf{W_2}$.

[0078] The width $\mathbf{W_1}$ of front openings **208A, 208B** could each be designed to be greater than eighty-five percent (85%) of the width $\mathbf{W_2}$ of the front side **202** of the main body **210** of the fiber optic module **190**. For example, the width $\mathbf{W_1}$ could be designed to be between ninety percent (90%) and ninety-nine percent (99%) of the width $\mathbf{W_2}$. As an example, the width $\mathbf{W_1}$ could be less than ninety (90) mm. As another example, the width W_1 could be less than eighty-five (85) mm or less than eighty (80) mm. For example, width W_1 may be eighty-three (83) mm and width W_2.may be eighty-five (85) mm, for a ratio of width W_1 to width W_2 of 97.6%. In this example, the front openings **208A, 208B** may support twelve (12) fiber optic connections in the widths W_1 to support fiber optic connection density of at least one fiber optic connection per 7.0 mm of width W_1 of the front openings **208A, 208B**. Further, each of the front openings **208A, 208B** may support twelve (12) fiber optic connections in the widths W_1 to support a fiber optic connection density of at least one fiber optic connection per 6.9 mm of width W_1 of the front openings **208A, 208B**.

[0079] Further as illustrated in **FIG. 21**, the height H_1 of front openings **208A, 208B** could be designed to be at least ninety percent (90%) of the height H_2 of the front side **202** of the main body **210** of the fiber optic module **190**. In this manner, the front openings **208A, 208B** have sufficient height to receive the fiber optic components **23**, while three (3) fiber optic modules **190** can be disposed in the height of a 1-U space. As an example, the height H_1 could be twelve (12) mm or less or ten (10) mm or less. As an example, the height H_1 could be ten (10) mm and the height H_2 could be eleven (11) mm, for a ratio of height H_1 to height H_2 of 90.9%.

[0080] **FIG. 22** illustrates another alternate fiber optic module **220** that may be provided in a fiber optic equipment tray **20'** to support a higher number of fiber optic connections and connection densities and bandwidths in a 1-U space. The fiber optic equipment tray **20'** in this embodiment is similar to the fiber optic equipment tray **20** previously discussed above; however, the fiber optic equipment tray **20'** only contains three (3) module rail guides **32** instead of five (5) module rail guides **32**. Thus, the fiber optic equipment tray **20'** only supports two fiber optic modules **220** across a 1-U width space. Thus, the fiber optic module **220** does not have to provide the channel **162** or receiver **192** of the fiber optic modules **160, 190**, respectively, to be disposed within the fiber optic equipment tray **20'**. **FIG. 23** is a right front perspective view of the fiber optic module **220** of **FIG. 22**. The fiber optic module **220** is designed to fit across one set of module rail guides **32** in the fiber optic equipment tray **20'**. Module rails **225A, 225B**, similar to the module rails **28A, 28B** of the fiber optic module **22** of **FIGS. 1-13**, are disposed on each side **228, 230** of the fiber optic module **220** that are configured to engage with tray channels **30** in the fiber optic equipment tray **20'**, as illustrated in **FIG. 22**.

[0081] Up to twenty-four (24) fiber optic components **23** can be disposed in a front side **232** of the fiber optic module **220**. In this embodiment, the fiber optic components **23** are comprised of up to twelve (12) duplex LC fiber optic adapters, which are connected to one twenty-four (24) fiber MPO fiber optic connector **234** disposed in a rear end **236** of the fiber optic module **220**. Thus, with three (3) fiber optic equipment trays **20'** disposed in the height of the chassis **12**, a total of six (6) fiber optic modules **220** can be supported in a given 1-U space. Supporting up to twenty-four (24) fiber optic connections per fiber optic module **220** equates to the chassis **12** supporting up to one hundred forty-four (144) fiber optic connections, or seventy-two (72) duplex channels, in a 1-U space in the chassis **12** (i.e., twenty-four (24) fiber optic connections X six (6) fiber optic modules **220** in a 1-U space). Thus, the chassis **12** is capable of supporting up to one hundred forty-four (144) fiber optic connections in a 1-U space by twenty (24) simplex or twelve (12) duplex fiber optic adapters being disposed in the fiber optic modules **220**. Supporting up to twenty (20) fiber optic connections per fiber optic module **220** equates to the chassis **12** supporting one hundred twenty (120) fiber optic connections, or sixty (60) duplex channels, in a 1-U space in the chassis **12** (i.e., twenty (20) fiber optic connections X six (6) fiber optic modules **220** in a 1-U space). Thus, the chassis **12** is also capable of supporting up to one hundred twenty (120) fiber optic connections in a 1-U space by twenty (20) simplex or ten (10) duplex fiber optic adapters being disposed in the fiber optic modules **220**.

[0082] **FIG. 24** illustrates a front view of the fiber optic module **220** of **FIGS. 22-23** without loaded fiber optic components **23** in the front side **232** to further illustrate the form factor of the fiber optic module **220** in this embodiment. A front opening **238** is through the front side **232** of a main body **240** of the fiber optic module **220** to receive the fiber optic components **23**. Width $\mathbf{W_4}$ of the front opening **238** is about twice the width $\mathbf{W_1}$ of the front opening **98** in the fiber optic module **22** illustrated in **FIG. 13**. Width $\mathbf{W_5}$ of the front side **232** is about one-hundred eighty-eight (188) millimeters, which is slightly greater than about twice the width $\mathbf{W_3}$ of the fiber optic module **22** illustrated in **FIG. 13**. The heights $\mathbf{H_1}$ and $\mathbf{H_2}$ are the same as in the fiber optic module **22** illustrated in **FIG. 13**. Thus, in this embodiment, the width **W_4** of the front opening **238** is designed to be at least eighty-five percent (85%) of the width **W_5** of the front side **232** of the main body **240** of the fiber optic module **220**. The greater the percentage of the width **W_4** to the width **W_5**, the larger the area provided in the front opening **238** to receive fiber optic components **23** without increasing the width **W_4**.

[0083] Width **W_4** of the front opening **238** could be designed to be greater than eighty-five percent (85%) of the width **W_5** of the front side **232** of the main body **240** of the fiber optic module **220**. For example, the width **W_4** could be designed to be between ninety percent (90%) and ninety-nine percent (99%) of the width of **W_5**. As an example, the width **W_4** could be less than one hundred eighty (180) mm. As another example, the width **W_4** could be less than one hundred seventy (170) mm or less than one hundred sixty (160) mm. For example, width **W_4** may be one hundred sixty-six (166) mm and width **W_5** may be 171 millimeters, for a ratio of width **W_4** to width **W_5** of 166/171=97%. In this example, the front opening **238** may support twenty-four (24) fiber optic connections in the width **W_4** to support a fiber optic connection density of at least one fiber optic connection per 7.0 mm of width **W_4** of the front opening **238**. Further, the front opening **238** may support twenty-four (24) fiber optic connections in the width **W_4** to support a fiber optic connection density of at least one fiber optic connection per 6.9 mm of width **W_4** of the front opening **238**.

[0084] Further, as illustrated in **FIG. 24**, the height **H_1** of the front opening **238** could be designed to be at least ninety percent (90%) of the height **H_2** of the front side **232** of the main body **240** of the fiber optic module **220**. In this manner, the front opening **238** has sufficient height to receive the fiber optic components **23**, while three (3) fiber optic modules **220** can be disposed in the height of a 1-U space. As an example, the height **H_1** could be twelve (12) mm or less or ten (10) mm or less. As an example, the height **H_1** could be ten (10) mm and height **H_2** could be eleven (11) mm, for a ratio of height **H_1** to height **H_2** of 90.9%.

[0085] **FIG. 25** illustrates another embodiment of fiber optic equipment **260** that can include fiber optic equipment trays previously described above and illustrated to support fiber optic modules. The fiber optic equipment **260** in this embodiment includes a 4-U sized chassis **262** configured to hold fiber optic equipment trays each supporting one or more fiber optic modules. The supported fiber optic equipment trays may be any of the fiber optic equipment trays **20, 20'** previously described above and thus will not be described again here. The supported fiber optic modules may be any of the fiber optic modules **22, 22', 22", 160, 190, 220** previously described above and thus will not be described again here. In this example, the chassis **262** is illustrated as supporting twelve (12) fiber optic equipment trays **20** each capable of supporting fiber optic modules **22**.

[0086] The tray guides **58** previously described are used in the chassis **262** to support tray rails **56** of the fiber optic equipment trays **20** therein and to allow each fiber optic equipment tray **20** to be independently extended out from and retracted back into the chassis **262**. A front door **264** is attached to the chassis **262** and is configured to close about the chassis **262** to secure the fiber optic equipment trays **20** contained in the chassis **262**. A cover **266** is also attached to the chassis **262** to secure the fiber optic equipment trays **20**. However, in the chassis **262**, up to twelve (12) fiber optic equipment trays **20** can be provided. However, the fiber optic connection densities and connection bandwidths are still the same per 1-U space. The fiber optic connection densities and connection bandwidth capabilities have been previously described and equally applicable for the chassis **4262** of **FIG. 25**, and thus will not be described again here.

[0087] Thus, in summary, the table below summarizes some of the fiber optic connection densities and bandwidths that are possible to be provided in a 1-U and 4-U space employing the various embodiments of fiber optic modules, fiber optic equipment trays, and chassis described above. For example, two (2) optical fibers duplexed for one (1) transmission/reception pair can allow for a data rate of ten (10) Gigabits per second in half-duplex mode or twenty (20) Gigabits per second in full-duplex mode. As another example, eight (8) optical fibers in a twelve (12) fiber MPO fiber optic connector duplexed for four (4) transmission/reception pairs can allow for a data rate of forty (40) Gigabits per second in half-duplex mode or eighty (80) Gigabits per second in full-duplex mode. As another example, twenty optical fibers in a twenty-four (24) fiber MPO fiber optic connector duplexed for ten (10) transmission/reception pairs can allow for a data rate of one hundred (100) Gigabits per second in half-duplex mode or two hundred (200) Gigabits per second in full-duplex mode. Note that this table is exemplary and the embodiments disclosed herein are not limited to the fiber optic connection densities and bandwidths provided below.

Connector Type	Max Fibers per 1RU	Max Fibers per 4RU	Number of Connectors per 1 RU Space	Number of Connectors per 4 RU Space	Bandwidth per 1U using 10 Gigabit Transceivers (duplex)	Bandwidth per 1U using 40 Gigabit Transceivers (duplex)	Bandwidth per 1U using 100 Gigabit Transceivers (duplex)
Duplexed LC	144	576	72	288	1,440 Gigabits/s.	960 Gigabits/s.	1,200 Gigabits/s.
12-F MPO	576	2,304	48	192	5,760 Gigabits/s.	3,840 Gigabits/s.	4,800 Gigabits/s.
24-F MPO	1,152	4,608	48	192	11,520 Gigabits/s.	7,680 Gigabits/s.	9,600 Gigabits/s.

[0088] Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which the invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. These modifications include, but are not limited to, number or type of fiber optic equipment, fiber optic module, fiber optic equipment tray, features included in the fiber optic equipment tray. Any size equipment, including but not limited to 1-U, 2-U and 4-U sizes may include some or all of the aforementioned features and fiber optic modules disclosed herein and some or all of their features. Further, the modifications are not limited to the type of fiber optic equipment tray or the means or device to support fiber optic modules installed in the fiber optic equipment trays. The fiber optic modules can include any fiber optic connection type, including but not limited to fiber optic connectors and adapters, and number of fiber optic connections, density, etc.

[0089] Further, as used herein, it is intended that the terms “fiber optic cables” and/or “optical fibers” include all types of single mode and multi-mode light waveguides, including one or more bare optical fibers, loose-tube optical fibers, tight-buffered optical fibers, ribbonized optical fibers, bend-insensitive optical fibers, or any other expedient of a medium for transmitting light signals.

[0090] Therefore, it is to be understood that the embodiments are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. It is intended that the embodiments cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A fiber optic module housing, comprising:

a main body defining an internal chamber disposed between a front side and a rear side; and

a front opening disposed along a longitudinal axis in the front side and configured to receive a plurality of fiber optic components;

wherein a width of the front opening is at least eighty-five percent (85%) of the width of the front side.

2. A fiber optic module housing, comprising:

a main body defining an internal chamber disposed between a front side and a rear side; and

a front opening disposed along a longitudinal axis in the front side and configured to support a fiber optic connection density of at least one fiber optic connection per 7.0 millimeters (mm) of width of the front opening.

3. A fiber optic module housing, comprising:

a main body defining an internal chamber disposed between a front side and a rear side; and

a front opening disposed along a longitudinal axis in the front side and configured to support at least twelve (12) fiber optic connections;

wherein a width of the front opening is 90 mm or less.

4. The fiber optic module housing of claims 1-3 being a fiber optic module further including a plurality of fiber optic components disposed through the front opening.

5. The fiber optic module housing of claim 4, wherein the plurality of fiber optic components is comprised of at least a plurality of fiber optic connectors and fiber optic adapters.

6. The fiber optic module housing of claims 1-3 being a fiber optic module further including a plurality of fiber optic components, wherein the plurality of fiber optic components provides a fiber optic connection density of at least one fiber optic connection per 6.9 mm of width of the front opening.

7. The fiber optic module housing of claims 1-3 being a fiber optic module further including a plurality of fiber optic components, wherein the plurality of fiber optic components provides a fiber optic connection density of at least one fiber optic connection per 1.7 mm of width of the front opening.

8. The fiber optic module housing of claims 1-3 being a fiber optic module further including a plurality of fiber optic components, wherein the plurality of fiber optic components provides a fiber optic connection density of at least one fiber optic connection per 0.85 mm of width of the front opening.

9. The fiber optic module housing of claims 1-8, wherein the width of the front opening is between ninety percent (90%) and ninety-nine percent (99%) of the width of the front side.

10. The fiber optic module housing of claims 1-9, wherein a height of the front opening is at least eighty-five percent (85%) of the height of the front side.

11. The fiber optic module housing of claims 1-10, wherein a height of the front opening is at least ninety-five percent (95%) of the height of the front side.

12. The fiber optic module housing of claims 1-11, wherein the width of the front opening is 85 mm or less.

13. The fiber optic module housing of claims 1-12, wherein the width of the front opening is 80 mm or less.

14. The fiber optic module housing of claims 1-9, 12 or 13, wherein a height of the front opening is 12 mm or less.

15. The fiber optic module housing of claims 1-9, 12, or 13, wherein a height of the front opening is 10 mm or less.

16. The fiber optic module housing of claims 1-5 or 9-15, wherein the plurality of fiber optic components provides at least twenty-four (24) fiber optic connections.

17. The fiber optic module housing of claims 1-5 or 9-15, wherein the plurality of fiber optic components provides at least forty-eight (48) fiber optic connections.

18. The fiber optic module housing of claims 1-17 being a fiber optic module further comprising at least one fiber optic component disposed through the rear side of the main body.

19. The fiber optic module housing of claims 1-18 being a fiber optic module wherein the plurality of fiber optic components is comprised of single fiber, fiber optic components.

20. The fiber optic module housing of claims 1-19 being a fiber optic module further comprising a fiber optic harness disposed in the internal chamber and connected to one or more fiber optic components.

21. The fiber optic module housing of claim 20, wherein the fiber optic harness is comprised of a plurality of optical fibers having a bend radius of 40 millimeters or less.

22. The fiber optic module housing of claims 1-21, further comprising at least one rail disposed on the main body.

23. The fiber optic module housing of claim 22, further comprising at least one latch attached to the at least one rail and configured to engage the at least one rail.

