(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 August 2012 (09.08.2012)

(10) International Publication Number
WO 2012/106518 A2

(51) International Patent Classification:
G02B 6/38 (2006.01) *G02B 6/44* (2006.01)

(21) International Application Number:
PCT/US2012/023635

(22) International Filing Date:
2 February 2012 (02.02.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/438,847 2 February 2011 (02.02.2011) US

(71) Applicant *(for all designated States except US)*: **CORNING CABLE SYSTEMS LLC** [US/US]; 800 17th Street NW, Hickory, North Carolina 28602 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **ISENHOUR, Micah C** [US/US]; 1008 Park Circle, Lincolnton, North Carolina 28092 (US). **KNECHT, Dennis M** [US/US]; 4921 Elmhurst Drive, Hickory, North Carolina 28601 (US). **LUTHER, James P** [US/US]; 2471 Rolling Ridge Drive, Hickory, North Carolina 28602 (US).

(74) Agent: **CARROLL, Michael E Jr.**; Corning Cable Systems LLC, Intellectual Property Department, SP-TI-3-1, Corning, New York 14831 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: OPTICAL BACKPLANE EXTENSION MODULES, AND RELATED ASSEMBLIES SUITABLE FOR ESTABLISHING OPTICAL CONNECTIONS TO INFORMATION PROCESSING MODULES DISPOSED IN EQUIPMENT RACKS

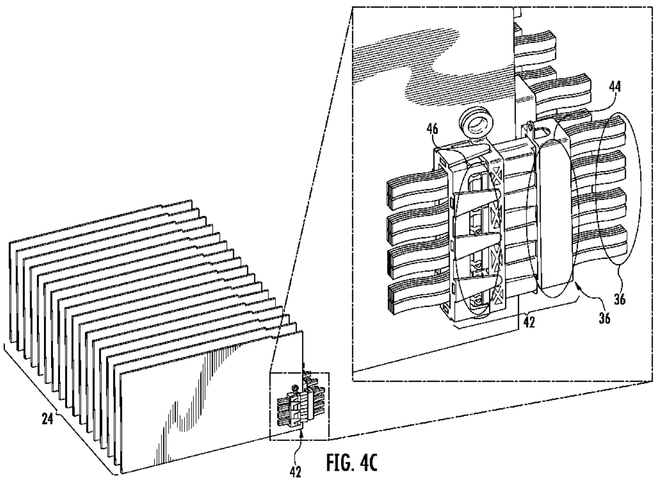


FIG. 4C

(57) **Abstract**: Optical backplane extension modules and related assemblies suitable for establishing optical connections to information processing modules disposed in equipment racks are disclosed. In one embodiment, an optical backplane extension module is provided. The optical backplane extension module comprises an extension module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, a right side disposed on a right end of the base opposite the left end, and a rear side disposed on a rear end of the base. A plurality of backplane fiber optic connectors are disposed through the rear side of the extension module housing and accessible through an exterior side of the rear side. The plurality of backplane fiber optic connectors configured to be directly optically connected to a plurality of blade fiber optic connectors disposed in a plurality of information processing modules disposed in a rack module housing.

WO 2012/106518 A2

OPTICAL BACKPLANE EXTENSION MODULES, AND RELATED ASSEMBLIES SUITABLE FOR ESTABLISHING OPTICAL CONNECTIONS TO INFORMATION PROCESSING MODULES DISPOSED IN EQUIPMENT RACKS

PRIORITY APPLICATION

[0001] The application claims the benefit of priority under 35 USC §119 of U.S. Provisional Application Serial No. 61/438,847 filed on February 2, 2011 and entitled "DENSE FIBER OPTIC CONNECTOR SOLUTIONS FOR OPTICAL BACKPLANES IN DATA CENTER SERVICE RACKS," the content of which is relied upon and incorporated herein by reference in its entirety.

RELATED APPLICATIONS

[0002] The present application is related to PCT Patent Application [_________] filed on even date herewith and entitled "DENSE FIBER OPTIC CONNECTOR ASSEMBLIES AND RELATED CONNECTORS AND CABLES SUITABLE FOR ESTABLISHING OPTICAL CONNECTIONS FOR OPTICAL BACKPLANES IN EQUIPMENT RACKS," which is incorporated herein by reference in its entirety.

[0003] The present application is also related to PCT Patent Application [_________] filed on even date herewith and entitled "DENSE SHUTTERED FIBER OPTIC CONNECTORS AND ASSEMBLIES SUITABLE FOR ESTABLISHING OPTICAL CONNECTIONS FOR OPTICAL BACKPLANES IN EQUIPMENT RACKS," which is incorporated herein by reference in its entirety.

BACKGROUND

Field of the Disclosure

[0004] The technology of the disclosure relates to dense fiber optic connectors, and related fiber optic components, housings, and modules for facilitating optical connections for information processing modules (e.g., a server blade) disposed in an equipment rack.

Technical Background

[0005] A data center is a facility used to remotely house computer systems and associated components. These systems may be used for a variety of purposes. Examples include telecommunications such as telecommunications and storage systems applications, server farms for web page accesses, remote storage, such as for backup storage purposes, and providing access to Enterprise applications. To provide for efficient management of these computer systems, data centers include equipment racks, such as the equipment rack **10** illustrated in **FIG. 1**. For example, the equipment rack **10** in **FIG. 1** is comprised of rails **12A, 12B** extending in a vertical direction and spaced a distance apart to support a plurality of modular housings **14** disposed between the rails **12A, 12B** in vertical space for efficient use of data center space. The modular housings **14** are configured to support information processing devices **16**, such as computer servers and data storage devices, as examples, in the form of cards **18**, also referred to as "blades **18**." The blades **18** may be printed circuit boards (PCBs) containing computer-based components and electrical traces for connections between components. The modular housings **14** may also include a backplane (not shown) connected to power and other data transfer devices which are coupled to the information processing devices **16** when installed in the modular housing **14** and connected to the backplane.

[0006] As the demand for access to remote applications and data storage increases, it will be desirable to find ways to increase computational power and data throughput of data center computer devices. It will be desirable to find ways to increase computational power and data throughput of data center computer devices without necessarily having to increase floor space of data centers.

SUMMARY OF THE DETAILED DESCRIPTION

[0007] Embodiments disclosed herein include optical backplane extension modules and related assemblies suitable for establishing optical connections to information processing modules disposed in equipment racks. In this regard in one embodiment, an optical backplane extension module is provided. The optical backplane extension module comprises an extension module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, a right side disposed on a right end of the base opposite the left end, and a rear side disposed on a rear end of the base. A plurality of backplane fiber optic connectors is disposed through the rear side of the extension module housing and accessible through an exterior side of the rear side. The plurality of backplane fiber optic connectors are configured to be directly optically connected to a plurality of blade fiber optic connectors disposed in a plurality of information processing modules disposed in a rack module housing.

[0008] In another embodiment, a method of connecting an optical backplane extension module to a rack module housing is provided. The method comprises providing an optical backplane extension module. The optical backplane extension module comprises an extension module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, a right side disposed on a right end of the base opposite the first end, and a rear side disposed on a rear end of the base. A plurality of backplane fiber optic connectors is disposed through the rear side of the extension module housing and accessible through an exterior side of the rear side. The method also comprises directly optically connecting the plurality of backplane fiber optic connectors disposed through the rear side of the extension module housing to a plurality of blade fiber optic connectors disposed in a plurality of information processing modules disposed in a rack module housing.

[0009] In another embodiment, a fiber optic rack module configured to be supported in an equipment rack is provided. The fiber optic rack module comprises a rack module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, and a right side disposed on a right end of the base opposite the left end. The rack module housing is configured to support at least one information processing module having at least one blade fiber optic connector in the interior space. At least one alignment member is disposed in the interior space of the rack module housing. The at least one alignment member is configured to provide at least one datum for the at least one information processing module to align the at least one information processing module disposed in the rack module housing.

[0010] 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 embodiments as described herein, including the detailed description that follows, the claims, as well as the appended drawings.

[0011] 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

[0012] **FIG. 1** is a front perspective view of an exemplary equipment rack supporting rack module housings each supporting a plurality of information processing modules;

[0013] **FIG. 2A** is a front perspective view of exemplary information processing modules disposed in rack module housings disposed in an equipment rack, with optical backplane extension modules directly optically connected to information processing modules in the rear of the rack module housings;

[0014] **FIG. 2B** is a rear perspective view of the optical backplane extension modules in **FIG. 2A** optically connected in the rear of the rack module housings to the information processing modules;

[0015] **FIG. 3** is a rear perspective view of the optical backplane extension modules in **FIG. 2B** optically connected in the rear of the rack module housings to information processing modules, with the doors of the optical backplane extension modules open to show the interior routing and cable management space in the optical backplane extension modules;

[0016] **FIG. 4A** is a right side perspective view of the optical backplane extension module in **FIG. 2B** optically connected to the information processing modules in the rear of a rack module housing;

[0017] **FIG. 4B** is a right side perspective view of the information processing modules in **FIG. 4A** with rack module housing removed, and illustrating an exemplary dense fiber optic connector assembly facilitating direct optical connections to the information processing modules through the optical backplane extension module in **FIGS. 2A-3**;

[0018] **FIG. 4C** is a close-up view of the dense fiber optic connector assembly in **FIG. 4B**;

[0019] **FIG. 5** is a perspective view of the dense fiber optic connector assembly in **FIG. 4B** comprised of dense information processing module fiber optic receptacles (“blade fiber optic receptacles”) configured to receive and optically connect to dense optical backplane extension module fiber optic plugs (“backplane fiber optic plugs”);

[0020] **FIG. 6A** is a close-up perspective view of the backplane fiber optic plugs in **FIG. 5**;

[0021] **FIG. 6B** is a close-up perspective view of the blade fiber optic receptacles in **FIG. 5**;

[0022] **FIG. 7A** is a perspective exploded view of the backplane fiber optic plugs in **FIGS. 5** and **6A**;

[0023] **FIG. 7B** schematically depicts a method for laser processing a plurality of optical fibers disposed in the backplane fiber optic plugs in **FIG. 7A** using a protection element disposed between a first row and a second row of optical fibers;

[0024] **FIG. 8** is a perspective exploded view of the blade fiber optic receptacles in **FIGS. 5** and **6B**;

[0025] **FIG. 9A** is a perspective quarter cut view of an exemplary dense fiber optic connector assembly configured to support GRIN lenses that may be employed in the blade fiber optic receptacles in **FIGS. 5, 6B,** and **8**;

[0026] **FIG. 9B** is a perspective cross-section view of an exemplary dense fiber optic connector assembly supporting blind holes and lenses that may be employed in the blade fiber optic receptacles in **FIGS. 5, 6B,** and **8**;

[0027] **FIGS. 10A** and **10B** are right side perspective views of the shuttered fiber optic receptacles that can be employed as the blade fiber optic receptacles in **FIGS. 5, 6B**, and **8** with the slideable shutters disposed in open and closed positions, respectively;

[0028] **FIGS. 11A** and **11B** are rear perspective views of another exemplary shuttered fiber optic receptacle that can be employed as the blade fiber optic receptacles in **FIGS. 5**, **6B**, and **8** with the slideable shutter disposed in closed and open positions, respectively;

[0029] **FIGS. 12A** and **12B** are side cross-sectional views of the shuttered fiber optic receptacles in **FIGS. 11A**, and **11B**, respectively, illustrating the slideable shutter disposed in closed and open positions, respectively;

[0030] **FIG. 13A** is a rear perspective view of an exemplary shuttered fiber optic plug that can be employed as the backplane fiber optic plug in **FIGS. 5**, **6A**, and **7** with the slideable shutter disposed in a closed position;

[0031] **FIG. 13B** is a rear perspective view of the shuttered fiber optic plug in **FIG. 13A**, with an actuation mechanism of the slideable shutter actuated to dispose the slideable shutter in an open position;

[0032] **FIG. 13C** is a close-up view of the slideable shutter actuated to dispose the slideable shutter in an open position in **FIG. 13B**;

[0033] **FIG. 14** is a rear perspective view of the shuttered fiber optic plug illustrated in **FIG. 13A**;

[0034] **FIG. 15A** is a side perspective view of the shuttered fiber optic receptacle in **FIGS. 11A** and **11B** with the actuation members unactuated to place the slideable shutters in closed positions before the shuttered fiber optic receptacle receipt of the fiber optic plug body in **FIGS. 13A-14**;

[0035] **FIG. 15B** is a side perspective view of the shuttered fiber optic receptacle in **FIGS. 11A** and **11B** with the actuation members actuated to place the slideable shutters in open positions as the shuttered fiber optic receptacle receives and is mated with the fiber optic plug body in **FIGS. 13A-14**;

[0036] **FIG. 16A** is a right side perspective view of the front of a rack module housing with information processing modules disposed therein;

[0037] **FIG. 16B** is a right side perspective view of the information processing modules in **FIG. 16A** without the rack module housing illustrated, and illustrating another exemplary dense fiber optic connector assembly to facilitate optical connections to the information processing modules through the optical backplane extension module in **FIGS. 2A-3**;

[0038] **FIG. 17A** is a side perspective view of the dense fiber optic connector assembly in **FIG. 16B** comprising a blade fiber optic plug configured to receive a backplane fiber optic plug;

[0039] **FIG. 17B** is a side perspective view of the dense fiber optic connector assembly in **FIG. 16B** with the blade fiber optic plug receiving the backplane fiber optic plug;

[0040] **FIG. 18A** is a side perspective, exploded view of another exemplary blade fiber optic receptacle and backplane fiber optic plug of a dense fiber optic connector assembly;

[0041] **FIG. 18B** is another close-up perspective, exploded view of the blade fiber optic receptacle and backplane fiber optic plug of the dense fiber optic connector assembly in **FIG. 18A**;

[0042] **FIG. 19** is another close-up view of the blade fiber optic receptacle and backplane fiber optic plug of the dense fiber optic connector assembly in **FIGS. 18A** and **18B**;

[0043] **FIGS. 20A** and **20B** are front and rear views, respectively, of an exemplary molded fiber optic plug body that may be employed in a dense fiber optic connector assembly;

[0044] **FIGS. 21A** and **21B** are front and rear perspective views, respectively, of the molded fiber optic plug body in **FIGS. 20A** and **20B**, respectively;

[0045] **FIG. 22A** is a close-up view of the rear perspective view of lead-in detail of the molded fiber optic plug body in **FIGS. 20A** and **20B**;

[0046] **FIG. 22B** is a close-up cutaway view of the lead-in detail of the molded fiber optic plug body in **FIGS. 20A** and **20B**;

[0047] **FIG. 23A** is a front perspective view of an intermediate organizer ferrule configured to facilitate fiber ribbonization and be disposed in the molded fiber optic plug body in **FIGS. 20A** and **20B**;

[0048] **FIG. 23B** is a rear perspective view of the organizer ferrule in **FIG. 23A**;

[0049] **FIG. 23C** is the organizer ferrule in **FIGS. 23A** and **23B** receiving optical fibers;

[0050] **FIG. 24A** is a rear perspective cutaway view of the organizer ferrule in **FIGS. 23A-23C** received in the molded fiber optic plug body in **FIGS. 20A** and **20B**;

[0051] **FIG. 24B** is a close-up cutaway view of **FIG. 24A**;

[0052] **FIG. 25A** is a perspective view of a projected fiber guide mold element that may be used to mold the fiber lead-in structure of the fiber optic plug body in **FIGS. 21A-22B** and organizer ferrule in **FIGS. 23A-23C**, respectfully;

[0053] **FIG. 25B** is a perspective close-up view of the tips of the projected fiber guide mold element in **FIG. 25A**;

[0054] **FIGS. 26** and **27** are front and rear perspective views, respectively, of the optical backplane extension module in **FIGS. 2A-3**;

[0055] **FIG. 28** is a rear perspective view of the optical backplane extension module in **FIGS. 27A** and **27B** illustrating a close-up view of the backplane fiber optic plugs disposed in the rear of the optical backplane extension module and interconnection fiber optic adapters disposed through interconnection ports in the side of the optical backplane extension module;

[0056] **FIG. 29** is a close-up view of the interconnection fiber optic adapters disposed through interconnection ports in the side of the optical backplane extension module;

[0057] **FIGS. 30A** and **30B** are rear and front perspective views, respectively, of exemplary information processing modules disposed in rack module housings, with another exemplary optical backplane extension module disposed in the rear of the rack module housing and optically connected to the information processing modules in the rear of the rack module housings using a dense fiber optic connector assembly;

[0058] **FIGS. 31A** and **31B** are front and rear perspective views, respectively, of the optical backplane extension module in **FIGS. 30A** and **30B**;

[0059] **FIG. 32A** is a close-up view of alignment members disposed in the optical backplane extension module to align the optical backplane extension module with the information processing modules disposed in a rack module housing;

[0060] **FIG. 32B** is a close-up perspective view of backplane fiber optic plugs disposed between alignment members in the optical backplane extension module in **FIGS. 30A** and **30B**;

[0061] **FIG. 33** is a side perspective view and close-up view of bias wheels that provides a lower datum for the information processing modules disposed in the rack module housing; and

[0062] **FIG. 34** is a side perspective view and close-up view of spring-loaded biasing members configured to push information processing modules down against the bias wheels in **FIG. 33** to securely align the information processing modules in the rack module housing.

DETAILED DESCRIPTION

[0063] Reference will now be made in detail to the embodiments, examples of which are illustrated in the accompanying drawings, in which some, but not all embodiments are shown. Indeed, the concepts may be embodied in many different forms and should not be construed as limiting 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.

[0064] Embodiments disclosed herein include optical backplane extension modules and related assemblies suitable for establishing optical connections to information processing modules disposed in equipment racks and the like. In this regard in one embodiment, an optical backplane extension module is provided. The optical backplane extension module comprises an extension module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, a right side disposed on a right end of the base opposite the left end, and a rear side disposed on a rear end of the base. A plurality of backplane fiber optic connectors is disposed through the rear side of the extension module housing and accessible through an exterior side of the rear side. The plurality of backplane fiber optic connectors is configured to be directly optically connected to a plurality of blade fiber optic connectors disposed in a plurality of information processing modules disposed in a rack module housing.

[0065] In this regard, **FIGS. 2A** and **2B** illustrate a data center **20** illustrating front and rear perspective views, respectively of an exemplary equipment rack **22**. Although only one equipment rack **22** is illustrated in **FIGS. 2A** and **2B**, it is understood that a plurality of equipment racks **22** may be present at the data center **20**. The equipment rack **22** is configured to support information processing modules **24** in rack module housings **26** disposed in the equipment rack **22**. For example, the information processing modules **24** may include computer servers, switches, and computer storage devices, and which may be referred to as server blades and storage blades, respectively. As will be discussed in greater detail below, the present disclosure provides fiber optic connectors, connector assemblies, cables, housings, and other related fiber optic components and methods that may be employed to connect and interconnect the information processing modules **24** to increase the data throughput of information process modules **24** thus increasing the throughput of the data center **20**. Benefits of optical fiber include extremely wide bandwidth and low noise operation, and thus higher data throughput as a result.

[0066] With continuing reference to **FIGS. 2A** and **2B**, because fiber optic components are used to connect and interconnect the information processing modules **24**, fiber optic cables are employed. It may be needed or desired to provide fiber optic cable management and neat storage and routing to avoid complexity in maintaining the data center **20** and to avoid or minimizing interfering with air flow between the information processing modules **24** disposing in the rack module housings **26**. In this regard, as will be discussed in more detail below, optical backplane extension modules **28** can be provided. As illustrated in **FIG. 3**, the optical backplane extension modules **28** are configured to be attached to the rear side **30** of the equipment rack **22** and a rack module housing **26** to manage and route fiber optic cables **32** extending from fiber optic connections to the information processing modules **24**.

[0067] As illustrated in **FIG. 3** generally and described later in this disclosure, the optical backplane extension modules **28** each comprise an interior space **34** defined by an extension module housing **35** for maintaining and routing of the fiber optic cables **32**. As illustrated in the close-up view of the optical backplane extension module **28** in **FIG. 3**, the optical backplane extension modules **28** also support a plurality of backplane fiber optic connectors **36** attached to the fiber optic cables **32**. The optical backplane extension module **28** supports disposing the backplane fiber optic connectors **36** through a rear side **38** of the extension module housing **35** to form an optical backplane. The optical backplane is configured to be directly optically connected to complementary fiber optic connectors disposed in information processing modules **24** to establish fiber optic connections when the optical backplane extension modules **28** are installed. By "directly connected," it is meant that there is not intermediate cabling used to make the connection. One connector is directly connected to another connector. The fiber optic connections can be intraconnections between information processing modules **24** within the same rack module housing **26** and thus the same optical backplane extension module **28**. However, in one embodiment, the optical backplane extension modules **28** also contain optical interconnection ports **40** to allow interconnections between optical backplane extension modules **28** and/or direction to information processing modules **24**.

[0068] Embodiments disclosed herein include dense fiber optic connector assemblies and related connectors and fiber optic cables suitable for establishing optical connections for optical backplanes in equipment racks. In this regard, **FIG. 4A** illustrates a right side perspective view of the optical backplane extension module **28** in **FIG. 2B** directly optically connected in the rear of the rack module housing **26** to the information processing modules **24**. **FIGS. 4B** and **4C** are right side perspective views of the information processing modules **24** with the rack module housing **26** removed for clarity purposes. As illustrated in **FIG. 4B** and the close-up view in **FIG. 4C**, an exemplary dense fiber optic connector assembly **42** is illustrated and provided to facilitate direct optical connections to the information processing modules **24** through the optical backplane extension module **28** in **FIGS. 2A-3**. A dense fiber optic connector assembly or related component is one in which a large number of optical fibers are supported to provide larger fiber optic connections in a dense area. Providing dense fiber optic connections can provide greater data throughput. For example, the dense fiber optic connector assembly **42** in **FIGS. 4B** and **4C** support any suitable number of fiber optic connections such as sixty-four (64), one-hundred and twenty-eight (128), two-hundred and fifty-six (256) optical fibers or more for providing the desired number of fiber optic connections.

[0069] With continuing reference to **FIGS. 4A-4C**, and as will be described in greater detail below, the dense fiber optic connector assembly **42** is comprised of one or more fiber optic connectors, which are backplane fiber optic plugs **44** in this embodiment. The backplane fiber optic plugs **44** are configured to be disposed through the rear side **38** of the extension module housing **35** (see **FIG. 3**). By the term "backplane," it refers to disposition in the optical backplane extension module **28**. The dense fiber optic connector assembly **42** also comprises one or more blade fiber optic connectors, which are blade fiber optic receptacles **46** in this embodiment, mounted on the information processing modules **24**. By the term "blade," it is meant to refer to a card, board, or other carrier used to provide the components of an information processing module **24** that is mechanically received in the rack module housing **26**. The blade fiber optic connectors **46** are connected to components in the information processing modules **24** to facilitate transfer of data from these components. Thus, when the backplane fiber optic plugs **44** are mated to the blade fiber optic receptacles **46**, optical connections are established to the information processing modules **24**. These optical connections can be routed through the fiber optic cables **32** connected to the backplane fiber optic plugs **44** (see **FIG. 3**) to other information processing modules **24** through intraconnections in the optical backplane extension module **38** and/or interconnections through the optical interconnection ports **40**.

[0070] **FIG. 5** is a close-up perspective view of the dense fiber optic connector assembly **42** in **FIGS. 4B** and **4C.** In this example, the dense fiber optic connector assembly **42** is comprised of dense information processing module fiber optic receptacles ("blade fiber optic receptacles **46**") configured to receive and directly optically connect to dense optical backplane extension module fiber optic plugs ("backplane fiber optic plugs **44**"). **FIG. 6A** is a close-up perspective view of the backplane fiber optic plugs **44** in **FIG. 5**. **FIG. 6B** is a close-up perspective view of the blade fiber optic receptacles **46** in **FIG. 5**. Note that the dense fiber optic connector assembly **42** is not limited to this connector configuration. For example, the blade fiber optic receptacles **46** could be configured as plugs, and the backplane fiber optic plugs **44** could be configured as receptacles.

[0071] **FIG. 7A** is a perspective exploded view of the backplane fiber optic plugs **44** in **FIGS. 5** and **6A**. With reference to **FIGS. 5**, **6A**, and **7**, the backplane fiber optic plugs **44** are comprised of four (4) backplane fiber optic plugs **44(1)-44(4)** in this embodiment. Each backplane fiber optic plug **44** supports sixty-four (64) optical fibers **48(1)-48(4)**. As will be described in more detailed below, the backplane fiber optic plugs **44(1)-44(4)** are configured to support multiple fiber optic cables **32(1)-32(4)** to provide a high density optical fiber count in the backplane fiber optic plugs **44(1)-44(4)**. In this embodiment, the fiber optic cables **32(1)-32(4)** are each comprised of a plurality of ribbonized fiber optic cables; however, other embodiments may use optical fibers without cable such as optical fibers that are ribbonized or not. Providing backplane fiber optic plugs **44(1)-44(4)** that are configured to receive ribbonized fiber optic cables is one method of allowing the backplane fiber optic plugs **44(1)-44(4)** to support high density optical fiber count since ribbonized fiber optic cables are flat and efficient in terms of optical fiber count versus space. Further in this embodiment, each of the fiber optic cables **32(1)-32(4)** are comprised of a plurality of ribbonized cables which allows flexibility in providing intraconnections and interconnections facilitated by the optical backplane extension module **28**. Each fiber optic cable **32(1)-32(4)** does not have to be intraconnected or interconnected to the same fiber optic connector depending on the design.

[0072] With continuing reference to **FIGS. 6A** and 7, each of the backplane fiber optic plugs **44(1)-44(4)** are disposed in a backplane connector frame **50** to group the backplane fiber optic plugs **44(1)-44(4)** together. The backplane connector frame **50** may be comprised of a plastic member that is molded or stamped, as non-limiting examples. The backplane connector frame **50** contains a plurality of openings **52(1)-52(4)** configured to receive the backplane fiber optic plugs **44(1)-44(4)**. The backplane connector frame **50** also includes a suitable number of mounting features such as two tabs **54(1), 54(2)** extending from ends **56(1), 56(2)** of the connector frame **50** for mounting the backplane connector frame **50** to the rear side **38** of the extension module housing **35** (see **FIG. 3**). Each mounting tab **54(1), 54(2)** contains an opening **57(1), 57(2)** that is configured to receive a fastener to secure the backplane connector frame **50** with the backplane fiber optic plugs **44(1)-44(4)** to the extension module housing **35** (see **FIG. 3**) to form an optical backplane for connection to the blade fiber optic receptacles **46(1)-46(4)**.

[0073] **FIG. 7A** also illustrates more detail of the backplane fiber optic plugs **44(1)-44(4)**. Each backplane fiber optic plug **44(1)-44(4)** is comprised of a fiber optic connector body in the form of a fiber optic plug bodies **58(1)-58(4)** and a fiber optic ferrule in the form of a fiber optic plug ferrules **60(1)-60(4)**. The fiber optic plug ferrules **60(1)-60(4)** are configured to be disposed through first ends **62(1)-62(4)** of the fiber optic plug bodies **58(1)-58(4)** and disposed in internal chambers in the fiber optic plug bodies **58(1)-58(4)**. Optical fibers **48(1)-48(4)** may be exposed and prepared from the sheaths **64(1)-64(4)** of the fiber optic cables **32(1)-32(4)** if necessary are aligned with fiber openings **66(1)-66(4)** disposed in end faces **68(1)-68(4)** of the fiber optic plug ferrules **60(1)-60(4)**. The second ends **69(1)-69(4)** of the fiber optic plug bodies **58(1)-58(4)**

contain lenses **70(1)-70(4)** are configured to be aligned with the fiber openings **66(1)-66(4)** of the fiber optic plug ferrules **60(1)-60(4)**. The lenses **70(1)-70(4)** allow for optical connections to be made to the optical fibers **48(1)-48(4)** when the backplane fiber optic plugs **44(1)-44(4)** are mated to the blade fiber optic receptacles **46(1)-46(4)**. With continuing reference to **FIG. 7A**, the purpose of the fiber optic plug ferrules **60(1)-60(4)** is to hold the optical fibers **48(1)-48(4)** together during fiber processing and during their insertion into the fiber optic plug bodies **58(1)-58(4)**. Laser processing of the optical fibers **48(1)-48(4)** can provide a quick and efficient method for producing a high-quality end face on the optical fibers **48(1)-48(4)** for termination. Examples of laser processing that can be provided to the optical fibers **48(1)-48(4)** are described in U.S. Patent Application Serial No. 13/028,799 filed on Feb. 16, 2011 and titled "METHODS FOR LASER PROCESSING ARRAYED OPTICAL FIBERS ALONG WITH SPLICING CONNECTORS". In this regard, **FIG. 7B** depicts a first method for laser processing the plurality of optical fibers **48** using a protection element **71**. Protection element **71** is used for protecting the optical fibers **48** in the array that are not intended for laser processing since they are located at a further distance from the laser than the optical fibers optical fibers **48** intended for processing. By way of example, the fiber optic plug ferrules **60** have the optical fibers **48** disposed in a first row **73** at a first distance and a second row **75** at a second distance so that the laser could not be focused for both distances. More or fewer rows can be provided as desired. As shown, the first row **73** and second row **75** of the optical fibers **48** are schematically shown disposed within the fiber optic plug ferrules **60**. The protection element 71 can reflect, absorb and/or disperse the laser energy after it passes the optical fibers being processed depending on the type of material used for the same. For instance, if the protection element 71 is a material that has a smooth surface such as a machined aluminum, stainless steel, etc. it will have a high-degree of reflection. On the other hand, if the protection element 71 is formed from a mica, carbon, ceramic plate or other similar porous material it will have a high-degree of absorption. Still further, the degree of dispersion caused by protection element 71 can depend on the surface finish. In other words, the rougher the surface, the greater the dispersion. Examples of surface finishes on protection element 71 that can create dispersion are grooves, knurling, etc.

[0074] With continued reference to **FIG. 7B**, the protection element 71 has a smooth surface that has a relatively high degree of reflection of the laser energy that impinges on the same. The protection element 71 allows the laser energy to reach the optical fibers being processed, but inhibits the laser energy from damaging the optical fibers not being processed, other portions of structure **30**, or from creating a safety issue, but the protection element 71 may also absorb and/or disperse a portion of the energy depending on the material used. This laser process method also uses an optional laser absorption element **77** to contain the reflected laser energy**.** As shown in **FIG. 7B**, the protection element 71 is positioned near the ends of the optical fibers **48**, and the absorption element **77** is disposed above the first row **73** of optical fibers **48** to inhibit the travel of any reflected laser energy from the protection element 71.