24. The fiber optic module housing of claims 1-23 being a fiber optic module disposed in fiber optic equipment comprised from the group consisting of a fiber optic chassis and a fiber optic equipment drawer.

25. The fiber optic module housing of claims 1-24, further including a fiber guide.

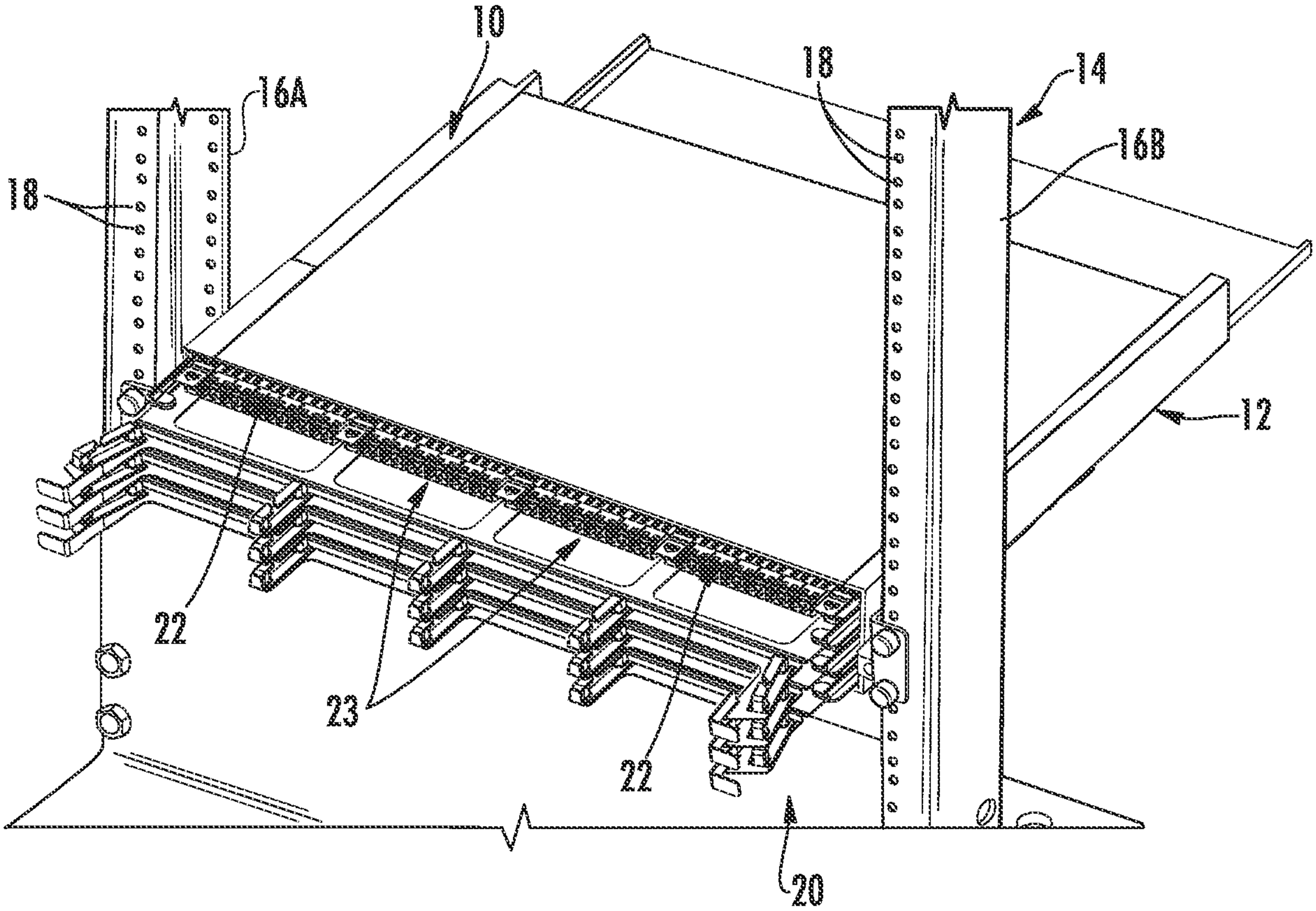
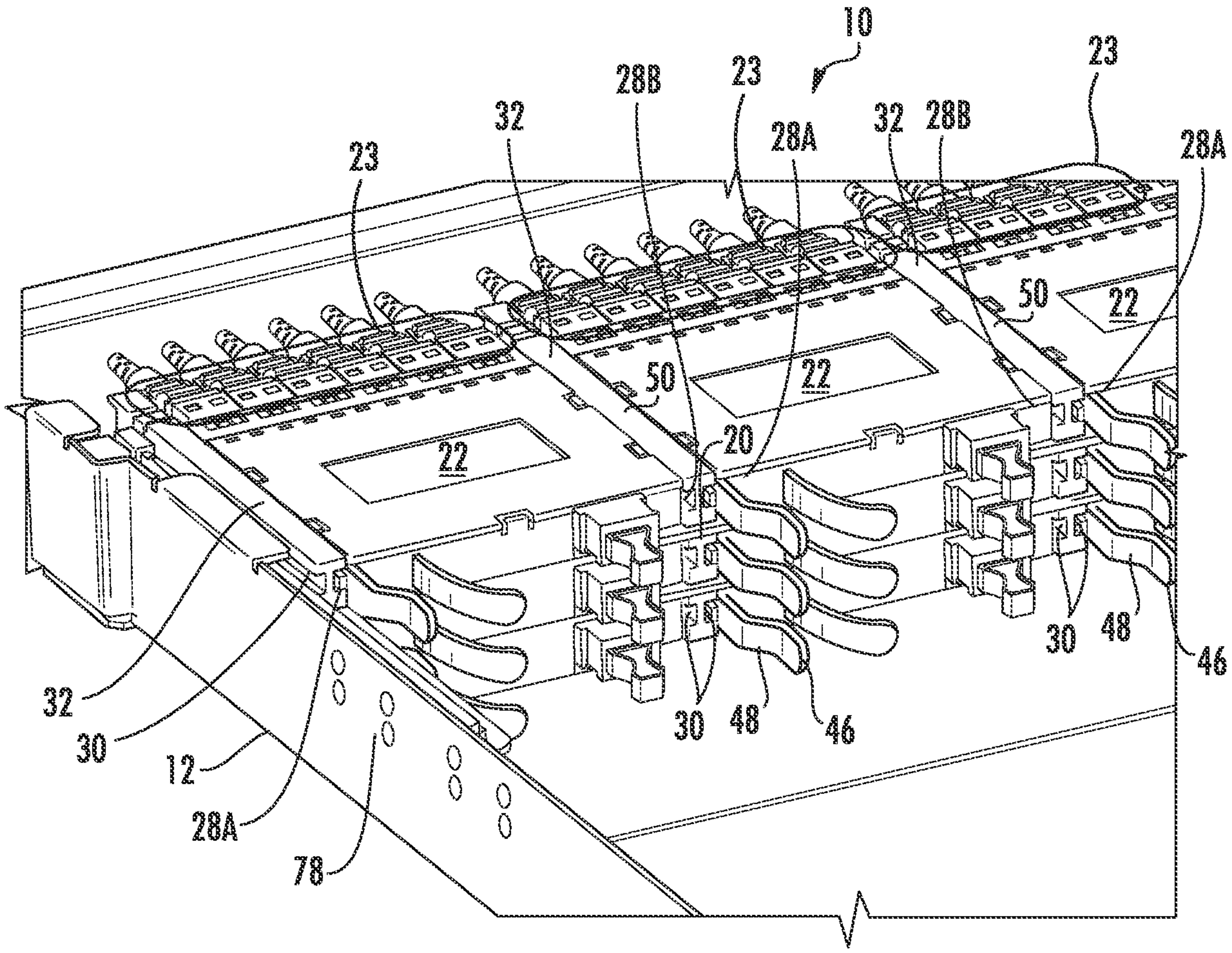


FIG. 1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28B
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28A
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28A
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FIG. 2