[0075] With reference back to **FIG. 7A**, the fiber optic plug bodies **58(1)-58(4)** can be configured to provide optical transmission to the optical fibers **48(1)-48(4)** disposed through the fiber optic plug ferrules **60(1)-60(4)** through lenses that are molded-in, GRIN lenses, or other suitable lenses disposed in the fiber optic plug bodies **58(1)-58(4)**. If molded-in lenses are used, the fiber optic plug bodies **58(1)-58(4)** is preferably manufactured of a light transmission material to provide blind holes internal to the fiber optic plug bodies **58(1)-58(4)** with lenses that extend to the second ends **69(1)-69(4)** of the fiber optic plug bodies **58(1)-58(4)**.

[0076] **FIG. 8** is a perspective exploded view of the blade fiber optic receptacles **46** in **FIGS. 5** and **6B**. With reference to **FIGS. 5**, **6B** and **8**, the blade fiber optic receptacles **46** are comprised of four (4) blade fiber optic receptacles **46(1)-46(4)** in this embodiment. Each blade fiber optic receptacle **46(1)-46(4)** supports sixty-four (64) optical fibers **72(1)-72(4)**. As will be described in more detailed below, the blade fiber optic receptacles **46(1)-46(4)** are configured to support multiple fiber optic cables **74(1)-74(4)** to provide the a high optical fiber count in the blade fiber optic receptacles **46(1)-46(4)**. In this embodiment, the fiber optic cables **74(1)-74(4)** are each comprised of a plurality of ribbonized fiber optic cables. Providing blade fiber optic receptacles **46(1)-46(4)** that are configured to receive ribbonized fiber optic cables is one method of allowing the blade fiber optic receptacles **46(1)-46(4)** to support high density optical fiber count since ribbonized fiber optic cables are flat and efficient in terms of optical fiber count versus space. Further in this embodiment, each of the fiber optic cables **74(1)-74(4)** are comprised of a plurality of ribbonized cables which allows flexibility in providing fiber optic connections to different component and/or to different areas on the information processing modules **24**.

[0077] With continuing reference to **FIGS. 6B** and **8**, each of the backplane fiber optic receptacles **46(1)-46(4)** are disposed in a blade connector frame **76** to group the blade fiber optic receptacles **46(1)-46(4)** together when disposed on the information processing module **24**. The blade connector frame **76** may be comprised of a plastic member that is molded or stamped as examples. The blade connector frame **76** contains an opening **78** configured to receive the blade fiber optic receptacles **46(1)-46(4)**. The blade connector frame **76** also includes suitable mounting features such as two tabs **80(1), 80(2)** extending from ends **82(1), 82(2)** of the blade connector frame **76** for mounting the blade connector frame **76** to a surface of the information processing module **24** (see **FIG. 3**). Each mounting tab **80(1), 80(2)** contains an opening **84(1), 84(2)** that is configured to receive a fastener to secure the blade connector frame **76** with the blade fiber optic receptacles **46(1)-46(4)** to the information processing module **24** (see **FIG. 3**) for optical connections. Washers or spacers **85(1), 85(2)** may be provided and disposed between the surface of the information processing module **24** and the blade connector frame **76**. The spacers **85(1), 85(2)** may be elastomeric elements that are intended to allow resilient coupling of the blade fiber optic receptacle **46** with the backplane fiber optic plug **44**. By the spacers **85(1), 85(2)** being elastomeric elements, when the backplane fiber optic plug **44** starts to mate with the blade fiber optic receptacle **46,** the spacers **85(1), 85(2)** allow the blade fiber optic receptacle **46** to be flexible and move slightly to allow for the backplane fiber optic plug **44** to properly mate with the blade fiber optic receptacles **44** in the event that the backplane fiber optic plug **46** and the blade fiber optic receptacles **44** are not perfectly aligned.

[0078] **FIG. 8** also illustrates more detail of the blade fiber optic receptacles **46(1)-46(4)**. Each blade fiber optic receptacle **46(1)-46(4)** is comprised of a fiber optic connector housing in the form of fiber optic receptacle bodies **86(1)-86(4)** and a fiber optic ferrule in the form of fiber optic receptacle ferrules **88(1)-88(4)**. The fiber optic receptacle ferrules **88(1)-88(4)** are configured to be disposed through first ends **90(1)-**

90(4) of the fiber optic receptacle bodies **86(1)-86(4)** and disposed in internal chambers **92(1)-92(4)** in the fiber optic receptacle bodies **86(1)-86(4)**. Optical fibers **72(1)-72(4)** that are exposed and prepared from the sheaths **94(1)-94(4)** of the fiber optic cables **74(1)-74(4)** are aligned with fiber openings **96(1)-96(4)** disposed in end faces **98(1)-98(4)** of the fiber optic receptacle ferrules **88(1)-88(4)**. Optical connections to the optical fibers **72(1)-72(4)** disposed in the fiber optic receptacle ferrules **88(1)-88(4)** are made when the backplane fiber optic plugs **44(1)-44(4)** are inserted into the internal chambers **92(1)-92(4)** of the fiber optic receptacle bodies **86(1)-86(4)**. The fiber optic receptacle bodies **86(1)-86(4)** align the fiber optic plug bodies **58(1)-58(4) (FIG. 7A)** and their lenses **70(1)-70(4)** with the fiber openings **96(1)-96(4)** in the end faces **98(1)-98(4)** of the fiber optic receptacle ferrules **88(1)-88(4)**.

[0079] With continuing reference to **FIG. 8**, the fiber optic receptacle ferrules **88(1)-88(4)** can be configured to provide optical transmission to the optical fibers **72(1)-72(4)** disposed therein through lenses such as molded-in lenses, GRIN lenses, or the like disposed in the fiber optic receptacle ferrules **88(1)-88(4)**. By way of example, fiber optic receptacle ferrules **88(1)-88(4)** may support GRIN lenses in bores. In this regard, **FIG. 9A** is a perspective quarter cut view of the blade fiber optic receptacles **46(1)-46(4)** in **FIGS. 5, 6B**, and **8**, wherein the fiber optic connector bodies **86(1)-86(4)** are configured to support GRIN lenses.

[0080] To assemble the blade fiber optic receptacles **46(1)-46(4)**, the blade fiber optic receptacles **46(1)-46(4)** are disposed through the blade connector frame **76**. The fiber optic receptacle ferrules **88(1)-88(4)** are disposed through a rear blade connector frame **97**. The blade connector frame **76** and rear blade connector frame **97** are secured to each other by latches **101** that contain protrusions **103** configured to engage with openings **105** disposed in the back connector frame **76**. Springs **107(1)-107(4), 109(1)-109(4)** are included to provide spring loading of the blade fiber optic receptacles **46(1)-46(4)** to the blade connector frame **76** and rear blade connector frame **97** to allow for movement, when needed, to be connected to the backplane fiber optic plugs **44(1)-44(4)**.

[0081] As illustrated in **FIG. 9A**, a fiber optic receptacle sub-carrier **99(1)** of the fiber optic receptacle body **86(1)** is configured to receive the fiber optic receptacle ferrule **88(1)**. In this embodiment, the fiber optic receptacle sub-carrier **99(1)** is comprised of

GRIN lens internal chambers **100(1)** aligned with GRIN lens openings **95(1)**. The GRIN lens internal chambers **100(1)** are configured to support GRIN lenses whose end portions are disposed at the end face **98(1)** through the GRIN lens openings **95(1)**. The fiber optic receptacle sub-carrier **99(1)** is also comprised of internal fiber chambers **102(1)** to support the optical fibers **72(1)** and align the optical fibers **72(1)** with the GRIN lens internal chambers **100(1)** to align the optical fibers **72(1)** with GRIN lenses. The internal fiber chambers **102(1)** are comprised of a coated fiber chamber **102A(1)** and a bare fiber chamber **102B(1)** to securely support the coated portions **72A(1)** and bare portions **72B(1)** of the optical fibers **72(1)** to avoid movement of the optical fibers **72(1)** in the fiber optic receptacle sub-carrier **99(1)**. Note that although only the fiber optic receptacle sub-carrier **99(1)** and fiber optic receptacle ferrule **88(1)** are discussed with regard to **FIG. 9A**, the discussion of **FIG. 9A** is equally applicable to the other fiber optic receptacle ferrules **88(2)-88(4)** and their fiber optic receptacle sub-carriers **99(2)-99(4)**.

[0082] Alternatively, the fiber optic receptacle bodies **86(1)-86(4)** can be manufactured of a light transmission material having molded-in lenses at the end of blind holes for receiving optical fibers for optical transmissions at the interface. In this regard, **FIG. 9B** is a perspective cross-section view of the fiber optic receptacle body **86(1)** providing a blind hole lens holder that may be employed in the blade fiber optic receptacles **46(1)-46(4)** in **FIGS. 5, 6B**, and **8**.

[0083] As illustrated in **FIG. 9B**, in this embodiment, a fiber optic receptacle sub-carrier is not employed. The fiber optic receptacle body **86(1)** in this embodiment is comprised of blind hole lenses **104(1)**. The blind hole lenses **104(1)** are disposed in the fiber optic receptacle body **86(1)**. The fiber optic receptacle body **86(1)** is comprised of a light transmissive material forming blind holes **106(1)** that allow light from the optical fibers **72(1)** to be transmitted through the light transmissive material and through the blind hole lenses **104(1).** The fiber optic receptacle body **86(1)** is comprised of internal fiber chambers **102(1)**, like in **FIG. 9A**, to support the optical fibers **72(1)** and align the optical fibers **72(1)** with the blind hole lenses **104(1)**. The internal fiber chambers **102(1)** are comprised of a coated fiber chamber **102A(1)** and a bare fiber chamber **102B(1)** to securely support the coated portions **72A(1)** and bare portions **72B(1)** of the optical fibers **72(1)** to avoid movement of the optical fibers **72(1)** in the fiber optic receptacle body

86(1). Note that although only the fiber optic receptacle body **86(1)** is discussed with regard to **FIG. 9B**, the features of **FIG. 9B** can be applicable to the other fiber optic receptacle bodies **86(2)-86(4)**.

[0084] As will be described in more detail below with regard to **FIGS. 10A-15B**, the lenses **70(1)-70(4)** can be shuttered. Shuttering allows for the optical fibers **48(1)-48(4)** to not be exposed through the lenses **70(1)-70(4)** when the backplane fiber optic plugs **44(1)-44(4)** are not mated to prevent debris from entering the fiber optic plug bodies **58(1)-58(4)** and affecting optical transmissions when the backplane fiber optic plugs **44(1)-44(4)** are not mated. When the backplane fiber optic plugs **44(1)-44(4)** are mated, the shutter exposes the optical transmission paths to the optical fibers **48(1)-48(4)** through the lenses **70(1)-70(4)**.

[0085] Debris entering the fiber optic plug bodies **58(1)-58(4)** and entering through the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, can attenuate optical transmissions. As will be described in more detail below with regard to **FIGS. 10A-15B**, the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, can be shuttered. Shuttering for the dense fiber optic connections can be provided in the backplane fiber optic plugs **44(1)-44(4)** and the blade fiber optic receptacles **46(1)-46(4)** when not mated to prevent debris from entering and affecting optical transmissions. When the backplane fiber optic plugs **44(1)-44(4)** and blade fiber optic receptacles **46(1)-46(4)** are mated, the shutter can be designed to be actuated to expose the optical transmission paths.

[0086] **FIGS. 10A** and **10B** are right side perspective views of shuttered blade fiber optic receptacles **46'(1)-46'(4)** that can be employed as the blade fiber optic receptacles **46(1)-46(4)** in **FIGS. 5**, **6B**, and **8** with slideable shutters **108(1)-108(4)** disposed in open and closed positions, respectively. **FIGS. 11A** and **11B** are rear perspective views of an exemplary shuttered fiber optic receptacle **46'** that can be employed as the blade fiber optic receptacles **46(1)-46(4)** in **FIGS. 5**, **6B**, and **8** with the slideable shutter **108** disposed in closed and open positions, respectively. **FIGS. 12A** and **12B** are side cross-sectional views of the shuttered fiber optic receptacle housing **86'** in **FIGS. 11A**, and **11B**, respectively, illustrating the slideable shutter **108** disposed in closed and open positions, respectively.

[0087] With reference to **FIGS. 10A-12B**, the shuttered fiber optic receptacle body **86'** may be a dense fiber optic receptacle housing. The slideable shutter **108** is disposed in the optical transmission paths of the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, of the fiber optic receptacle body **86'**. The slideable shutter **108** has openings **110** configured to be aligned with the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, in the fiber optic receptacle body **86'** in an open position, as illustrated in **FIG. 11B**. The openings **110** of the slideable shutter **108** is also configured to block access to lenses disposed in the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, in a closed position, as illustrated in **FIG. 11A**. As illustrated in **FIGS. 11A** and **11B**, an actuation member **112** is coupled to the slideable shutter **108**. The actuation member **112** is configured to move the slideable shutter **108** from the closed position in **FIG. 11A** to the open position in **FIG. 11B**. The actuation member **112** may be a linear action actuation member configured to be linearly moved to linearly move the slideable shutter **108**. By way of example, the slidable shutter is movable in a plane that is generally perpendicular to the optical axis of the fiber optic connector.

[0088] In this embodiment, because high density fiber count is supported by the fiber optic receptacle ferrule **88'**, a low actuation distance is provided. The slideable shutter **108** can be configured to move at least the distance of the inner diameter of the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, to achieve dust sealing and/or eye safety. The slideable shutter **108** is planar, thin, and requires little actuation distance. It can be actuated in a linear fashion with no rotation by the actuation member **112**, as will be described in more detail below. The slideable shutter **108** can be use in collimated beam paths.

[0089] For example, as illustrated in **FIG. 12A**, when the actuation member **112** is not pressed down as is provided in **FIG. 12B**, the slideable shutter **108** is not in an open position. Solid sections **114** adjacent the openings **110** in the slideable shutter **108** are aligned with the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, in a closed position, and thus block light transmission in **FIG. 12A**. In **FIG. 12B**, the solid sections **114** of the slideable shutter **108** are offset from the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, , and the openings **110** are aligned with the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be, in an open position, and thus light transmission is not blocked.

[0090] **FIGS. 13A** and **13B** are perspective views of an exemplary shuttered backplane fiber optic plug **44'** that can be employed as the backplane fiber optic plug **44** in **FIGS. 5**, **6A**, and 7, with a slideable shutter **116** disposed in a closed and open position, respectively. **FIG. 13C** is a close-up view of **FIG. 13B** illustrating the slideable shutter in an open position. The slideable shutter **116** is an optical path of the lenses **70** disposed in the fiber optic plug ferrule **60'** (see **FIG.** 7A). **FIG. 14** is a bottom perspective view of the shuttered fiber optic plug **44'** illustrated in **FIG. 13A**. The shuttered backplane fiber optic plug **44'** may be a dense backplane fiber optic plug. The slideable shutter **116** has openings **118** configured to be aligned with the lenses **70** in the fiber optic plug ferrule **60** in an open position, as illustrated in **FIGS. 13B** and **13C**. The slideable shutter **116** in this embodiment is protected behind a face plate **117** that is configured with openings **119** having the same geometry as openings **118**, but the face plate **117** is optional. The openings **118** of the slideable shutter **116** are also configured to block access to the lenses **70** in a closed position, as illustrated in **FIG. 13A**. As illustrated in **FIGS. 13A-13C**, an actuation member **120** is coupled to the slideable shutter **116**. The actuation member **120** is configured to move the slideable shutter **116** from the closed position in **FIG. 13A** to the open position in **FIGS. 13B** and **13C**.

[0091] For example, as illustrated in **FIG. 13A**, when the actuation member **120** is not pressed down as is provided in **FIGS. 13B** and **13C**, the slideable shutter **116** is not in an open position. Solid sections **122** adjacent the openings **118** in the slideable shutter **116** are aligned with the lenses **70** in a closed position, and thus block light transmission in **FIGS. 13A** and **14**. In **FIGS. 13B** and **13C**, the solid sections **122** of the slideable shutter **116** are offset from the GRIN lens openings **95(1)-95(4)** or blind hole lenses **104(1)-104(4)**, as the case may be,, and the openings **118** are aligned with the lenses **70** in an open position, and thus light transmission is not blocked.

[0092] **FIG. 15A** is a side perspective view of the shuttered fiber optic receptacle body **86'** in **FIGS. 11A** and **11B** with the actuation members **112, 120** unactuated to place the slideable shutters **108, 116** in closed positions before the shuttered fiber optic receptacle body **86'** receipt of the fiber optic plug body **58'** in **FIGS. 13A-14**. **FIG. 15B** is a side perspective view of the shuttered fiber optic receptacle body **86'** in **FIGS. 11A** and **11B** with the actuation members **112, 120** actuated to place the slideable shutters **108, 116** in open positions as the shuttered fiber optic receptacle body **86'** receives and is mated with the fiber optic plug body **58'** in **FIGS. 13A-14**.

[0093] With continuing reference to **FIGS. 15A** and **15B**, the fiber optic plug body **58'** contains a mating actuation member **124**. The mating actuation member **124** is comprised of a mount **126** supporting an actuation arm **128**. The actuation arm **128** is configured to engage the fiber optic receptacle actuation member **112** when the fiber optic plug body **58'** is received by the fiber optic receptacle body **86'**. The actuation arm **128** contains a protrusion **130** disposed on a distal end **132** of the actuation arm **128**. As the fiber optic plug body **58'** is received in the blade fiber optic receptacle **46'**, an end portion **134** of the actuation arm **128** is disposed in an engagement orifice **136** wherein the protrusion **130** will cause a lifting force to be disposed in the engagement orifice **136** to move the slideable shutter **108** in the blade fiber optic receptacle **46'** from a closed to an open position. As the backplane fiber optic plug **44'** penetrates the blade fiber optic receptacle **46'**, the actuation member **120** is indexed to open the slideable shutter **116** disposed in the backplane fiber optic plug **44'** to an open position.

[0094] Other embodiments of dense fiber optic connector assemblies and related connectors and fiber optic cables suitable for establishing optical connections for optical backplanes in equipment racks are possible and disclosed herein. In this regard, **FIG. 16A** illustrates rack module housing **26** with information processing modules **24** disposed therein. **FIG. 16B** is a perspective view of the information processing modules **24** with the rack module housing **26** removed. As illustrated in **FIG. 16B**, another exemplary dense fiber optic connector assembly **131** is illustrated and provided to facilitate direct optical connections to the information processing modules **24** through the optical backplane extension module **28** illustrated previously in **FIGS. 2A-3**. As non-limiting examples, the dense fiber optic connector assembly **131** in **FIG. 16B** can support sixty-four (64), one-hundred and twenty-eight (128), two-hundred and fifty-six (256), or more optical fibers to provide sixty-four (64), one-hundred and twenty-eight (128), two-hundred and fifty-six (256), or more fiber optic connections, respectively.

[0095] **FIG. 17A** is a side perspective view of the dense fiber optic connector assembly **131** in **FIG. 16B** comprising a blade fiber optic receptacle **133** configured to receive a backplane fiber optic plug **135**. **FIG. 17B** is a side perspective view of the dense fiber optic connector assembly **133** in **FIG. 16B** with the blade fiber optic receptacle **133** receiving the backplane fiber optic plug **135** to establish an optical connection between information processing modules **24** and the optical backplane extension module **28** illustrated previously in **FIGS. 2A-3**.

[0096] With continuing reference to **FIGS. 16B-17B**, the fiber optic connector assembly **131** is comprised of one or more the backplane fiber optic plugs **135** configured to be disposed through the rear side **38** of the extension module housing **35** (see **FIG. 3**). As illustrated in **FIG. 17A**, the backplane fiber optic plug **135** is configured to receive a plurality of fiber optic cables **138** or optical fibers. In this embodiment, the fiber optic cables **138** are ribbon cables that are stacked on top of each other with their wide axis $\mathbf{W_1}$ disposed along the short axis $\mathbf{S_1}$ of the backplane fiber optic plug **135**. This arrangement allows the backplane fiber optic plug **135** to support a high fiber count and thus provide a dense backplane fiber optic plug **135**.

[0097] With continuing reference to **FIGS. 16B-17B**, the fiber optic connector assembly **131** also comprises one or more blade fiber optic receptacles **133** mounted on the information processing modules **24**. The blade fiber optic receptacles **133** are connected to components in the information processing modules **24** to facilitate transfer of data from these components. As illustrated in **FIG. 17A**, the blade fiber optic receptacle **133** is configured to receive a plurality of fiber optic cables **143** or optical fibers that may be ribbonized. In this embodiment, the fiber optic cables **143** are ribbon cables that are stacked on top of each other with their wide axis $\mathbf{W_2}$ disposed along the short axis $\mathbf{S_2}$ of the blade fiber optic receptacle **135**. This arrangement allows the blade fiber optic receptacle **135** to support a high fiber count and thus provide a dense blade fiber optic receptacle **135**.

[0098] When the backplane fiber optic plugs **135** are mated to the blade fiber optic receptacles **133**, optical connections are established to the information processing modules **24**. These optical connections can be routed through the fiber optic cables **32** connected to the backplane fiber optic plugs **135** (see **FIG. 3**) to other information processing modules **24** through intraconnections in the optical backplane extension module **28** and/or interconnections through the optical interconnection ports **40** (see **FIG. 3**). The blade fiber optic receptacle **133** include a mounting structure **139** that may be spring loaded to allow the blade fiber optic receptacles **133** to move when mounted on information processing modules **24** to assist in axis alignment and connection to the backplane fiber optic plug **135**.

[0099] Another exemplary dense fiber optic connector assembly **131'** is illustrated in **FIGS. 18A-19B**. **FIG. 18A** is a side perspective, exploded view of a blade fiber optic receptacle **133'** and backplane fiber optic plug **135'**of a dense fiber optic connector assembly **131'**. **FIG. 18B** is another close-up perspective, exploded view of the blade fiber optic receptacle **133'** and backplane fiber optic plug **135'** of the dense fiber optic connector assembly **131'** in **FIG. 18A**. **FIG. 19** is another close-up view of the blade fiber optic receptacle **133'** and backplane fiber optic plug **135'** of the dense fiber optic connector assembly **131'** in **FIGS. 18A** and **18B**. The dense fiber optic connector assembly **131'** in **FIGS. 18A-19** is similar to the dense fiber optic connector assembly **131** in **FIGS. 16B-17B**. However, as will be discussed below in more detail, the dense fiber optic connector assembly **131'** in **FIGS. 18A-19** includes organizer ferrules that allow wider, higher fiber count, ribbonized fiber optic cables to be stacked and organized along their wide axis to be supported in the blade fiber optic receptacle **133'** and the backplane fiber optic plug **135'** to support a dense fiber count.

[00100] With reference to **FIGS. 18A** and **18B**, the backplane fiber optic plug **135'** supports up to two-hundred and fifty-six (256) or more optical fibers **137** in a single connector form factor. As will be described in more detailed below, the backplane fiber optic plug **135'** is configured to support multiple stacked fiber optic cables **138(1)-138(4)** or optical fibers for providing a high optical fiber count in the backplane fiber optic plug **135'**. In this embodiment, the fiber optic cables **138(1)-138(4)** are each comprised of a plurality of ribbonized fiber optic cables. As illustrated in **FIG. 18A**, the fiber optic cables **138(1)-138(4)** are stacked along their wide axis $\mathbf{W_3}$. Providing a backplane fiber optic plug **135'** that is configured to receive ribbonized fiber optic cables is one method of allowing the backplane fiber optic plug **135'** to support high density optical fiber count since ribbonized fiber optic cables are flat and efficient in terms of optical fiber count versus space. Further in this embodiment, each of the fiber optic cables **138(1)-138(4)** are each comprised of a plurality of ribbonized cables which allows flexibility in providing intraconnections and interconnections facilitated by the optical backplane extension module **28** (see **FIG. 3**). Each fiber optic cable **138(1)-138(4)** does not have to be intraconnected or interconnected to the same fiber optic connector depending on the design.

[00101] With continuing reference to **FIGS. 18A** and **18B**, the backplane fiber optic plug **135'** is comprised of a fiber optic plug body **140**. The fiber optic plug body **140** may be a ferrule body. The fiber optic plug body **140** is configured to receive an organizer ferrule **142** that receives the fiber optic cables **138(1)-138(4)** in an opening **144** disposed in the organizer ferrule **142**. The organizer ferrule **142** is particularly well suited to facilitate ribbonization and insure that optical fibers engage the connector body **154** in an array structure. In this manner, the organizer ferrule **142** disposes end portions **146(1)-146(4)** of the fiber optic cables **138(1)-138(4)** in a compacted high density to be disposed in an opening **148** in the fiber optic plug body **140**. The organizer ferrule **142** also facilitates pre-insertion laser processing of massed optical fibers exposed from the fiber optic cables **138(1)-138(4)** for laser processing, including, without limitation, using the laser processing examples discussed above. In this embodiment, the fiber optic cables **138(1)-138(4)** are disposed in the organizer ferrule **142** along the wide axis $\mathbf{W_4}$ of the ferrule organizer **142**. An adhesive may be provided to secure the organizer ferrule **142** in the fiber optic plug body **140** during assembly. The fiber optic plug body **140** and organizer ferrule **142** may be comprised of a plastic member that is molded or stamped, as examples. As illustrated in **FIGS. 18B** and **19**, the fiber optic plug body **140** has an end face **149** that has a plurality of lenses **151** disposed therein to provide an optical transmission path to the end portions **146(1)-146(4)** of optical fibers **147(1)-147(4)** exposed from the fiber optic cables **138(1)-138(4)**.

[00102] With continuing reference to **FIGS. 18A-19**, the fiber optic plug body **140** also contains two tabs **150(1), 150(2)** extending from the fiber optic plug body **140** for mounting the backplane fiber optic plug **135'** to the rear side **38** of the extension module housing **35** (see **FIG. 3**). Each mounting tab **150(1), 150(2)** contains an opening **152(1), 152(2)** (**FIG. 18B**) that is configured to receive a fastener to secure the backplane connector frame **50** with the backplane fiber optic plugs **44(1)-44(4)** to the extension module housing **35** (see **FIG. 3**) to form an optical backplane for connection to the blade fiber optic receptacles **46(1)-46(4)**.

[00103] **FIGS. 18A** and **18B** illustrate details regarding the components of the blade fiber optic receptacle **133'**. The blade fiber optic receptacle **133'** includes a fiber optic receptacle body **154** and an organizer ferrule **156**. The fiber optic receptacle body **154** is configured to receive the organizer ferrule **156**, which then receives fiber optic cables **158(1)-158(4)** from the information processing module **24** in an opening **160** disposed in the organizer ferrule **156**. In this manner, the organizer ferrule **156** disposes end portions **162(1)-162(4)** of the fiber optic cables **158(1)-158(4)** in a compacted high density to form to be disposed in an opening **164** (**FIG. 18B**) in the fiber optic receptacle body **154**. As illustrated in **FIG. 18A**, in this embodiment, the wide axis $\mathbf{W_5}$ of the fiber optic cables **138(1)-138(4)** are disposed in the organizer ferrule **142** along the wide axis $\mathbf{W_6}$ of the ferrule organizer **142**. An adhesive may be provided to secure the organizer ferrule **156** in the fiber optic receptacle body **154** during assembly. A soft elastomer **165** may be disposed in the fiber optic receptacle body **154** as illustrated in **FIG. 19** to enable small movements of the organizer ferrule **156** in the connection direction axis. The fiber optic receptacle body **154** and organizer ferrule **156** may be comprised of a plastic member that is molded or stamped, as examples.

[00104] As illustrated in **FIG. 18B**, the fiber optic receptacle body **154** has an end face **167** disposed in a lens block **168** that has a plurality of lenses **170** disposed therein to provide an optical transmission path to end portions **162(1)-162(4)** of the optical fibers **166(1)-166(4)** (**FIG. 18A**) exposed from the fiber optic cables **158(1)-158(4)**. As illustrated in **FIG. 19**, the lens block **168** also has a plurality of lenses **172** disposed on an end face **173** of the fiber optic plug body **140** side of the fiber optic receptacle body **154** that are configured to be aligned with the end portions **146(1)-146(1)** of the fiber optic cables **138(1)-138(4)**. In this manner, the lens block **168** is configured to provide a transmission path between the lenses **170, 172** to optically connect the end portions **146(1)-146(4)** of the optical fibers **147(1)-147(1)** disposed in the backplane fiber optic plug **135'** to the end portions **162(1)-162(4)** of the optical fibers **166(1)-166(4)** disposed in the blade fiber optic receptacle **133'**.

[00105] To provide the dense fiber optic connector disclosed herein, the dense fiber optic connectors may be molded. In this regard, **FIGS. 20A** and **20B** are front and rear views, respectively, of an exemplary molded fiber optic plug body **180** that may be employed in a dense fiber optic connector assembly. **FIGS. 21A** and **21B** are front and rear perspective views, respectively, of the molded fiber optic plug body **180** in **FIGS. 20A** and **20B**. The molded fiber optic plug body **180** may be employed either as a blade fiber optic connector or a backplane fiber optic connector.

[00106] As illustrated in **FIGS. 20A** and **21A**, the molded fiber optic plug body **180** has an end face **182** that includes fiber openings **184** disposed at a first end **186** to provide optical transmission paths to end portions of optical fibers disposed in the molded fiber optic plug body **180**. The fiber openings **184** may be formed by curvatures formed in the end face **182** of the molded fiber optic plug body **180** wherein the molded fiber optic plug body **180** is formed from transmissive material having molded-in lenses, as previously described. Alternatively, the fiber openings **184** may receive GRIN lenses disposed in the molded fiber optic plug body **180** and end portions of the GRIN lenses disposed through the openings, as previously described. The top row **181** and the bottom row **183** of fiber openings disposed in the molded fiber optic plug body **180** are provided by the mold in this embodiment for mold robustness only, for example so that another strong material such as steel, can be inserted therein.