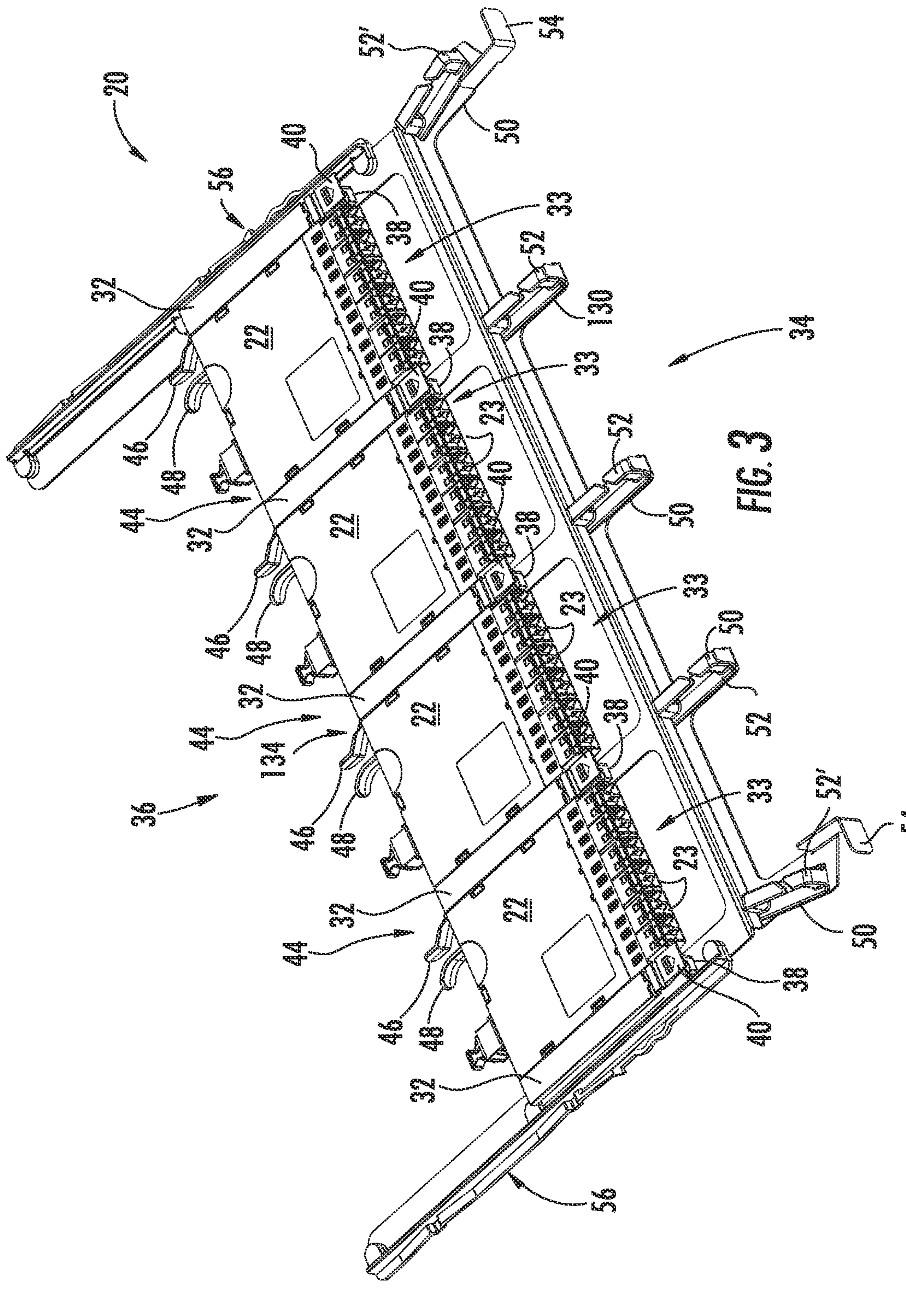


FIG. 3

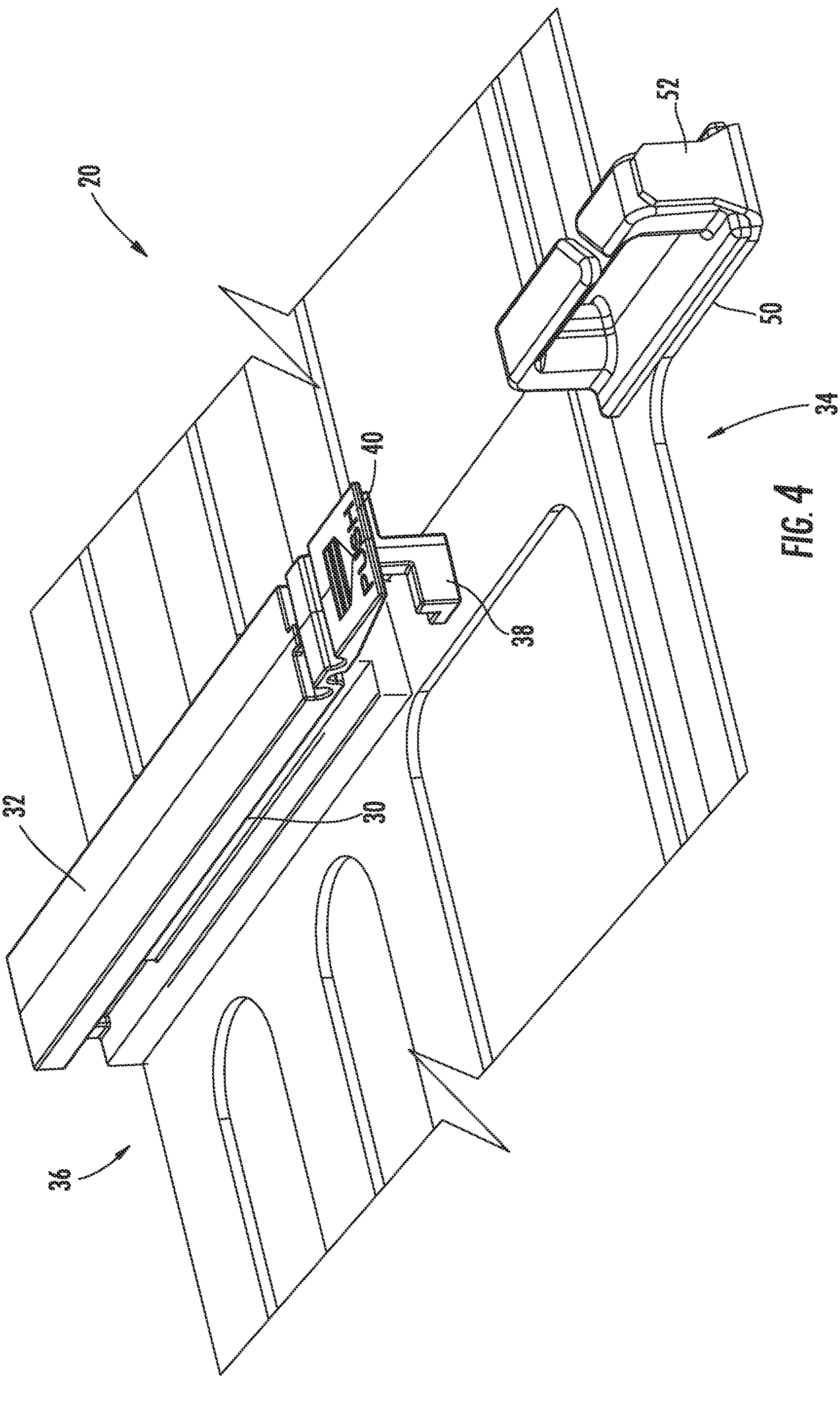
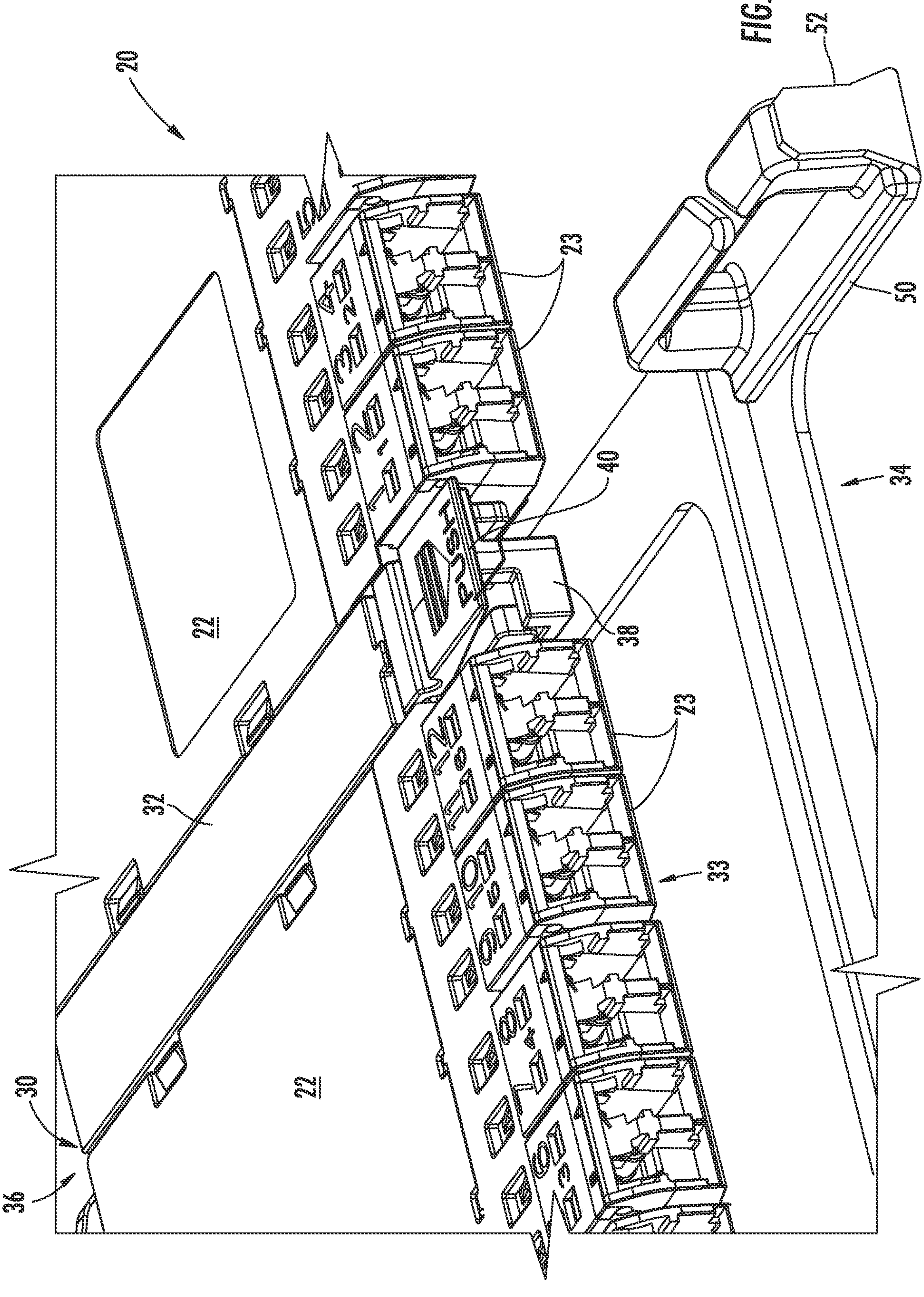


FIG. 4

FIG. 5



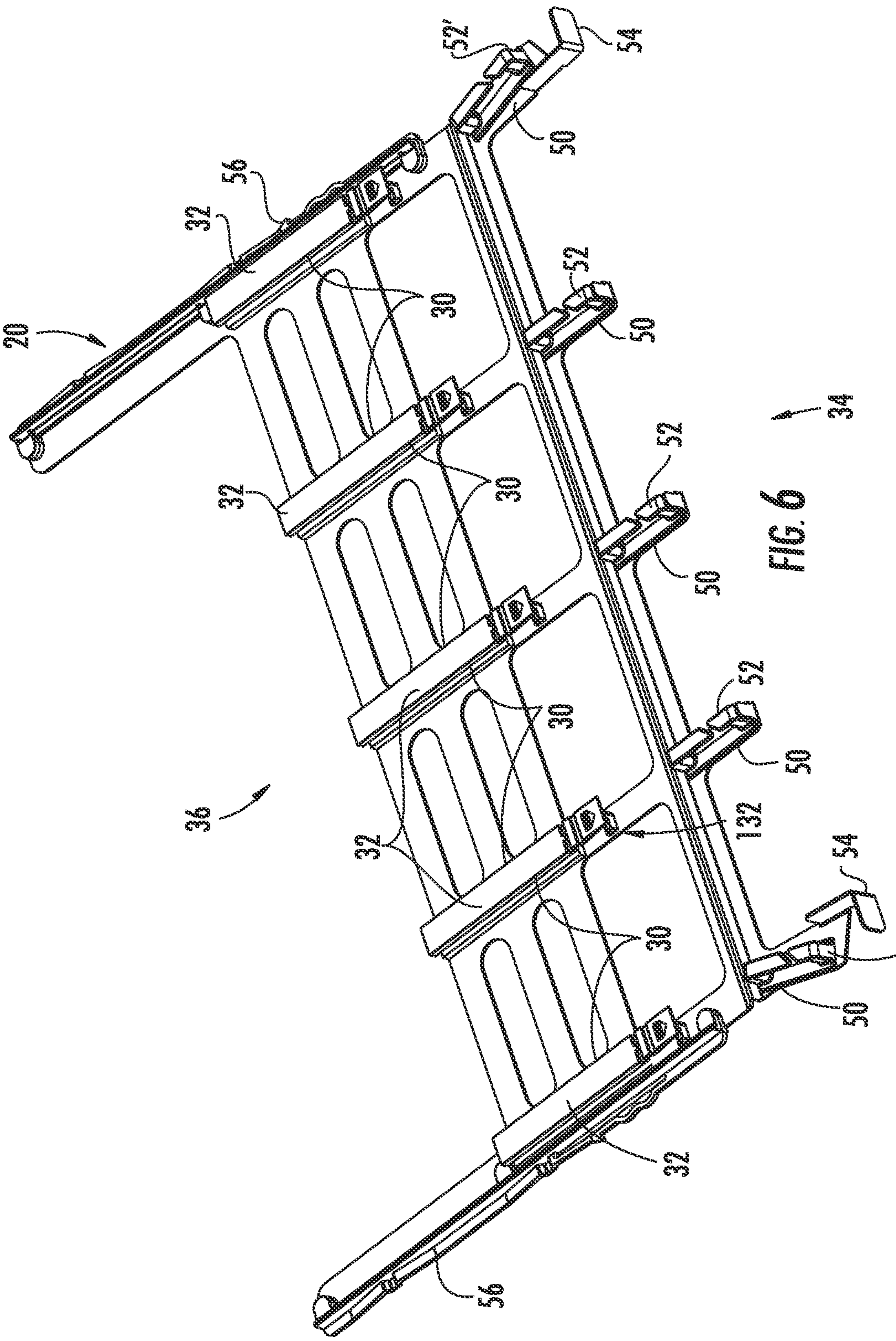
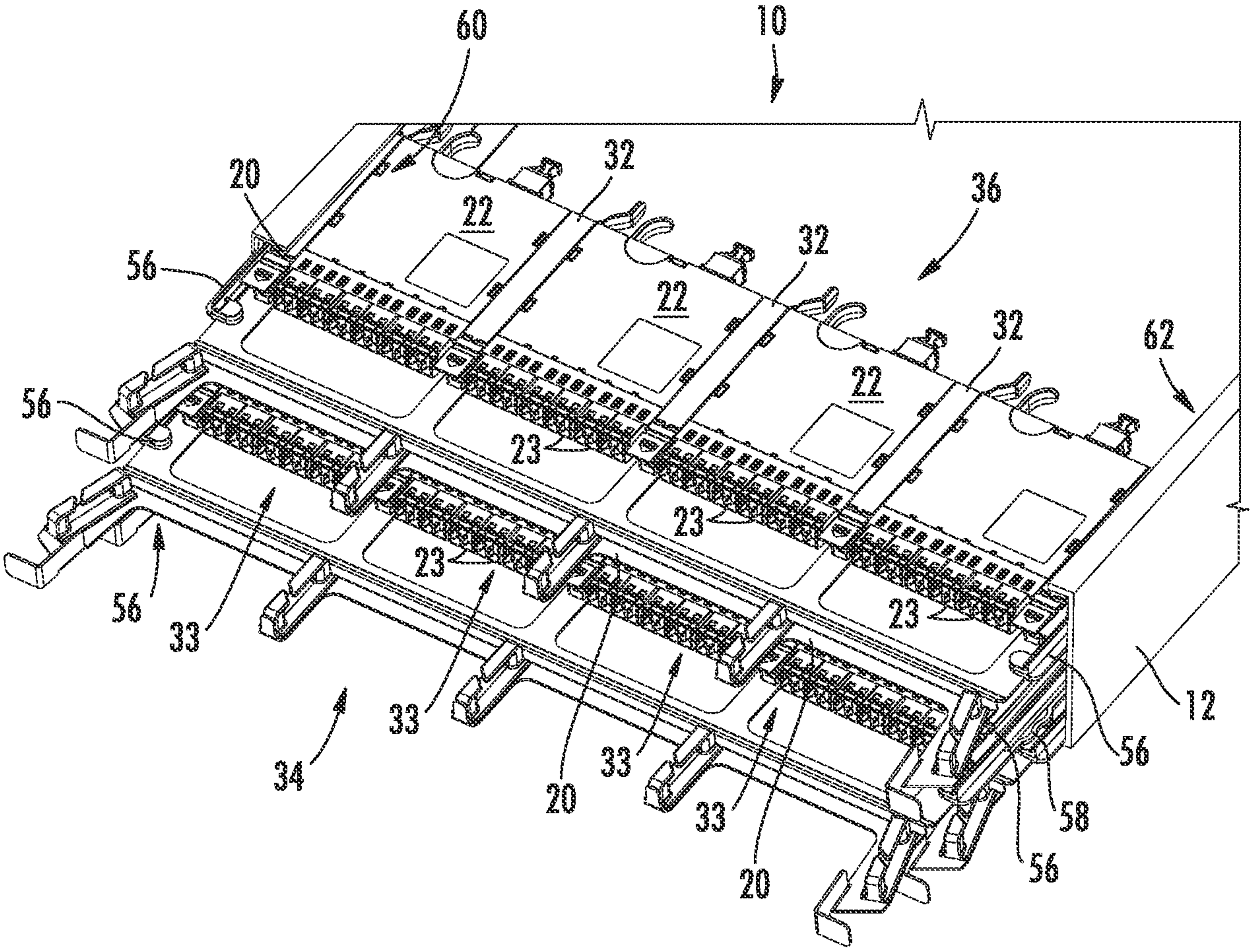


FIG. 6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33
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33
58
33
20
56