[00107] As illustrated in **FIGS. 20B** and **21B**, an internal chamber **187** forming an opening **188** is molded into fiber optic plug body **180** on a second end **190**. The opening **188** is configured to receive an organizer ferrule **192** illustrated in **FIGS. 23A-23C** and described below. A fiber lead-in structure **194** is disposed in the rear **196** of the internal chamber **187** to receive end portions of optical fibers disposed through the organizer ferrule **192**. **FIG. 22A** is a close-up view of the rear perspective view of fiber lead-in structure **194** as a detail of the molded fiber optic plug body **180**. As illustrated therein and in **FIG. 22B**, the fiber lead-in structure **194** is formed as part of the mold forming the internal chamber **187**. The fiber lead-in structure **194** is comprised of row structures **198** with intermediate fiber lead-in areas **200** disposed therebetween. Vertical members **202** are disposed between the row structures **198** and spaced apart by width **W** to form openings **204** for receiving end portions of optical fibers. The number of row structures

198 and vertical members **202** and the width **W** between the vertical members **202** determine the number of optical fibers that can be supported by the molded fiber optic plug body **180**. As an example, the outer diameter of the intermediate fiber lead-in areas **200** may be fifty (50) micrometers (μm) or more to support a high density of optical fibers in molded fiber optic plug body **180**. MT technology or wire EDM may be leveraged to form intermediate fiber lead-in areas **200**. The use of wire EDM to form the molded fiber optic plug body **180** can provide the fiber lead-in structure **194**. For example, for a target one hundred (100) μm fiber coating, a ten to fifteen (10-15) μm “window” on either side of the square intermediate fiber lead-in areas **200** is available for fiber centering.

[00108] **FIG. 23A** is a front perspective view of the molded intermediate organizer ferrule **192** configured to facilitate optical fiber ribbonization and be disposed in the molded fiber optic plug body **180** in **FIGS. 20A** and **20B** to form a dense fiber optic plug **206** in **FIG. 24A**. **FIG. 23B** is a rear perspective view of the organizer ferrule **192** in **FIG. 23A**. **FIG. 23C** is the organizer ferrule **192** receiving end portions **208** of optical fibers **210**. As illustrated in **FIG. 23A**, the molded organizer ferrule **192** has an end face **212** that includes openings **214** disposed at a first end **216** to receive the end portions **208** of the optical fibers **210** disposed in the organizer ferrule **192**, as illustrated in **FIGS. 23C-24B**. Note the inclusion of corner ribs **213** in the organizer ferrule **192** to allow high centering accuracy while still allowing draft, whether a ribbon, loose tube, or collection of small ribbon fibers are used.

[00109] As illustrated in **FIGS. 23B**, an internal chamber **217** forming an opening **218** is molded into organizer ferrule **192** on a second end **220**. The opening **218** is configured to receive the end portions **208** of the optical fibers **210** as illustrated in **FIGS. 23C-24B** and described below. A fiber lead-in structure **222** is disposed in the rear **224** of the internal chamber **217** to receive the end portions **208** of the optical fibers **210** disposed through the organizer ferrule **192**. **FIG. 24B** is a close-up view of the rear perspective view of fiber lead-in structure **222** of the first end **216** of the organizer ferrule **192** interfaced with the fiber lead-in structure **194** of the molded fiber optic plug body **180**. As illustrated therein and in **FIG. 23B**, the fiber lead-in structure **222** is formed as part of the mold forming the internal chamber **217**. The fiber lead-in structure **222** is comprised of a plurality of the through holes **226** disposed in the rear **224** of the molded organizer ferrule **192** that form the openings **214** in the end face **212**, as illustrated in **FIG. 24B**. The number of through holes **226** determines the number of optical fibers that can be supported by the organizer ferrule **192**.

[00110] **FIG. 25A** is a perspective view of a projected fiber guide mold element **230** that may be used to mold the internal chambers **187, 217** and fiber lead-in structures **194, 222** in the fiber optic plug body **180** in **FIGS. 21A-22B** and the organizer ferrule **192** in **FIGS. 23A-23C**, respectfully. **FIG. 25B** is a perspective close-up view of the fiber lead-in mold tips **232** of the projected fiber guide mold element **230** in **FIG. 25A**. The projected fiber guide mold elements **230** may be constructed out of a suitable steel. As illustrated in **FIGS. 25A** and **25B**, the fiber lead-in mold tips **232** of the projected fiber guide mold element **230** form the negative of the fiber lead-in structures **194, 222**. The number of fiber lead-in mold tips **232** dictates the number of optical fibers supported. As illustrated in **FIGS. 25A** and **25B**, there are up to two-hundred and fifty-six (256) fiber lead-in mold tips **232** or more to support up to two hundred fifty six (256) optical fibers or more.

[00111] As illustrated in **FIG. 25B**, the intermediate members **238** are square-shaped to form square-shaped passages when molding using the projected fiber guide mold element **230**. Square-shaped passages can provide stronger mold elements as opposed to circular-shaped passages. Square-shaped passages also allow easier optical fiber insertion to reduce friction on the optical fiber and to provide additional space to support epoxy placing less sheer force on the optical fibers inserted therein. The end portions **234** of the fiber lead-in mold tips **232** are also square-shaped.

[00112] One purpose of the design of the mass array of the fiber lead-in mold tips **232** was to allow them to be brought against or adjacent to a planar mold surface. This may simplify the projected fiber guide mold element **230** by eliminating the need for a female side in which the fiber lead-in mold tips **232** are inserted into. In one embodiment, the array of fiber lead-in mold tips **232** could be brought into contact with a planar surface and open up the square-shaped members end portions **234** by a brushing or grinding operation. As an example, the fiber lead-in mold tips **232** of the projected fiber guide mold element **230** can be brought proximate to a planar surface in the mold. A secondary operation can be provided to open up the internal chambers **187, 217** formed by the fiber lead-in mold tips **232**. The projected fiber guide mold element **230** used in a mold where the projected fiber guide mold element **230** is brought up against a planar mold surface such that the fiber lead-in mold tips **232** seal off.

[00113] With continuing reference to **FIG. 25B**, the side length or width of the tips **232** is **SL** (e.g., 100 um). The end portions **234** of the tips **232** are formed at the end of a length **L** of end sections **236** of the tips **232**. The end section **236** is designed to provide a lead-in for a bare optical fiber and is sized appropriately. The intermediate member **238** is designed to provide a lead-in for a coated optical fiber and thus is sized larger than the end section **236**. In one embodiment, the length **L** of the end sections **236** of the tips **232** is approximately one to three times the length of the side length **SL** of the end portions **234** of tips **232**. This sizing is provided to provide an angled lead-in for the optical fiber as it is disposed in a lead-in formed by the fiber lead-in mold tip **232**. If the ratio of length **L** of the end sections **236** of the tips **232** to the length of the side length **SL** of the end portions **234** of tips **232** is less than one (1), suppression of angular error may not be accomplished introducing optical attentuation.

[00114] More detail regarding the optical backplane extension module **28** illustrated in **FIGS. 2A-3** will now be described. In this regard, **FIGS. 26** and **27** are front and rear perspective views, respectively, of the optical backplane extension module **28.** The optical backplane extension module **28** comprises the interior space **34** defined by the extension module housing **35** for maintaining and routing of the fiber optic cables **32** (see **FIG. 3**). The optical backplane extension module **28** support a plurality of backplane fiber optic connectors **36** attached to the fiber optic cables **32**, which in this embodiment are backplane fiber optic plugs **44** described above.

[00115] As illustrated in **FIGS. 26-28**, the optical backplane extension module **28** supports disposing the fiber optic connectors **36** through a rear side **38** of the extension module housing **35** to form an optical backplane **240**. The fiber optic connectors **36** are disposed through the rear side **38** of the extension module housing **35** along longitudinal axis $\mathbf{A_1}$. The optical backplane **240** is provided to allow the backplane fiber optic connectors **36** to be directly optically connected to blade fiber optic connectors disposed in information processing modules **24**. The backplane fiber optic connectors **36** may be comprised of different types of fiber optic connectors supporting different numbers of optical fibers. For example, as illustrated in **FIGS. 26** and **27**, the backplane fiber optic connector **36A** is configured to be connected to a blade switch fiber optic connector. As an example, the switch fiber optic connector could be a monolithic connector that has enough fiber count to supp ort connections to the other backplane fiber optic connectors **36B**, with the fiber count being multiple of the number of other backplane fiber optic connectors **36B**. The backplane fiber optic connectors **36B** are configured to be connected to a server or data storage information processing modules **24**.

[00116] With continuing reference to **FIG. 26**, the extension module housing **35** defines the interior space **34** by a base **242**, a left side **244** disposed on a left end **245** of the base **242**, and a right side **246** disposed on a right end **247** of the base **242**. The rear side **38** is disposed on a rear end **248** of the base **242**. A top side **250** is disposed on a top end **252** of the base **242**. The base **242**, left side **244**, right side **246**, rear side **38**, and top side **250** form the extension module housing **35**. A door **254** is hinged to base **242** to allow the internal chamber **34** to be closed off and opened for access.

[00117] The optical interconnection ports **40** are illustrated in more detail in **FIGS. 28** and **29**. The optical interconnection ports **40** are disposed through the extension module housing **35** to allow fiber optic interconnections between the backplane fiber optic connectors **36** forming the optical backplane **240** and backplane fiber optic connectors **36** located outside of the extension module housing **35**. For example, it may be desirable to optically connect one or more backplane fiber optic connectors **36** to other information processing modules **24** not optically connected to the backplane extension module **28** and/or other backplane extension modules **28** located in other areas of an equipment rack. Otherwise, the door **254** could not be fully closed on the backplane extension module **28** if fiber optic interconnections are desired. In this regard, fiber optic adapters **256** can be disposed in the optical interconnection ports **40** to allow for fiber optic interconnections in the backplane extension module **28**. Debris shutters **258** may be provided as part of the fiber optic adapters **256** to prevent debris from entering the fiber optic adapters **256** when not in use. **FIG. 28** shows the debris shutters **258** closed, and **FIG. 29** shows the debris shutters **258** open.

[00118] Other forms of the backplane extension module are possible. For example, **FIGS. 30A** and **30B** are rear and front perspective views, respectively, of another backplane extension module **28'** attached to a rack module housing **26**. The rack module housing **26** supports information processing modules **24** as previously described. In this embodiment, the backplane extension module **28'** includes an extension module housing **35'** that is not rectangular and does not have the same height along the optical backplane. The extension module housing **35'** is configured with different minimum height $\mathbf{H_1}$ and maximum height $\mathbf{H_2}$ to improve air flow from the information processing modules **24** in the rack module housing **26**. This is because the fiber optic connectors disposed in the extension module housing **35'** are not the same height, as illustrated in **FIGS. 31A** and **31B** discussed below. Thus, the height of the extension module housing **35'** can be tailored to avoid unnecessarily reducing air flow.

[00119] **FIGS. 31A** and **31B** are front and rear perspective views, respectively, of the optical backplane extension module **28'** in **FIGS. 30A** and **30B**. As illustrated in **FIG. 31B**, a number of backplane fiber optic connectors **36'** are disposed through a rear side **38'** of the extension module housing **35'** to provide an optical backplane **41** similar to that described above with respect to the optical backplane extension module **28**. As illustrated, some of the backplane fiber optic connectors **36A'** are less in height than other backplane fiber optic connectors **36B'**. Thus, the height of the extension module housing **35'** is provided as a non-planar height to avoid the height of the extension module housing **35'** being greater than needed to support the backplane fiber optic connectors **36A'** and backplane fiber optic connectors **36B'** forming the optical backplane **41**. This will reduce the surface area of the rear side **38'** that is abutted adjacent to the rack module housing **26** when the extension module housing **35'** is installed to reduce blocking air flow. Also, the backplane fiber optic connectors **36A'** and **36B'** are provided in pairs for redundant fiber optic connections in this embodiment.

[00120] When installing the optical backplane extension module **28'** to a rack module housing **28**, it is important to align the optical backplane **41** with the fiber optic connectors disposed on the information processing modules **24** for proper connection. Any alignment errors increase among stacked rack module housings **28**. In this regard, **FIG. 32A** is a close-up view of alignment members **260** disposed in the rear side **38'** of

the optical backplane extension module **28'** to align the optical backplane extension module **28'** with the information processing modules **24** disposed in a rack module housing **26**. **FIG. 32B** is a close-up perspective view of backplane fiber optic connectors **36** disposed between alignment members **260** in the optical backplane extension module **28'**. The alignment members **260** are disposed on the exterior side of the rear side **38'** of the extension module housing **35'**.

[00121] With reference to **FIGS. 32A** and **32B**, the alignment members **260** are configured to engage with a complementary alignment member disposed in the rack module housing **26** to align the plurality of backplane fiber optic connectors **36** with the plurality of blade fiber optic connectors. The intent of providing the alignment members **260** is to provide a more accurate rack module housing **26** for optical information processing modules **24**, which may in turn allow simplified fiber optic connectors to be employed.

[00122] With continuing reference to **FIGS. 32A** and **32B**, in this embodiment, the alignment members **260** are formed from a non-planar surface **262** disposed in the rear side **38'** of the extension module housing **35'**. The non-planar surface **262** is comprised of a plurality of protrusions **264** forming a plurality of grooves **266** each formed between adjacent protrusions **264** among the plurality of protrusions **264**. Because the backplane fiber optic connectors **36'** are disposed through the rear side **38'** of the extension module housing **35**' in a fixed, known location, the backplane fiber optic connectors **36** are located in known fixed location with respect to the alignment members **260**. When the alignment members **260** mate with complementary grooves and alignment members **260** in the rack module housing **26**, an alignment is forced to the extension module housing **35'** that will assist in proper connection between the backplane fiber optic connectors **36'** and the blade fiber optic connectors. The alignment members **260** may be disposed in the optical backplane extension module **28** in **FIGS. 2A-3** as well.

[00123] It may also be desired to provide for the base member **267** in which the alignment members **260** are disposed to extend out beyond the rear side **38'** of the backplane extension housing **35'** to extend into the rack module housing **26**. In this manner, the information processing modules **24** can be disposed on their bottom ends with the base member **267** and register with the base member **267** through a registration means. In this case, since both the information processing modules **24** and the backplane fiber optic connectors **36'** would be fixedly disposed in the base member **267**, alignment is forced to exist between the backplane fiber optic connectors **36'** and the blade fiber optic connectors **46** (see **FIG. 4B**).

[00124] Even with alignment of backplane fiber optic connectors **36, 36'** aligned with the rack module housing **26**, the information processing modules **24** can be aligned and provided in known locations in the rack module housing **26**. In this manner, alignment of an optical backplane extension module **28, 28'** with the rack module housing **26** will ensure an alignment between the backplane fiber optic connectors **36, 36'** and the blade fiber optic connectors. It may be desired to provide both vertical and horizontal alignment of the information processing modules **24** in the rack module housing **26**.

[00125] In this regard, **FIG. 33** is a side perspective view and close-up view of bias wheels **270** that provides a lower datum for the information processing modules **24** disposed in the rack module housing **26**. Only one bias wheel **270** is shown, but a plurality of bias wheels **270** can be provided, including one for each information processing module **24**. The bias wheel **270** is mounted to a mounting structure **273**. The bias wheel **270** is allowed to rotate in the mounting structure **273**. As illustrated in **FIG. 33**, the bias wheel **270** is disposed in an interior space **272** on a base **274** of the rack module housing **26** in alignment with an insertion slot for an information processing module **24**. For example, the base **274** may be the base member **267** in which the alignment members **260** are disposed to extend out beyond the rear side **38'** of the backplane extension housing **35'** to extend into the rack module housing **26**. When the information processing module **24** is inserted in rack module housing **26**, a bottom **276** of the information processing module **24** will engage the bias wheel **270**. The bias wheel **270** will ensure the information processing module **24** is disposed in a fixed, known vertical location with the rack module housing **26** for vertical alignment.

[00126] To provide an upper datum for horizontal alignment of information processing modules **24** disposed in the rack module housing **26, FIG. 34** is provided. **FIG. 34** illustrates a side perspective view and close-up view of spring-loaded biasing members **280**. A spring-loaded biasing member **280** may be provided for each slot in the rack module housing **26** that can accept an information processing module **24**. The spring-loaded biasing member **280** is installed at the top interior side **282** of the rack module housing **26** to be disposed above an information processing module **24** when installed in the rack module housing **26**. The spring-loaded biasing member **280** comprises an alignment member **284** configured with a slot **286** to receive a spring **288**. The spring **288** abuts the top interior side **282** of the rack module housing **26**. When an information processing module **24** is inserted into the rack module housing **26**, the top interior side **282** of the information processing module **24** is configured to abut and the alignment member **284** is configured push down against information processing module **24** to form an upper datum. Along with the lower datum provided by the bias wheels **270** in **FIG. 33**, the spring-loaded biasing member **280** assists in vertical alignment of the information processing module **24** disposed in the rack module housing **26**.

[00127] Further, as used herein, it is intended that terms "fiber optic cables" and/or "optical fibers" include all types of single mode and multi-mode light waveguides, including one or more optical fibers that may be upcoated, colored, buffered, ribbonized and/or have other organizing or protective structure in a cable such as one or more tubes, strength members, jackets or the like. The optical fibers disclosed herein can be single mode or multi-mode optical fibers. Likewise, other types of suitable optical fibers include bend-insensitive optical fibers, or any other expedient of a medium for transmitting light signals. An example of a bend-insensitive, or bend resistant, optical fiber is ClearCurve® Multimode fiber commercially available from Corning Incorporated. Suitable fibers of this type are disclosed, for example, in U.S. Patent Application Publication Nos. 2008/0166094 and 2009/0169163, the disclosures of which are incorporated herein by reference in their entireties.

[00128] Many modifications and other embodiments of the embodiments set forth herein will come to mind to one skilled in the art to which the embodiments pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. For example, embodiments provide for fiber optic plugs to be disposed on the optical backplane extension module and fiber optic receptacles to be disposed on the information processing modules, the opposite configuration could be provided and is encompassed within the scope of the disclosure and the claims. Fiber optic receptacles could be disposed in the optical backplane extension module and fiber optic plugs disposed on the information processing modules.

[00129] Therefore, it is to be understood that the description and claims 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 the embodiments 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.

We claim:

1. An optical backplane extension module, comprising:

an extension module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, a right side disposed on a right end of the base opposite the left end, and a rear side disposed on a rear end of the base; and

a plurality of backplane fiber optic connectors disposed through the rear side of the extension module housing and accessible through an exterior side of the rear side;

the plurality of backplane fiber optic connectors configured to be directly optically connected to a plurality of blade fiber optic connectors disposed in a plurality of information processing modules disposed in a rack module housing.

2. The optical backplane extension module of claim 1, wherein the extension module housing further comprises a door attached to a front end of the base, the door configured to be opened to allow access to the interior space.

3. The optical backplane extension module of claims 1 or 2, further comprising at least one alignment member disposed on the exterior side of the rear side of the extension module housing, the at least one alignment member configured to engage with a complementary alignment member disposed in an equipment rack to align the plurality of backplane fiber optic connectors with the plurality of blade fiber optic connectors.

4. The optical backplane extension module of claim 3, wherein the at least one alignment member is comprised of a non-planar surface.

5. The optical backplane extension module of claim 4, wherein the non-planar surface is comprised of a plurality of protrusions forming a plurality of grooves each formed between adjacent protrusions among the plurality of protrusions.

6. The optical backplane extension module of claims 1-5, wherein each of the plurality of backplane fiber optic connectors is comprised of a plurality of backplane fiber optic plugs configured to be directly optically connected to the plurality of blade fiber optic connectors comprised of a plurality of blade fiber optic receptacles disposed in the plurality of information processing modules.

7. The optical backplane extension module of claims 1-6, further comprising at least one interconnection port disposed in the extension module housing, the at least one interconnection port configured to establish an optical connection with one or more of the plurality of backplane fiber optic connectors.

8. The optical backplane extension module of claims 1-7, wherein the interior space is configured to provide a routing area inside the extension module housing for fiber optic cables optically connected to the plurality of backplane fiber optic connectors.

9. The optical backplane extension module of claims 1-8, wherein the plurality of backplane fiber optic connectors is comprised of at least one backplane fiber optic connector having a first height and at least one second backplane fiber optic connector having a second height.

10. The optical backplane extension module of claims 1-9, wherein the plurality of backplane fiber optic connectors are each configured to receive a plurality of backplane fiber optic ribbon ends.

11. The optical backplane extension module of claims 1-10, wherein the plurality of backplane fiber optic connectors are each comprised of backplane fiber optic connectors supporting at least one hundred twenty eight (128) optical fibers.

12. The optical backplane extension module of claims 1-11, wherein the plurality of backplane fiber optic connectors are aligned along a longitudinal axis of the rear side of the extension module housing.

13. A method of connecting an optical backplane extension module to a rack module housing, comprising:

providing an optical backplane extension module, comprising:

an extension module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, a right side disposed on a right end of the base opposite the left end, and a rear side disposed on a rear end of the base; and

a plurality of backplane fiber optic connectors disposed through the rear side of the extension module housing and accessible through an exterior side of the rear side; and

directly optically connecting the plurality of backplane fiber optic connectors disposed through the rear side of the extension module housing to a plurality of blade fiber optic connectors disposed in a plurality of information processing modules disposed in a rack module housing.

14. The method of claim 13, further comprising attaching the extension module housing to the rack module housing.

15. The method of claims 13 or 14, further comprising engaging at least one alignment member disposed on the exterior side of the rear side of the extension module housing with a complementary alignment member disposed in an equipment rack to align the plurality of backplane fiber optic connectors with the plurality of blade fiber optic connectors.

16. The method of claim 15, wherein the at least one alignment member extends from the exterior side of the rear side of the extension module housing configured to be disposed in a rack module housing.

17. The method of claims 13-16, comprising directly optically connecting the plurality of backplane fiber optic connectors comprised of a plurality of first backplane

fiber optic plugs, to the plurality of blade fiber optic connectors comprised of a plurality of blade fiber optic receptacles disposed in the plurality of information processing modules.

18. The method of claims 13-17, further comprising connecting at least one backplane fiber optic cable from at least one of the plurality of backplane fiber optic connectors to at least one interconnection port disposed in the extension module housing.

19. A fiber optic rack module configured to be supported in an equipment rack, comprising:

a rack module housing comprising an interior space defined by a base, a left side disposed on a left end of the base, and a right side disposed on a right end of the base opposite the left end;

the rack module housing configured to support at least one information processing module having at least one backplane fiber optic connector in the interior space; and

at least one alignment member disposed in the interior space of the rack module housing, the at least one alignment member configured to provide at least one datum for the at least one information processing module to align the at least one information processing module disposed in the rack module housing.

20. The fiber optic rack module of claim 19, wherein the at least one alignment member is comprised of at least one bias wheel disposed in the interior space.

21. The fiber optic rack module of claim 20, wherein the at least one bias wheel is disposed in the interior space on the base.

22. The fiber optic rack module of claim 19, wherein the at least one alignment member is comprised of at least one spring-loaded biasing member disposed in the interior space configured to provide the at least one datum.

23. The fiber optic rack module of claim 22, wherein the at least one spring-loaded biasing member is disposed in the interior space on a top side of the rack module housing.

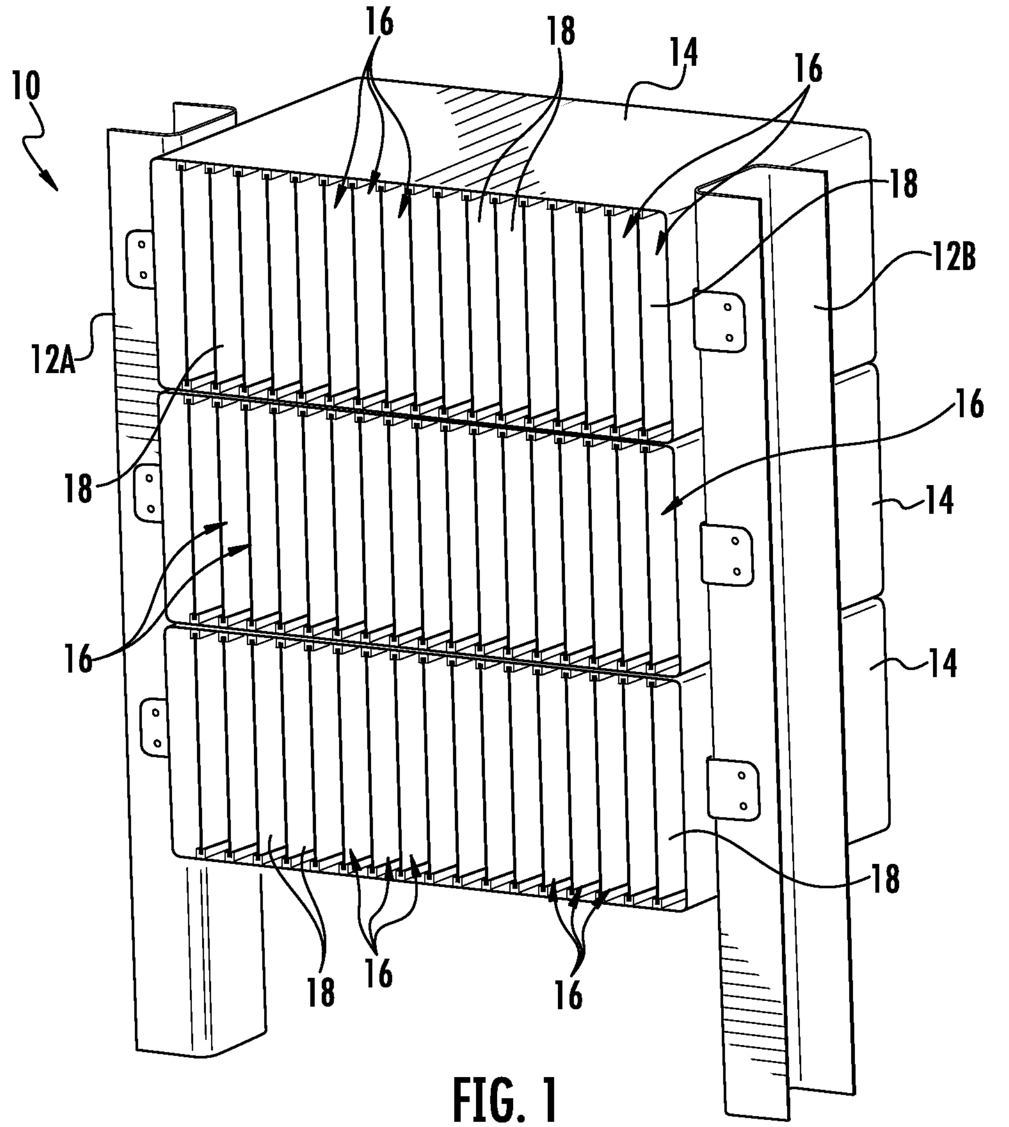


FIG. 1
(PRIOR ART)