FIG. 7

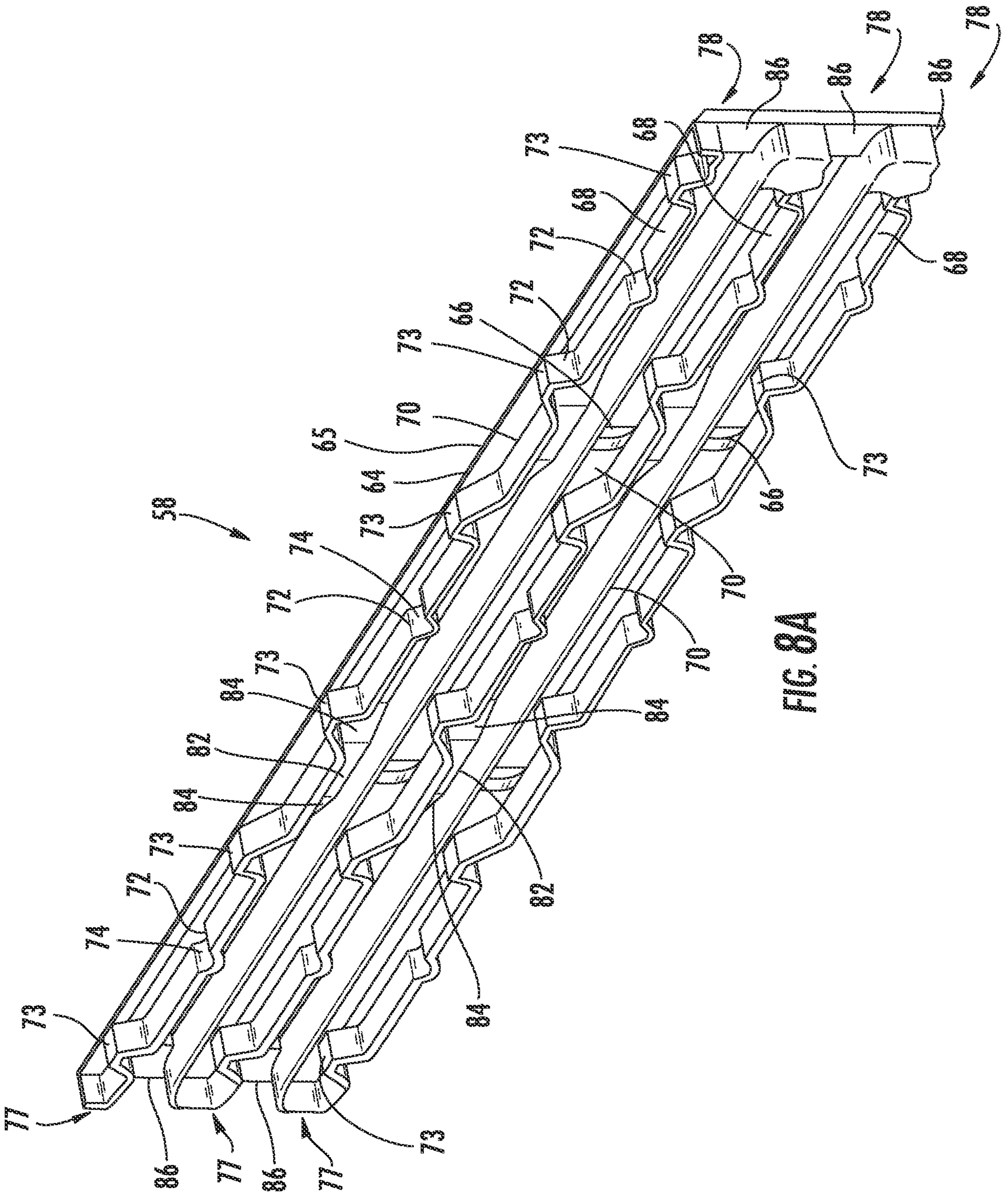


FIG. 8A

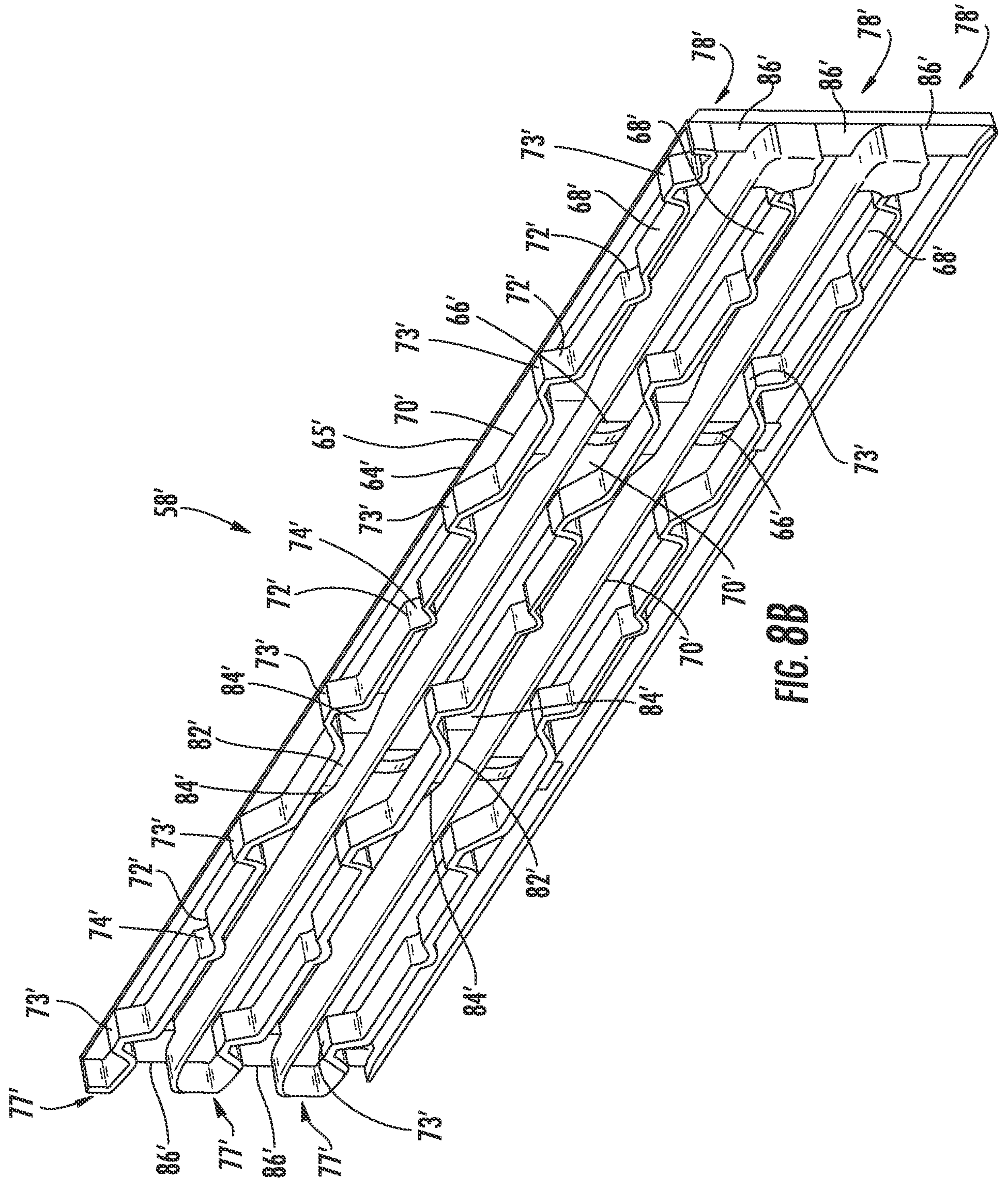


FIG. 8B

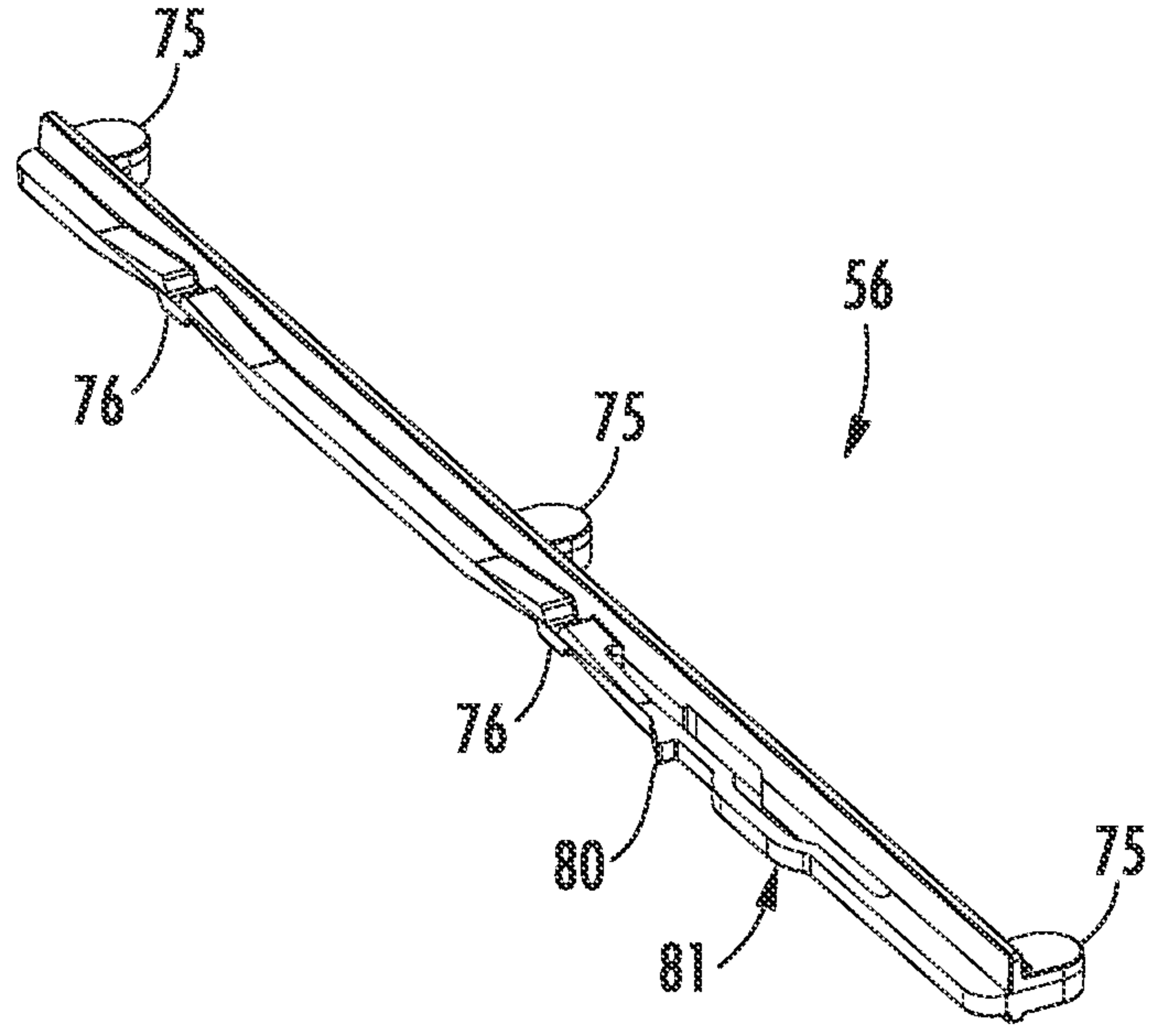


FIG. 9A

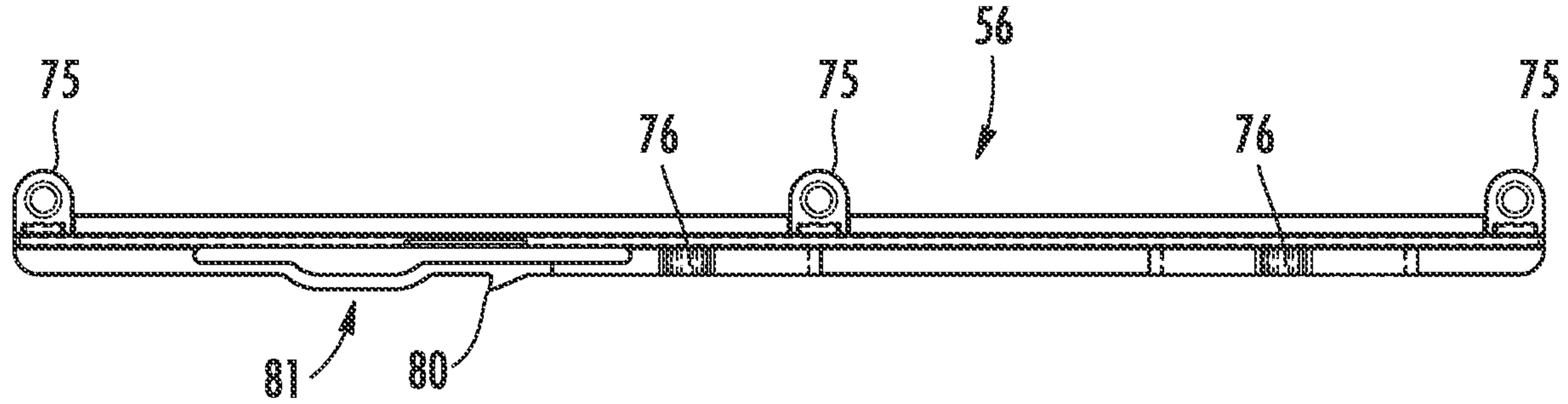


FIG. 9B

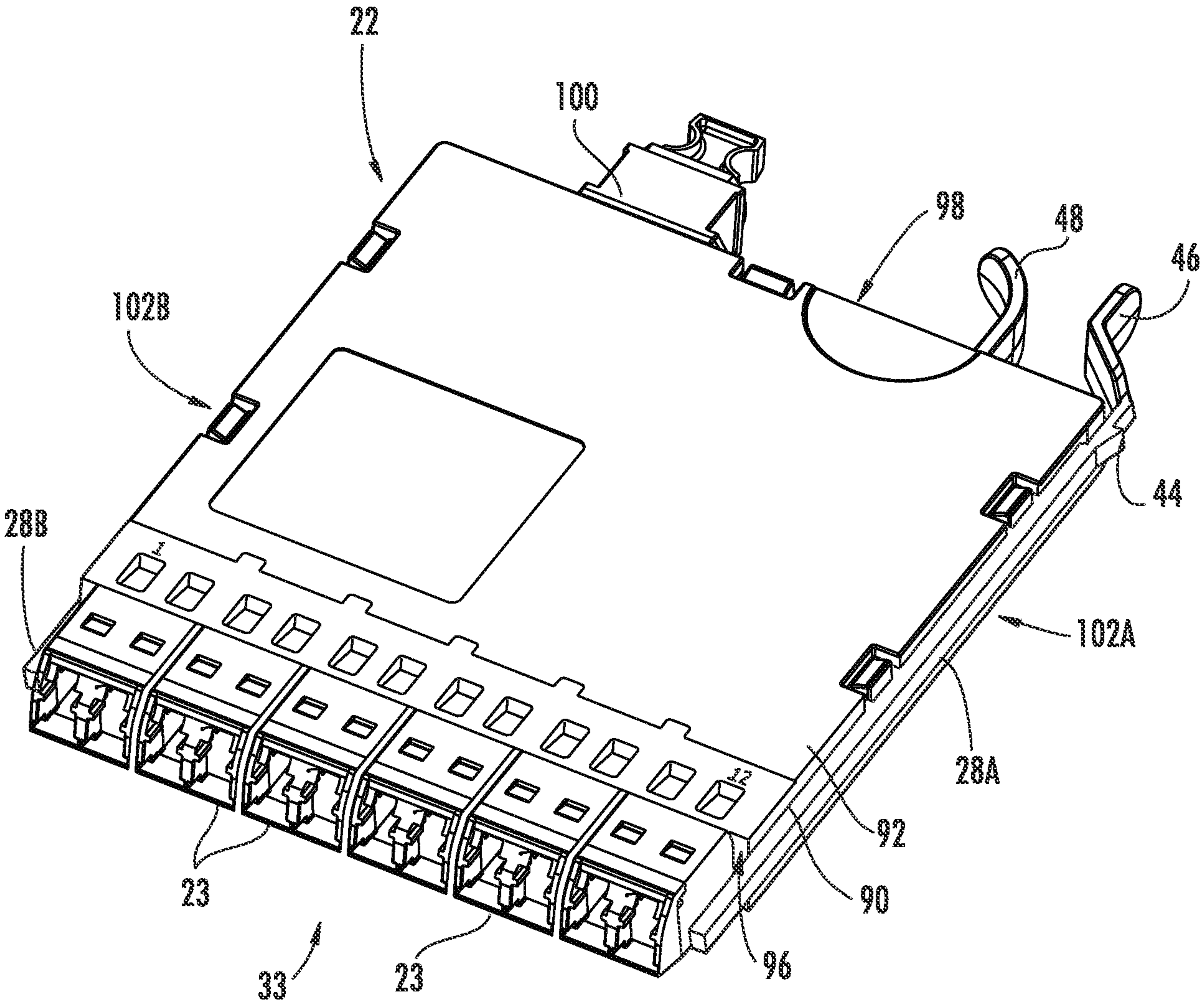


FIG. 10A

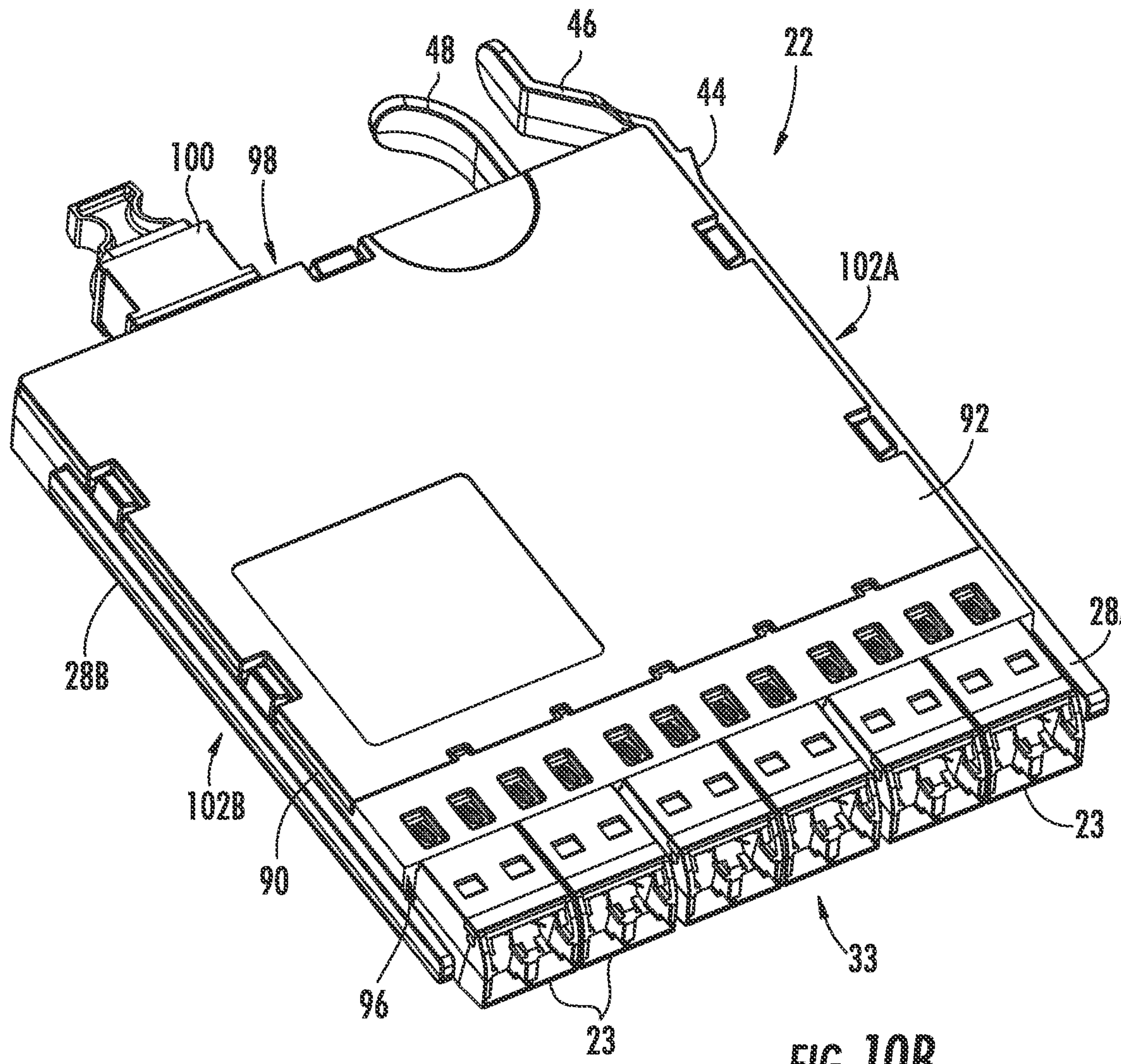
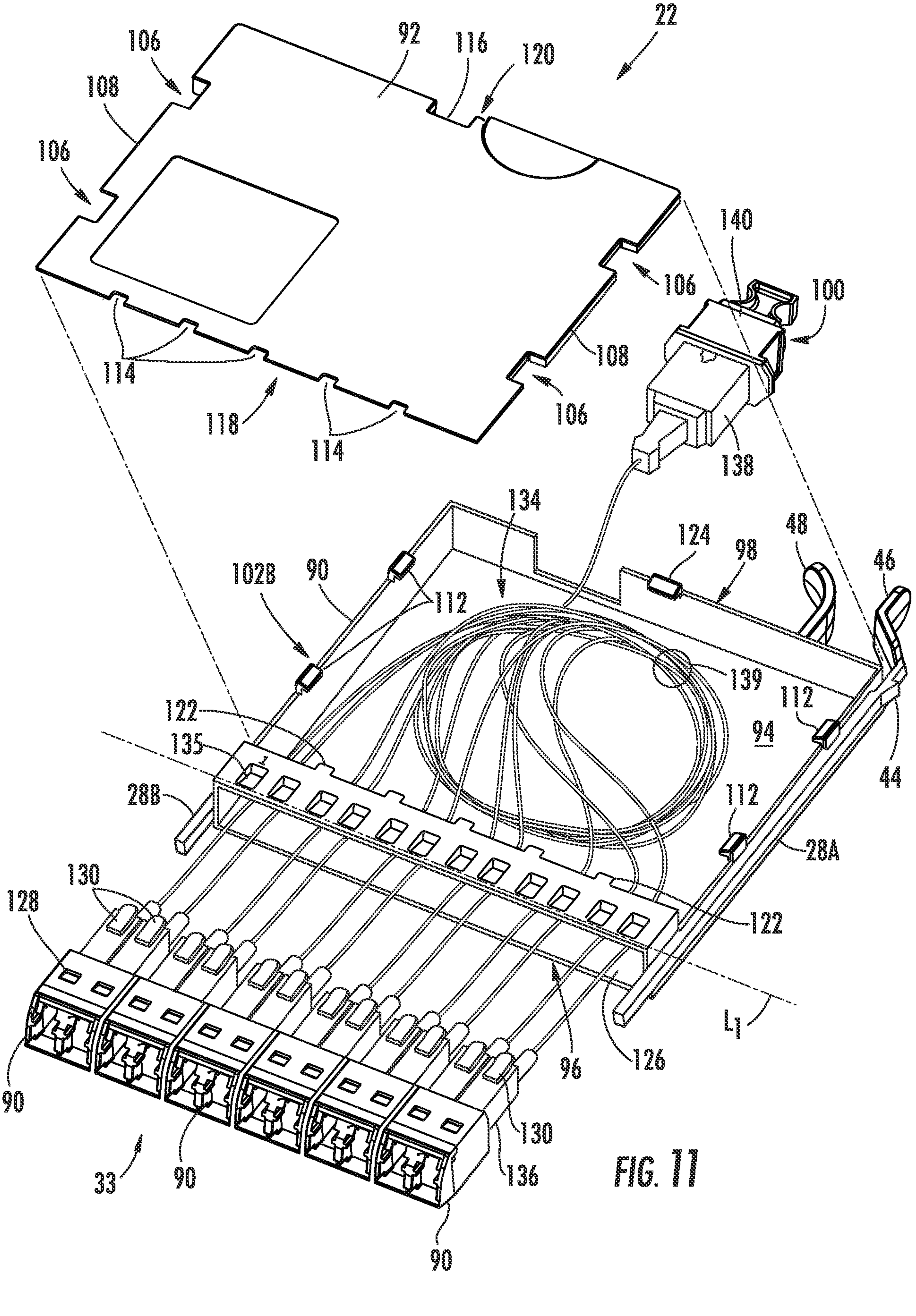


FIG. 10B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102B