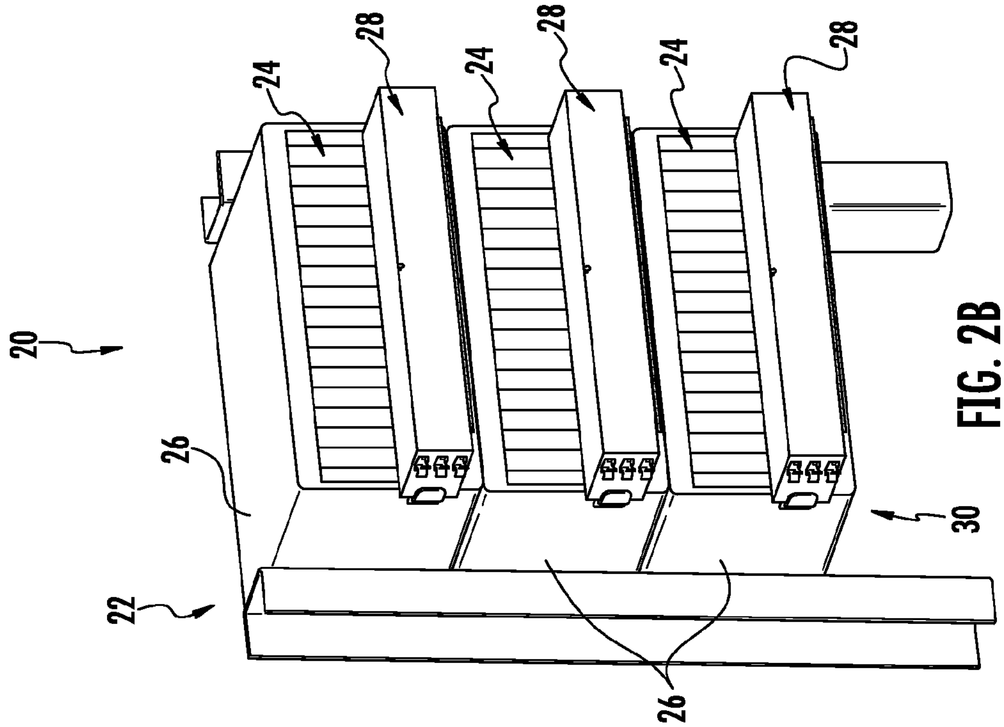


FIG. 2B

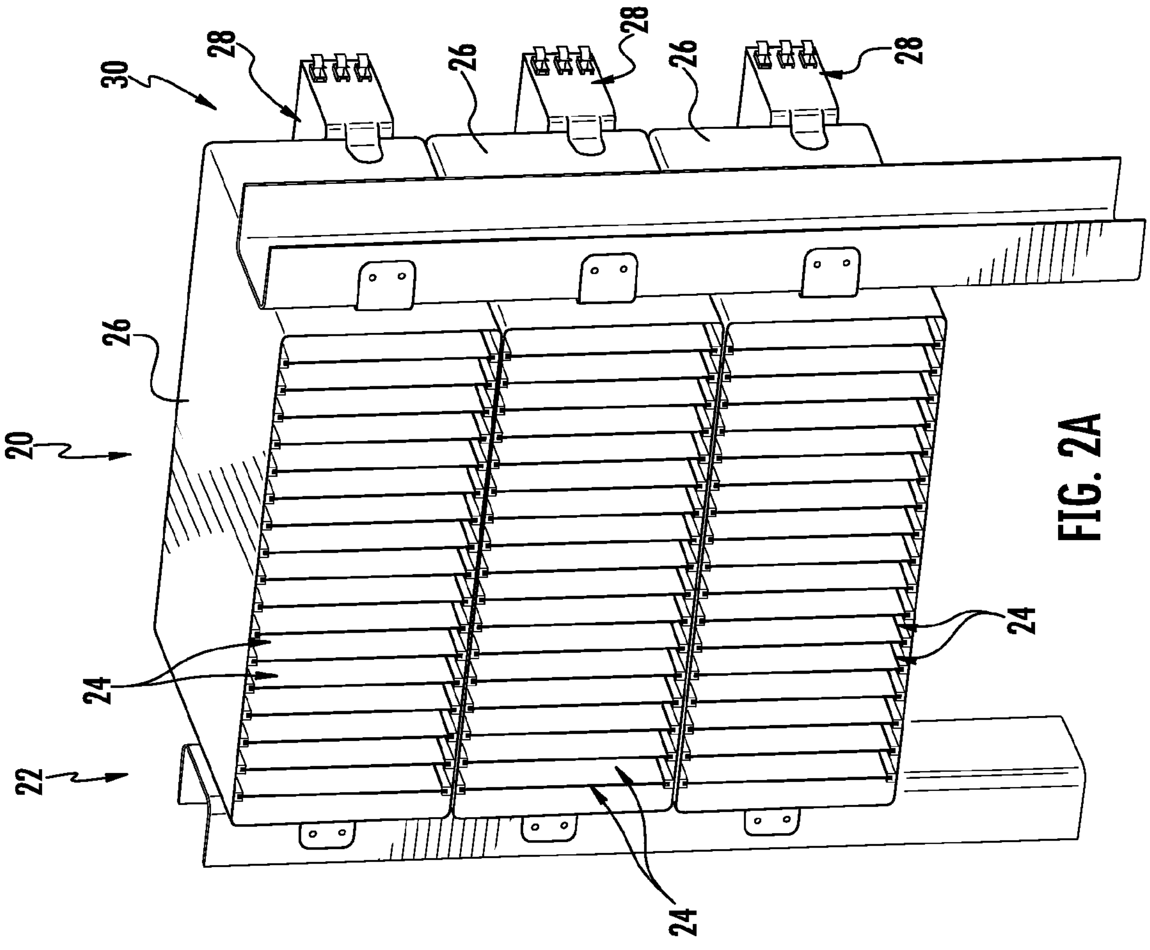


FIG. 2A

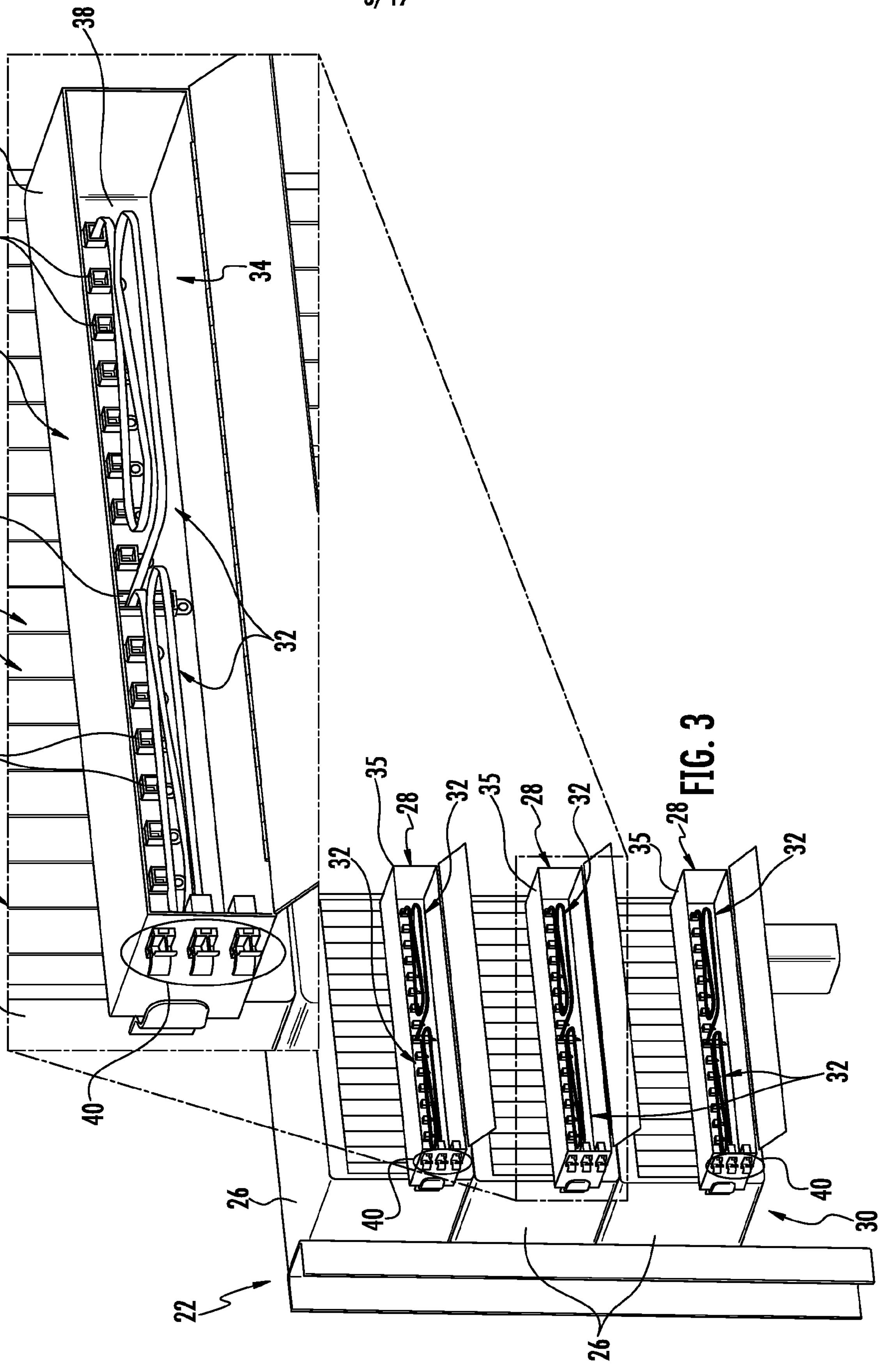

38
35
36
34
28
36
32
24
36
24
26
40
35
28
32
35
28
32
35
28
32
32
32
40
40
30
26
22
26