90
112
139
122
135
112
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44
28B
112
28A
130
128
122
126
96
L1
90
130
33
90
136
90

FIG. 11

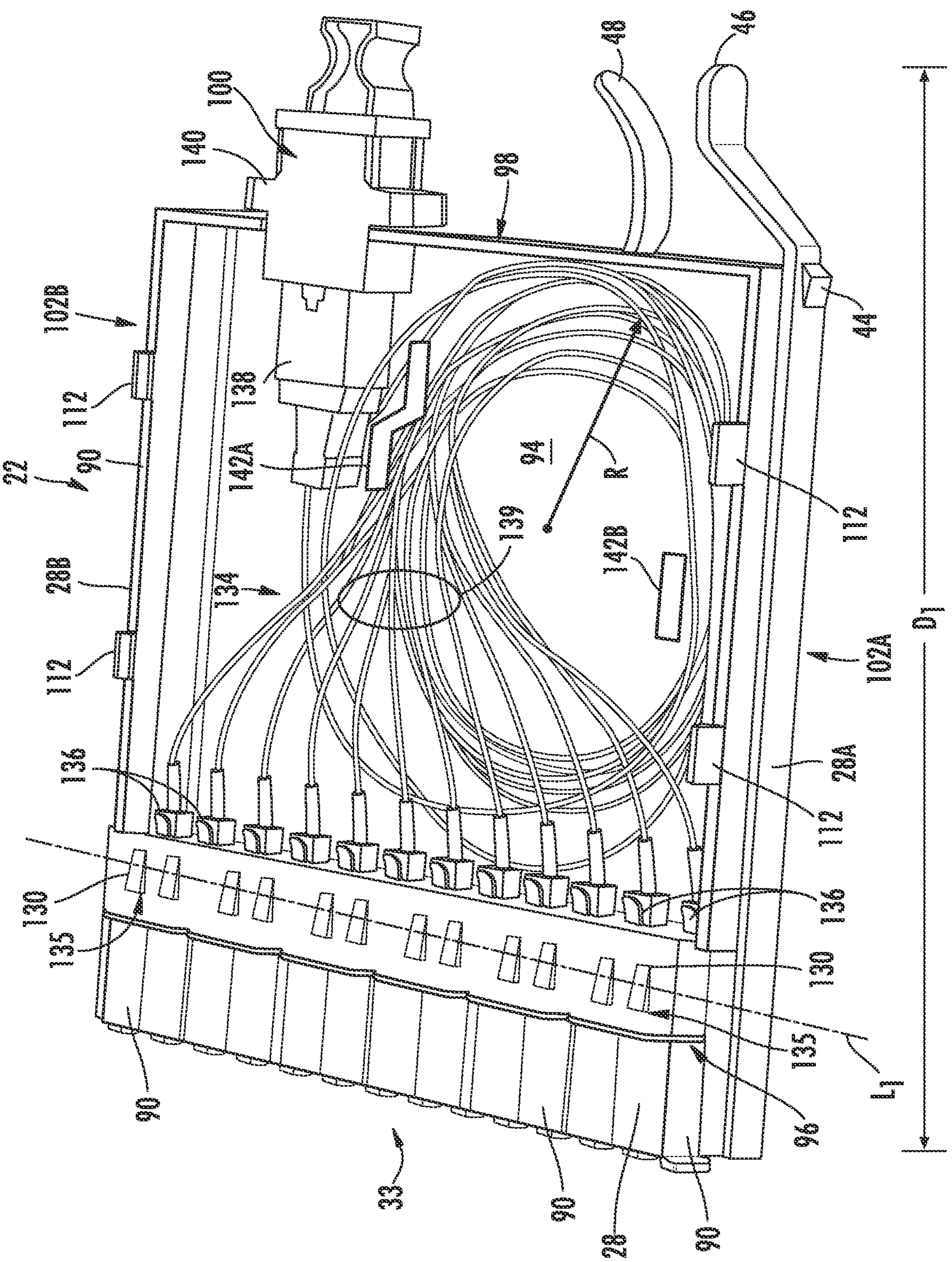
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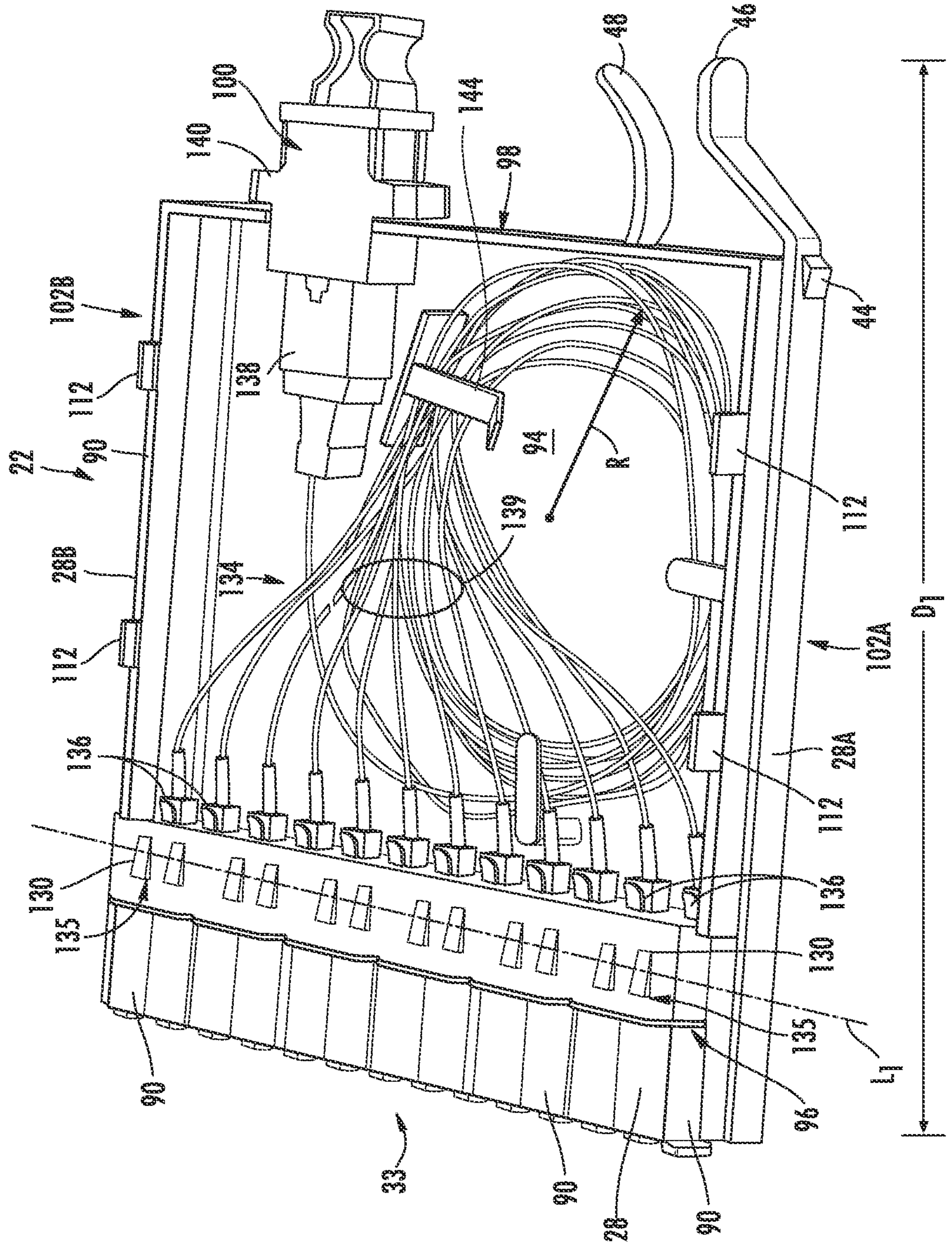
FIG. 12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128
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FIG. 12A

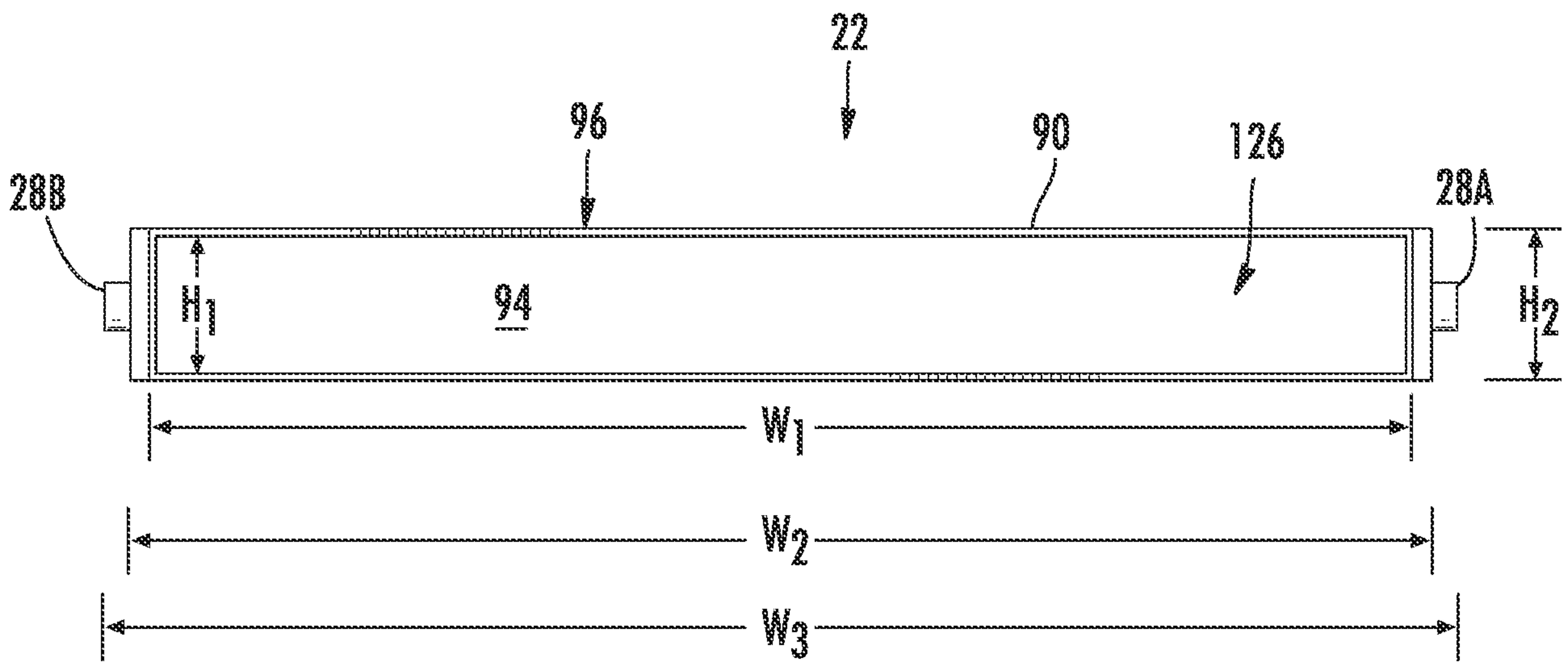
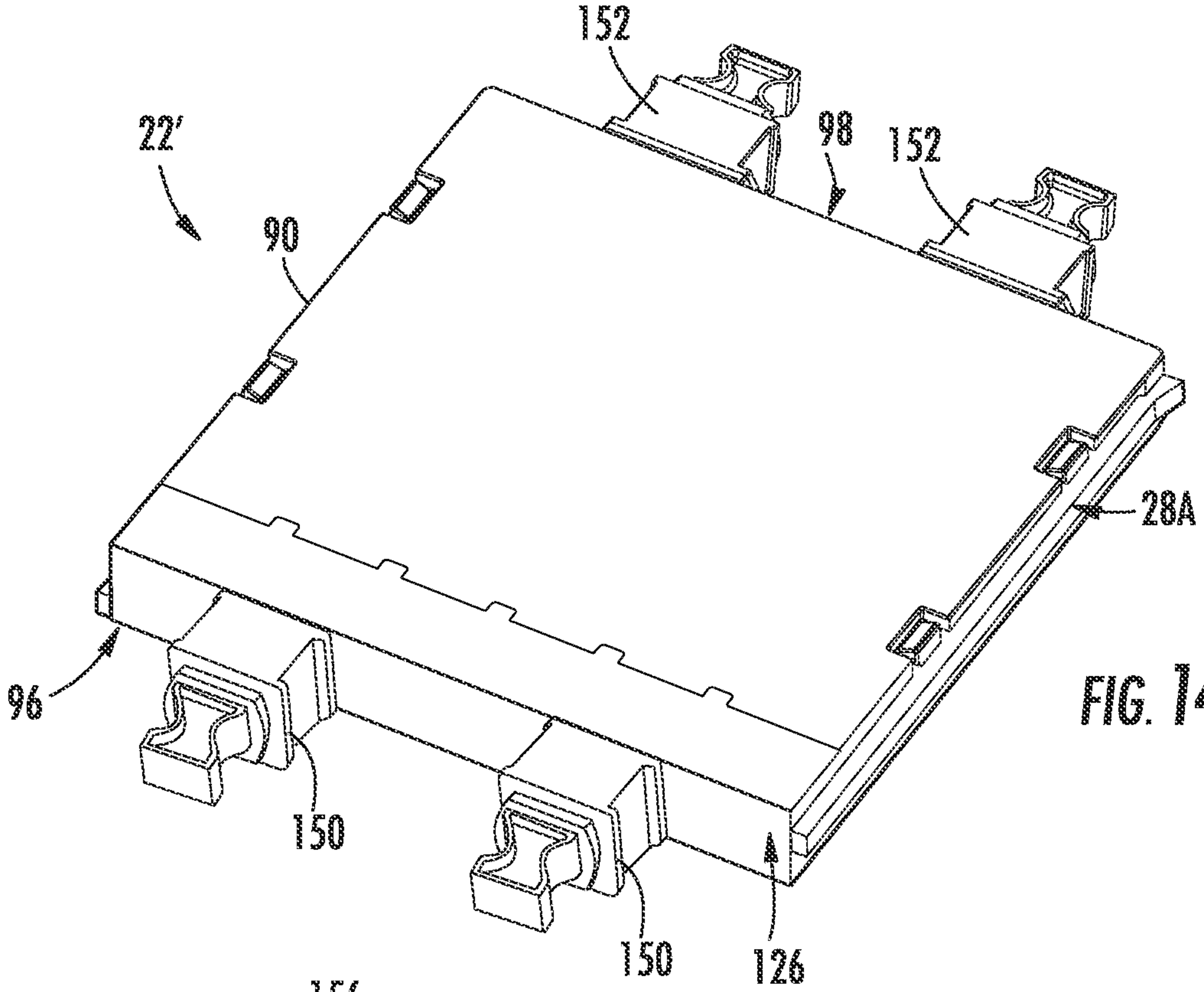


FIG. 13


152
22'
98
152
90
28A
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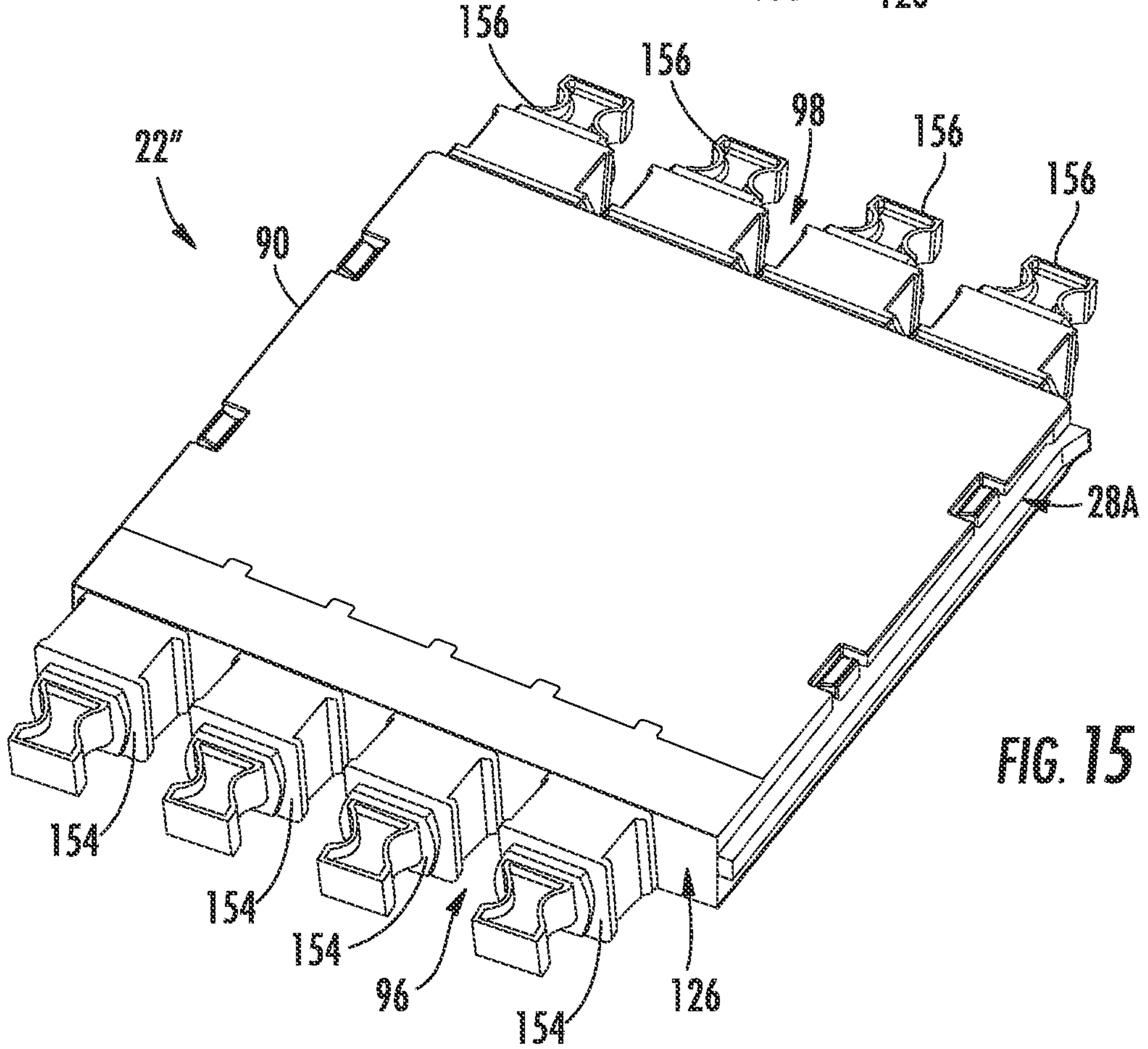
126

FIG. 14


156
156
98
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156
22"
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28A
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154
154
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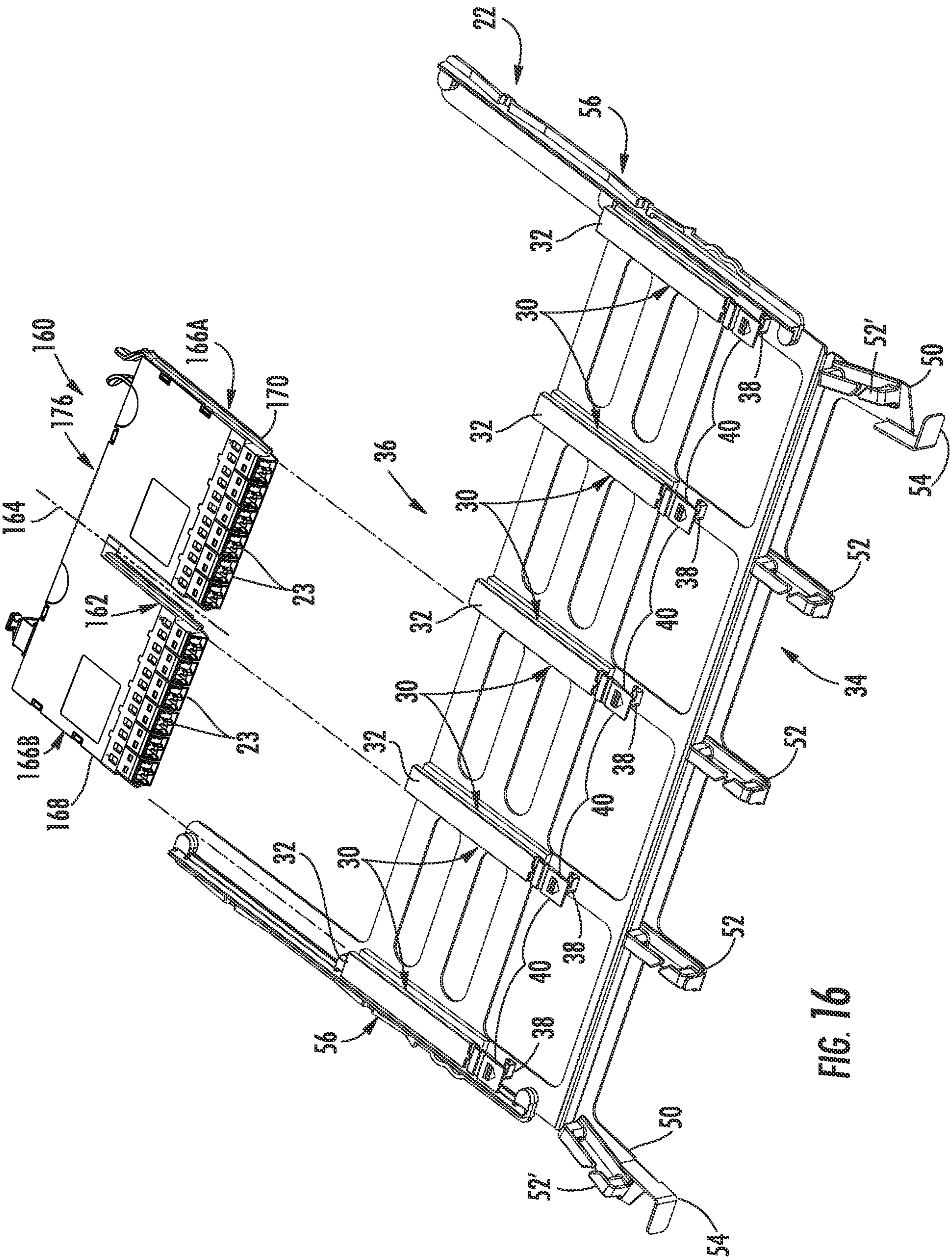
154
126

FIG. 15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166A
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166B
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FIG. 16

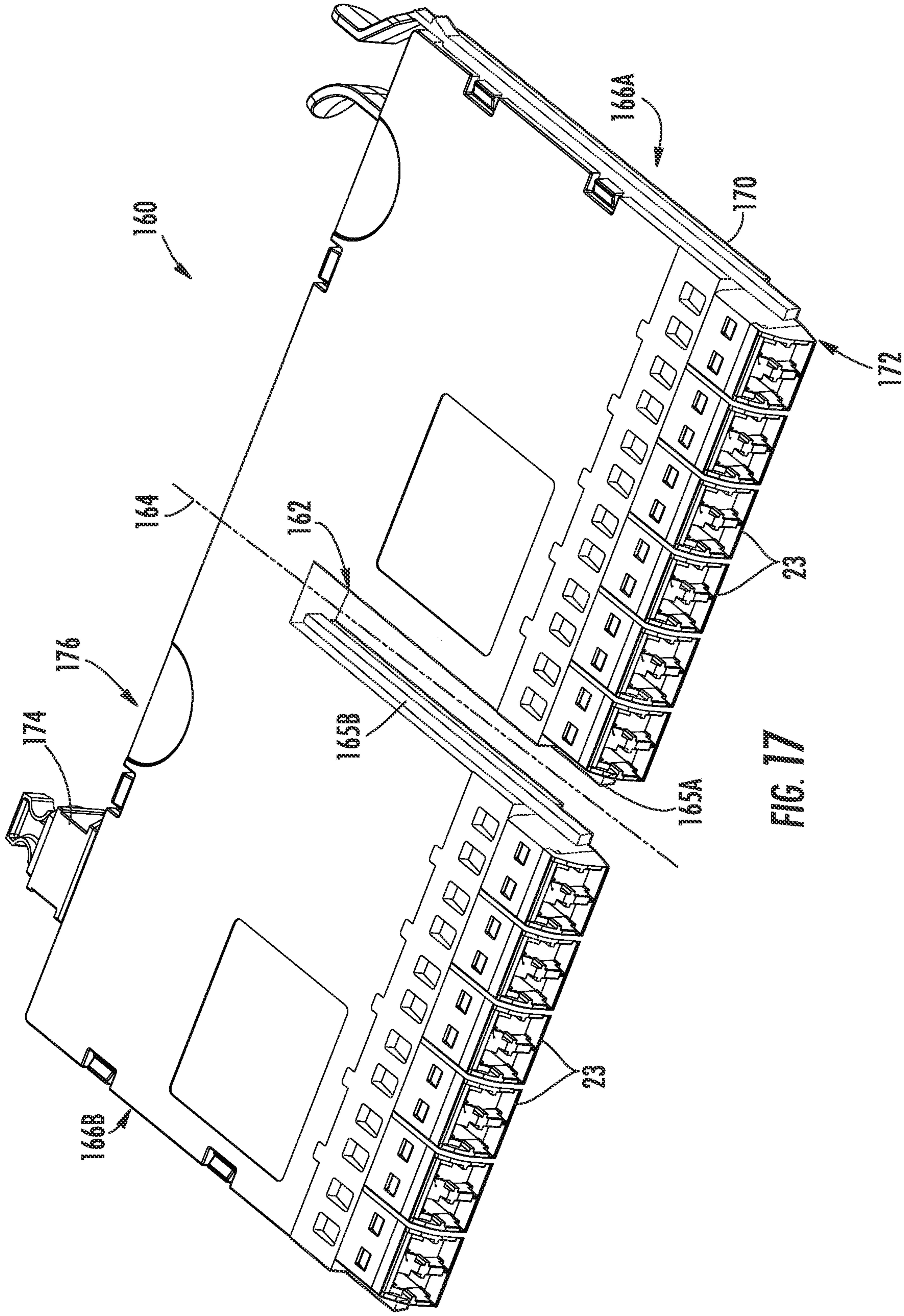

FIG. 17

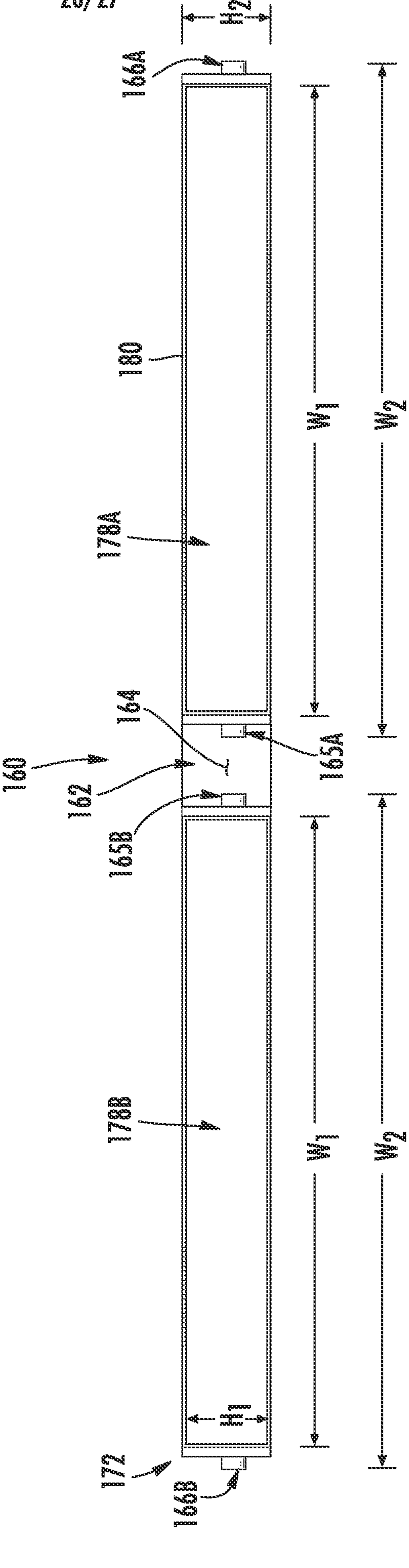

FIG. 18

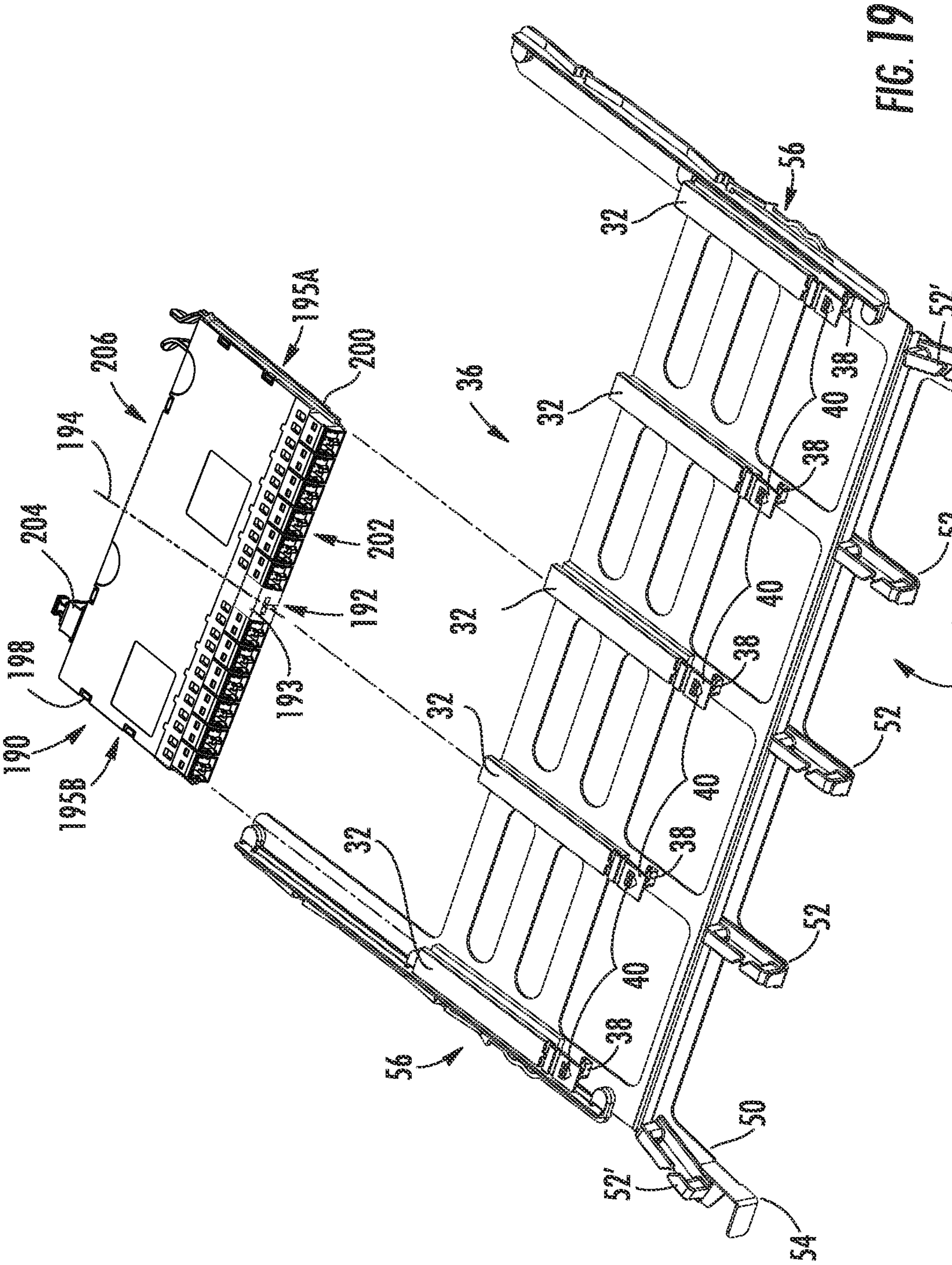
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FIG. 19

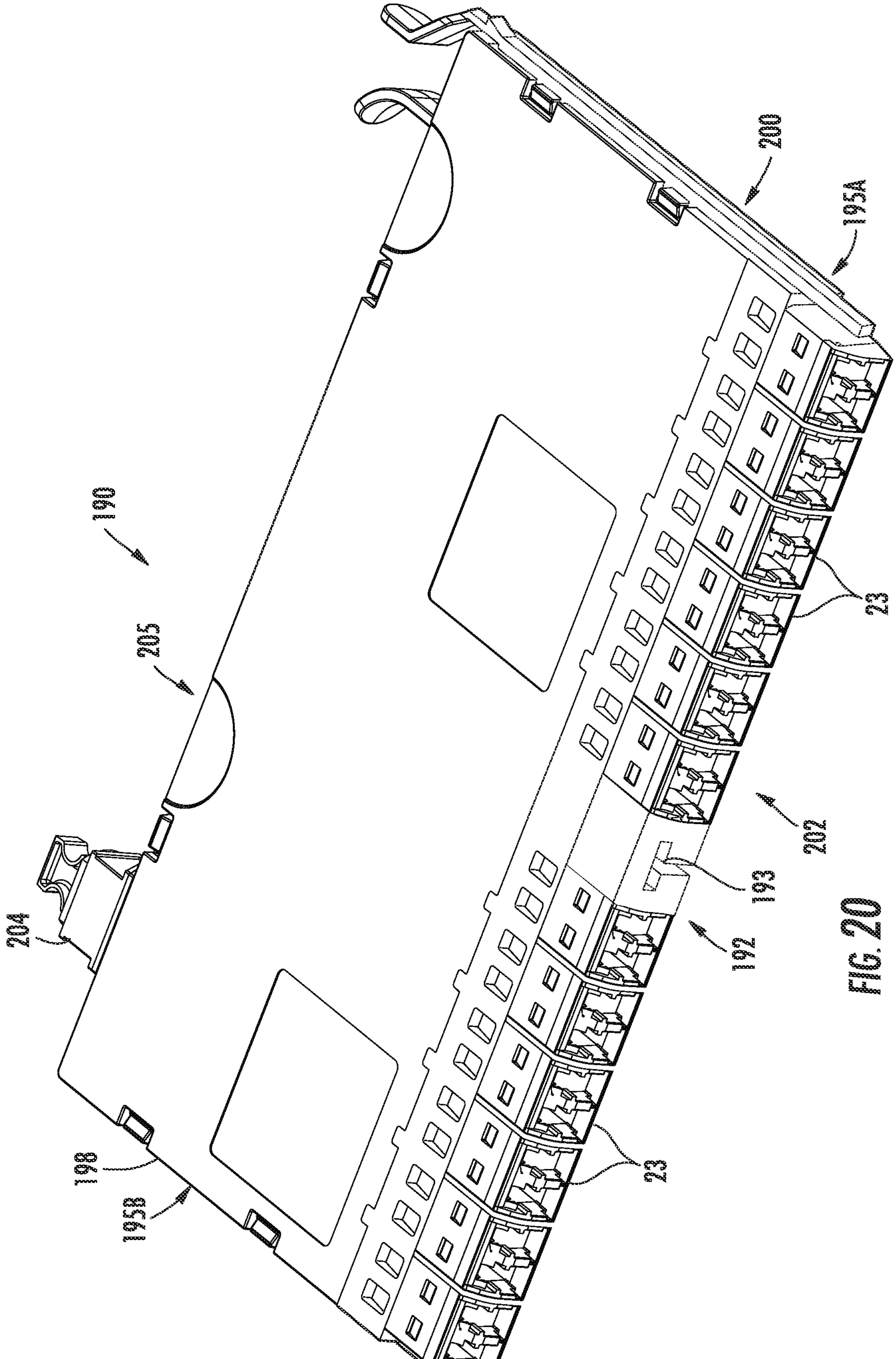


FIG. 20

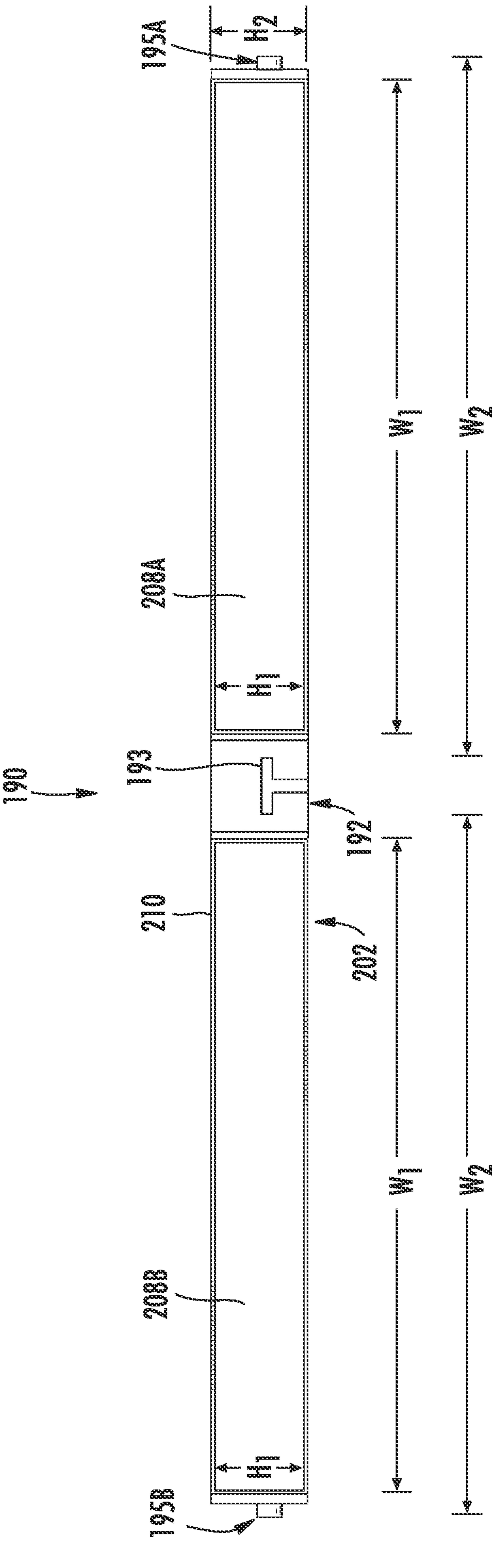
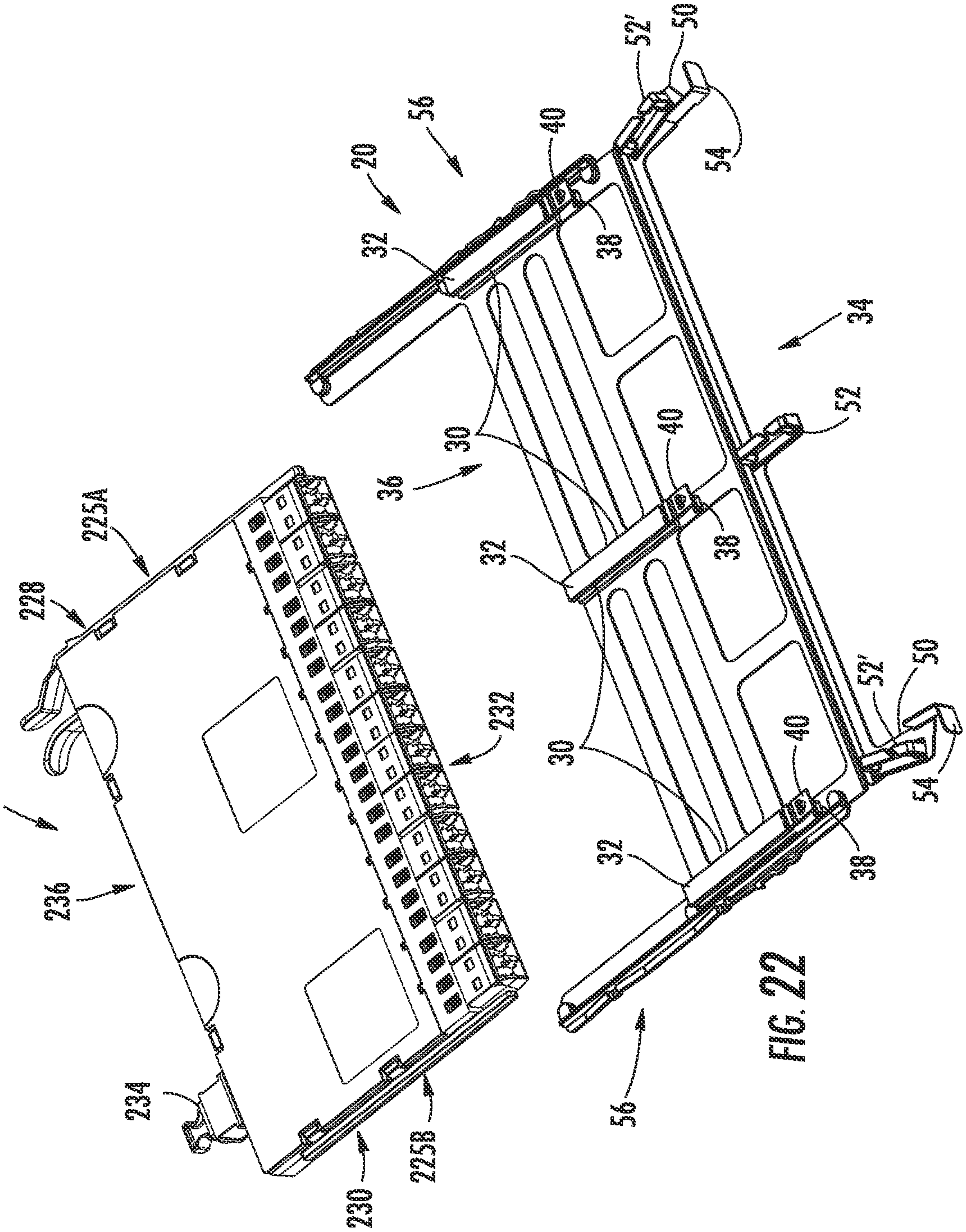


FIG. 21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225A
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225B

FIG. 22

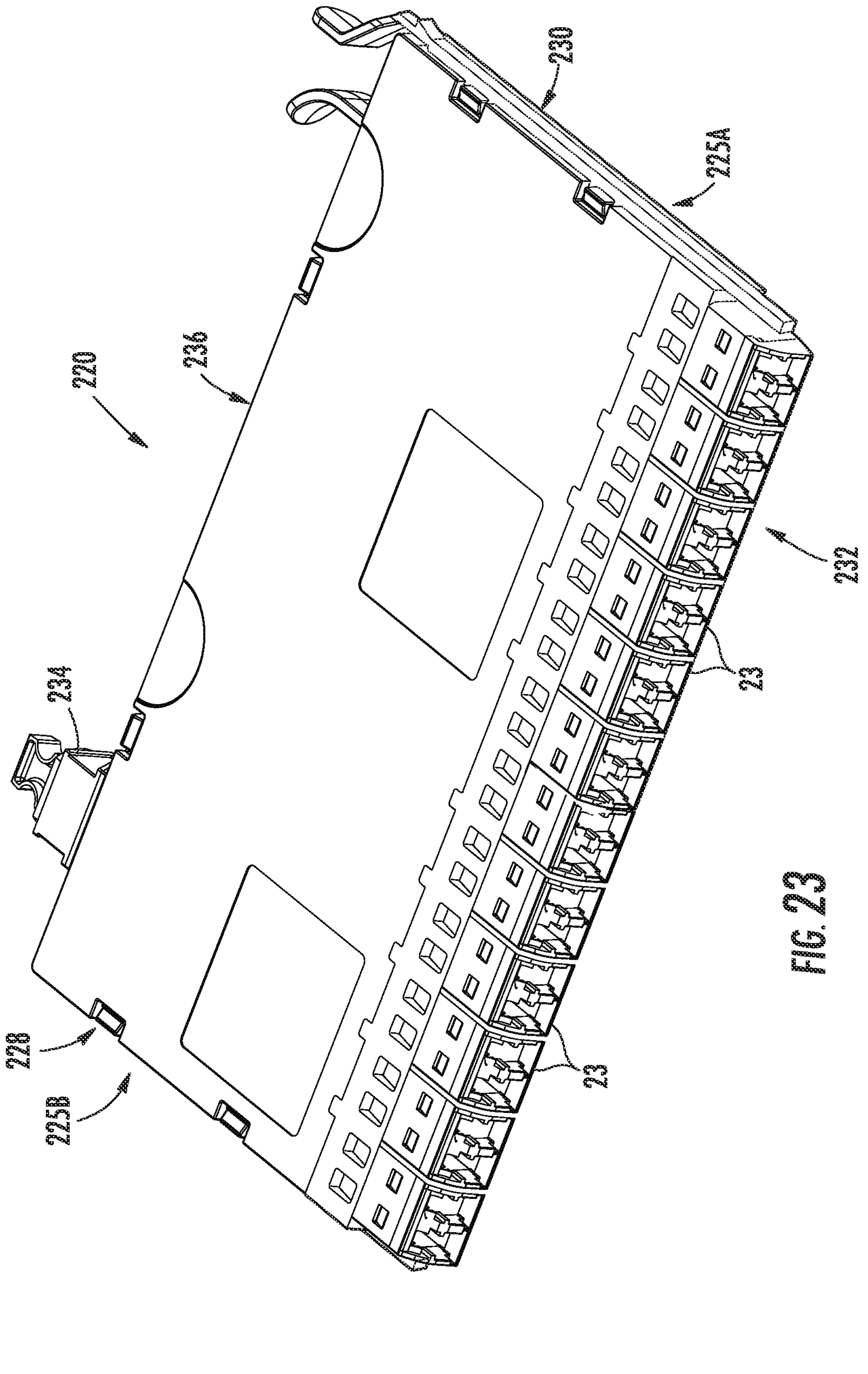

FIG. 23

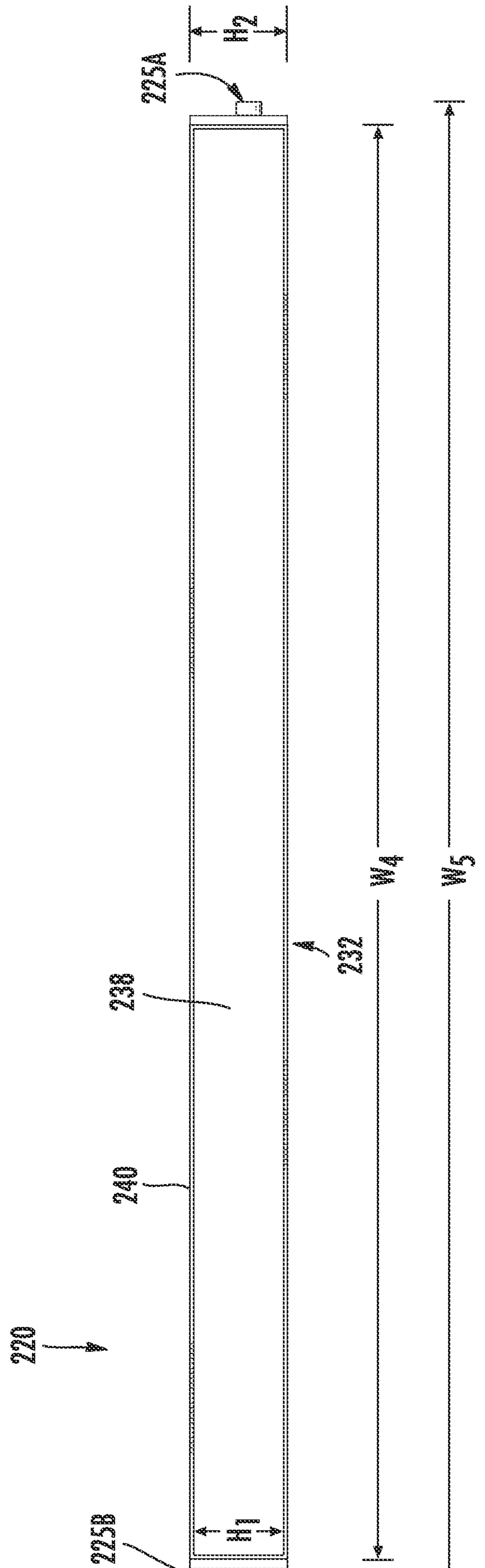

FIG. 24

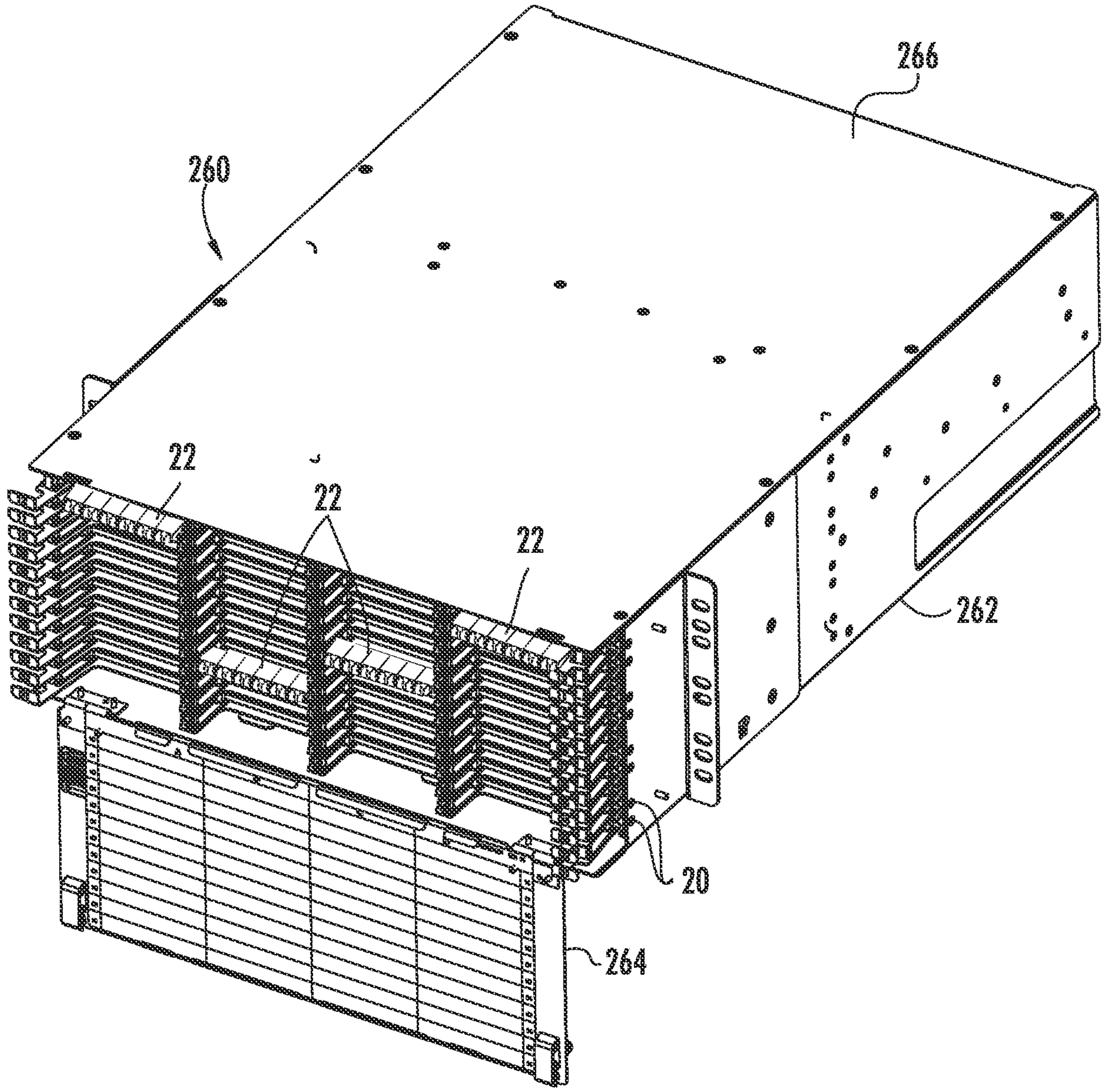

FIG. 25

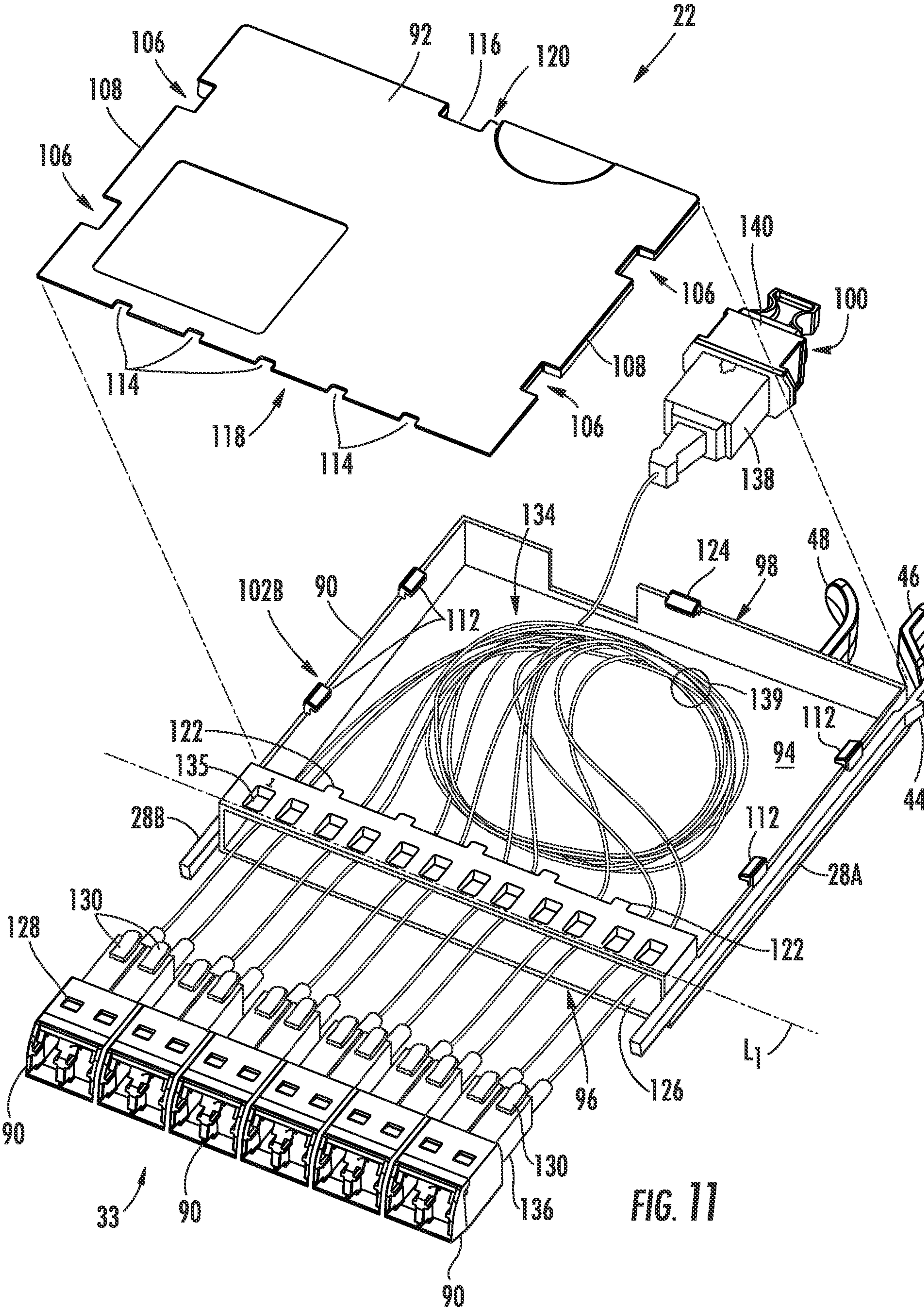
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FIG. 11