FIG. 3

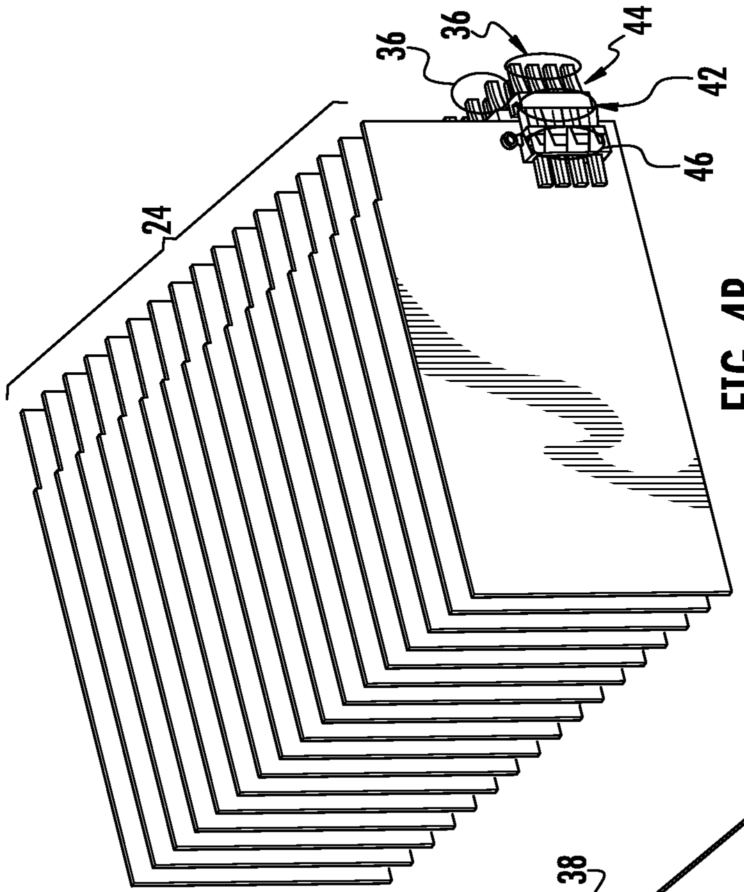


FIG. 4B

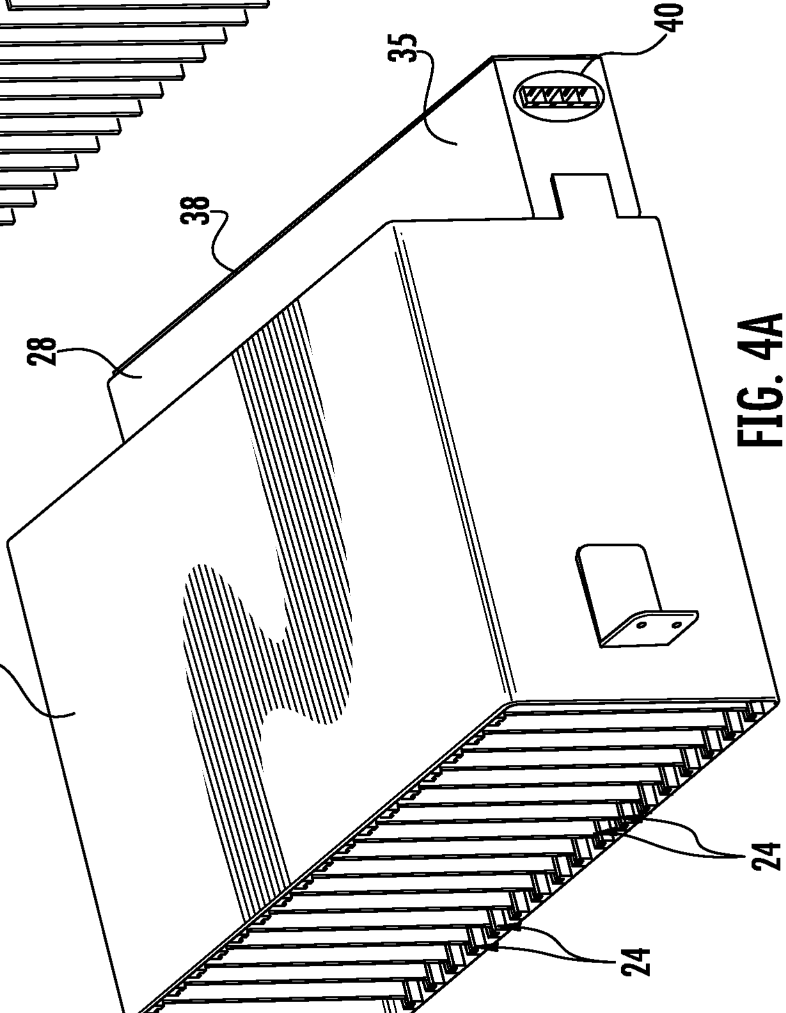


FIG. 4A

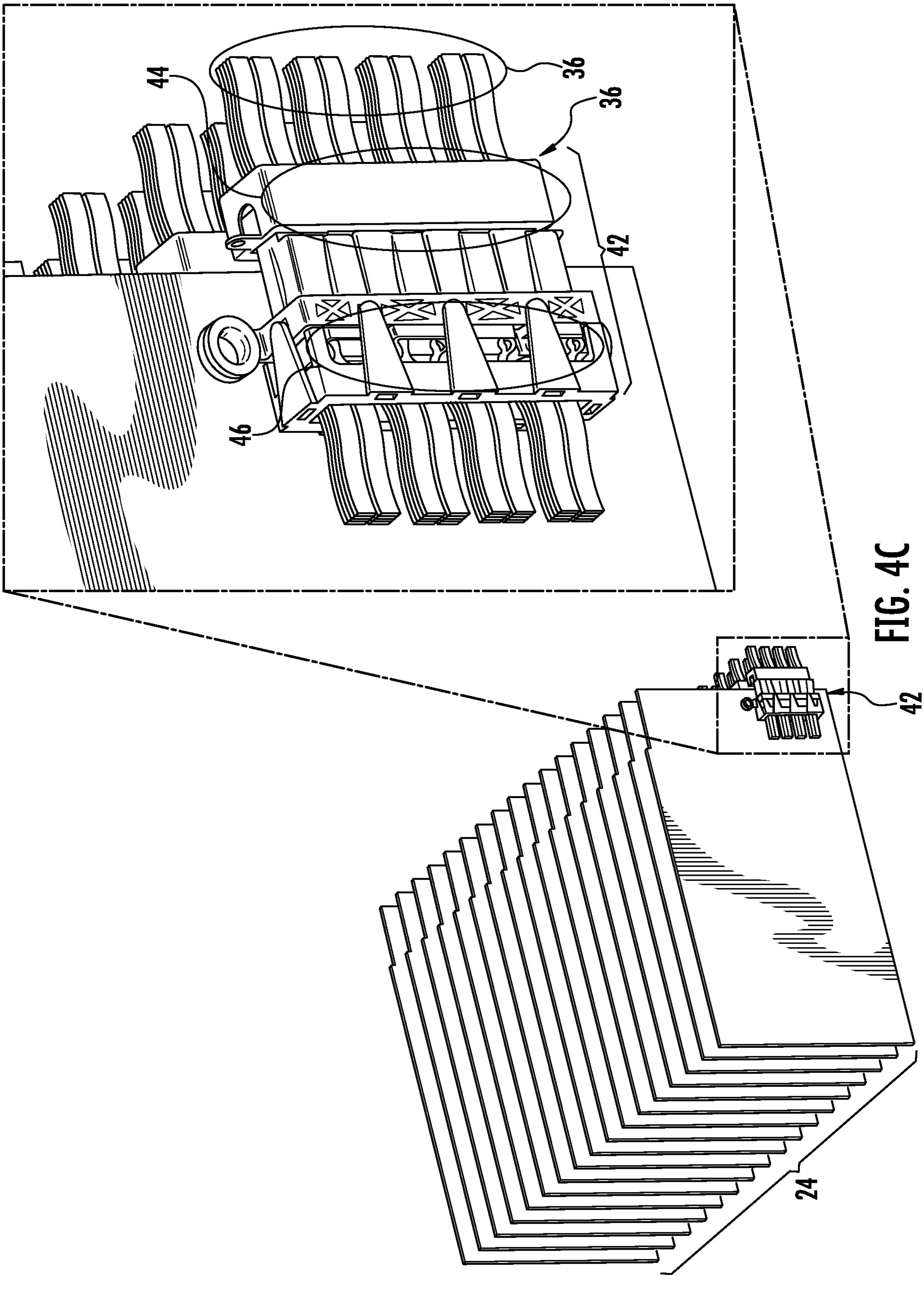


FIG. 4C

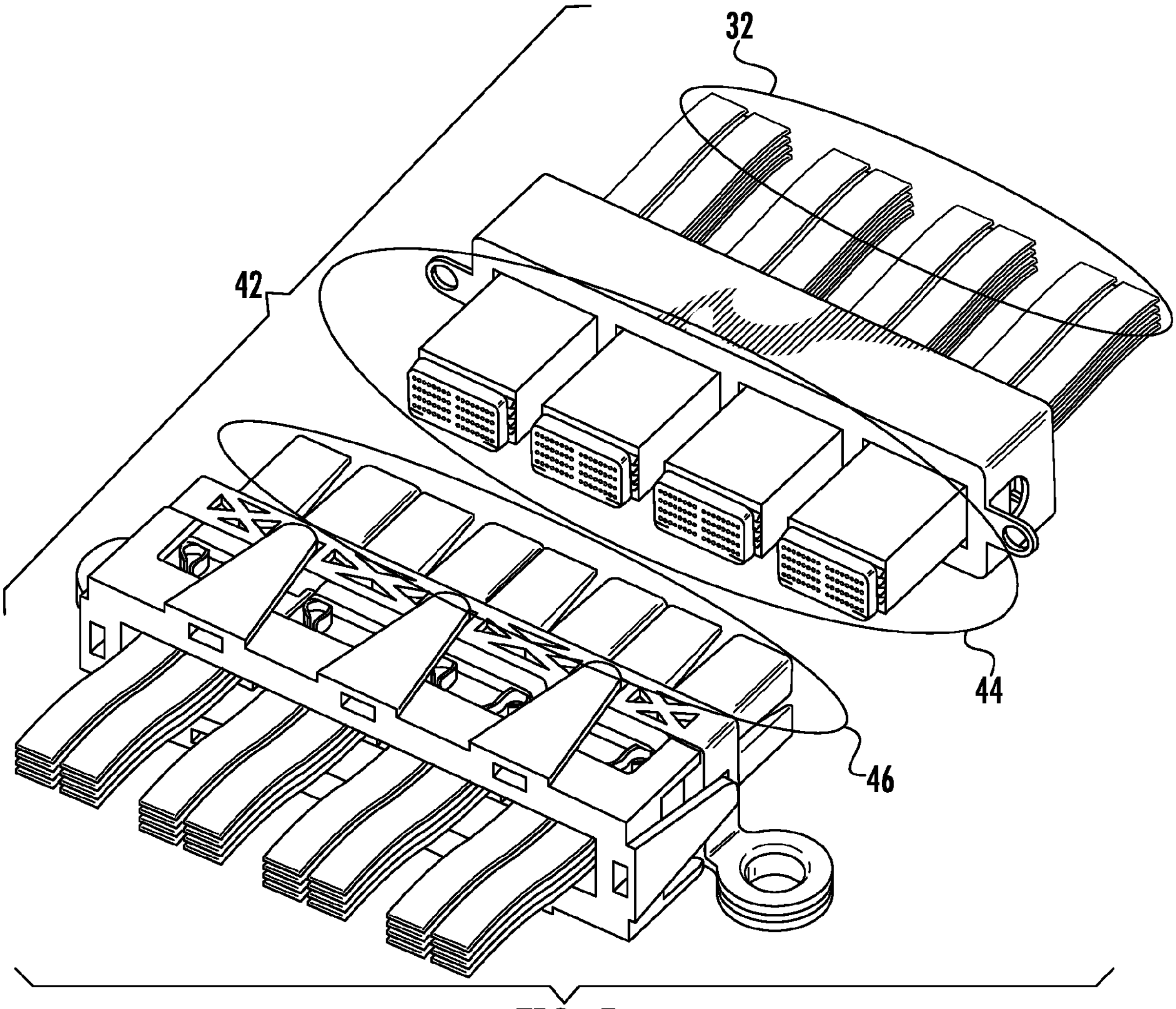


FIG. 5

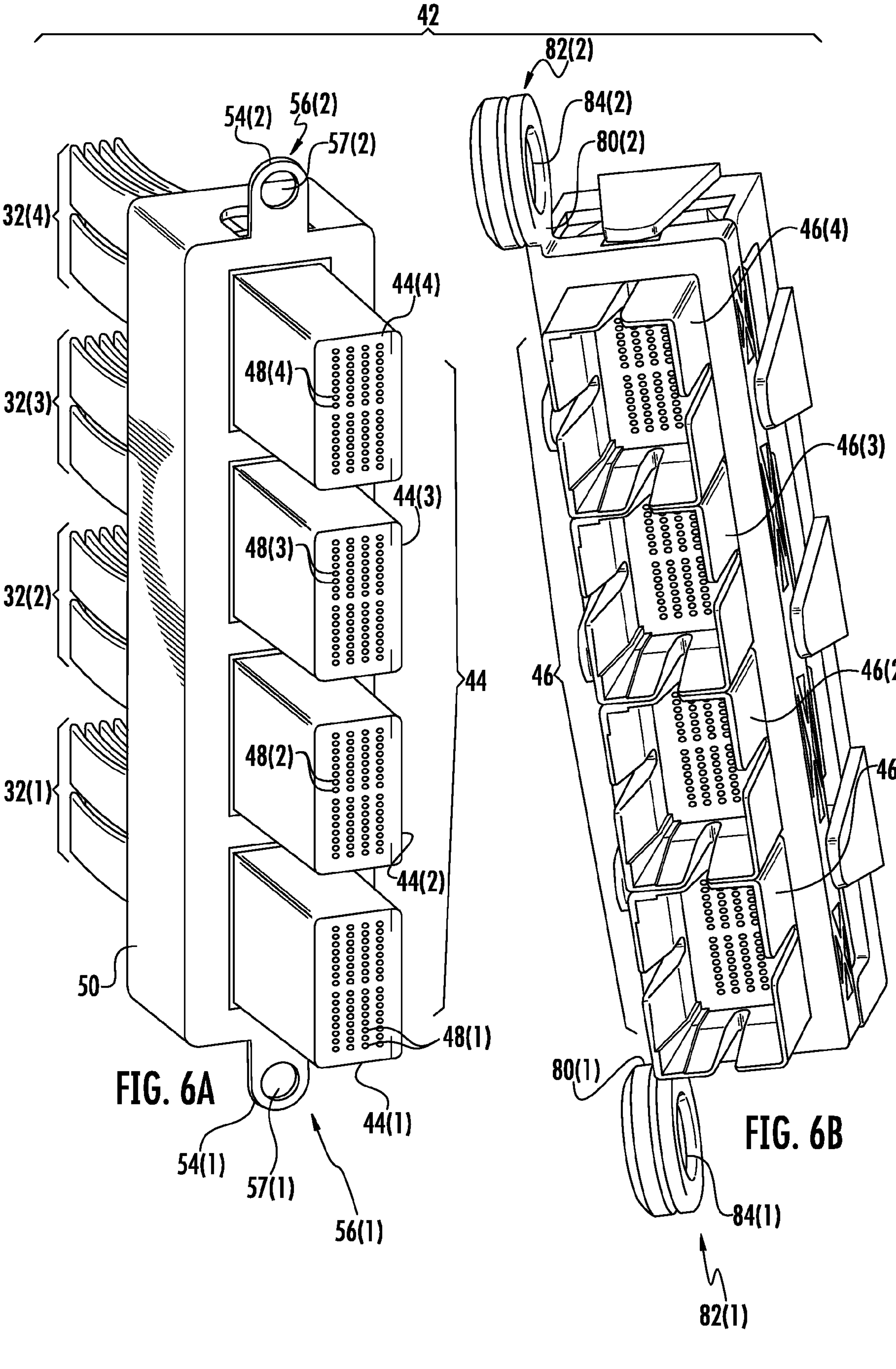

42
54(2)
56(2)
57(2)
32(4)
32(3)
32(2)
32(1)
44(4)
48(4)
44(3)
48(3)
48(2)
44(2)
44
50
48(1)
44(1)
54(1)
57(1)
56(1)
82(2)
84(2)
80(2)
46(4)
46(3)
46
46(2)
46(1)
80(1)
84(1)
82(1)

FIG. 6A

FIG. 6B

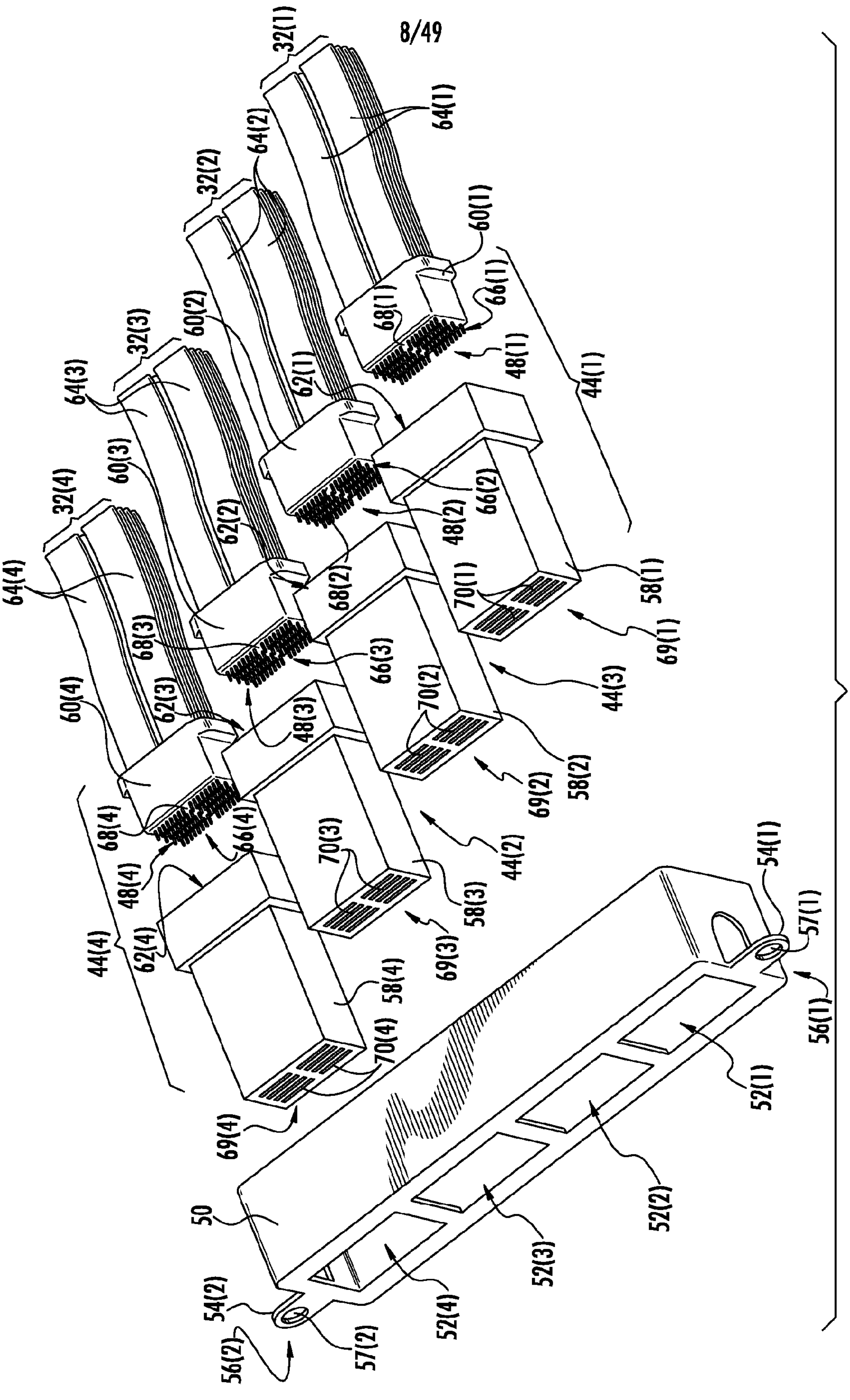

32(1)
64(1)
32(2)
64(2)
60(1)
66(1)
68(1)
48(1)
44(1)
32(3)
60(2)
64(3)
62(1)
66(2)
48(2)
68(2)
58(1)
70(1)
69(1)
32(4)
60(3)
64(4)
62(2)
68(3)
66(3)
44(3)
70(2)
69(2)
58(2)
60(4)
62(3)
48(3)
68(4)
66(4)
48(4)
44(2)
70(3)
69(3)
58(3)
44(4)
62(4)
58(4)
70(4)
69(4)
54(1)
57(1)
56(1)
52(1)
52(2)
50
52(3)
52(4)
54(2)
57(2)
56(2)

FIG. 7A

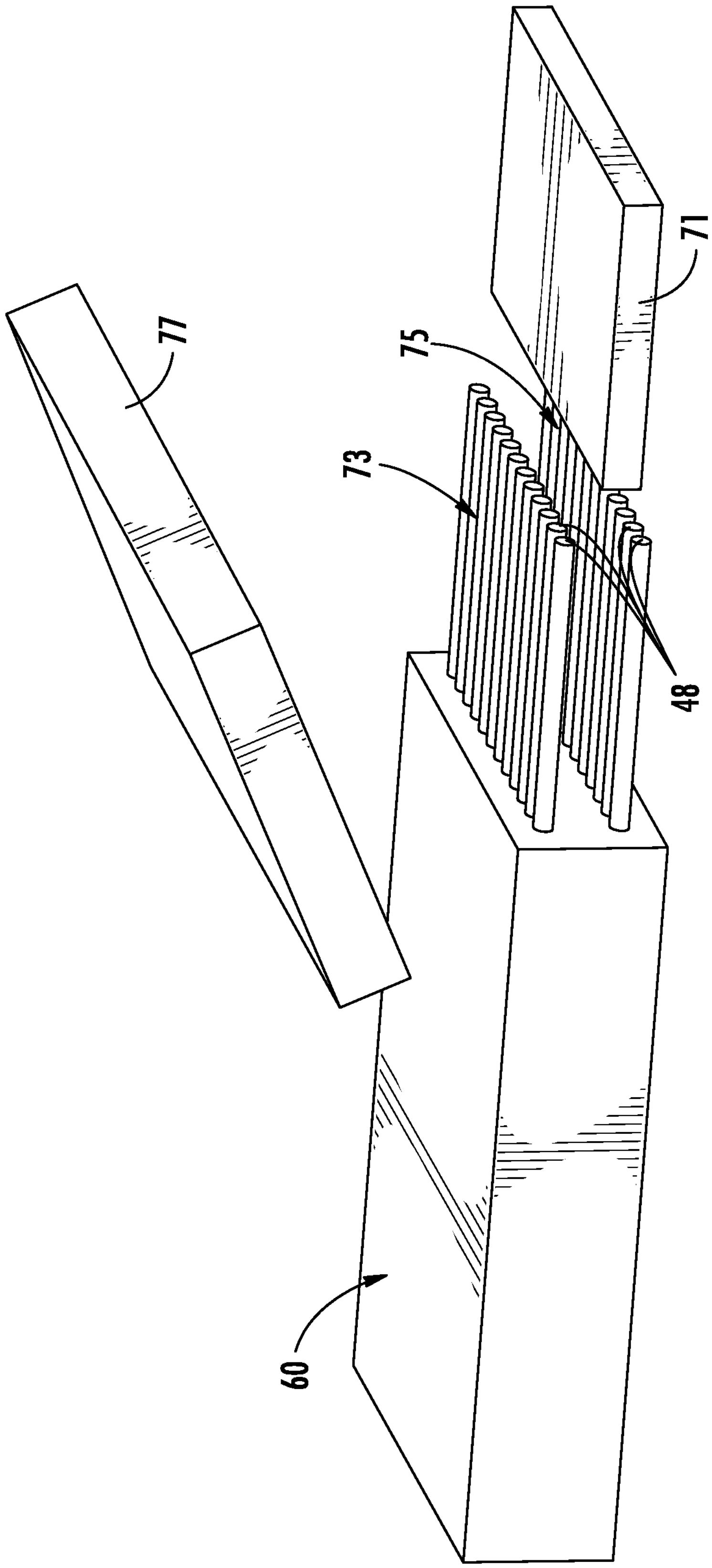


FIG. 7B

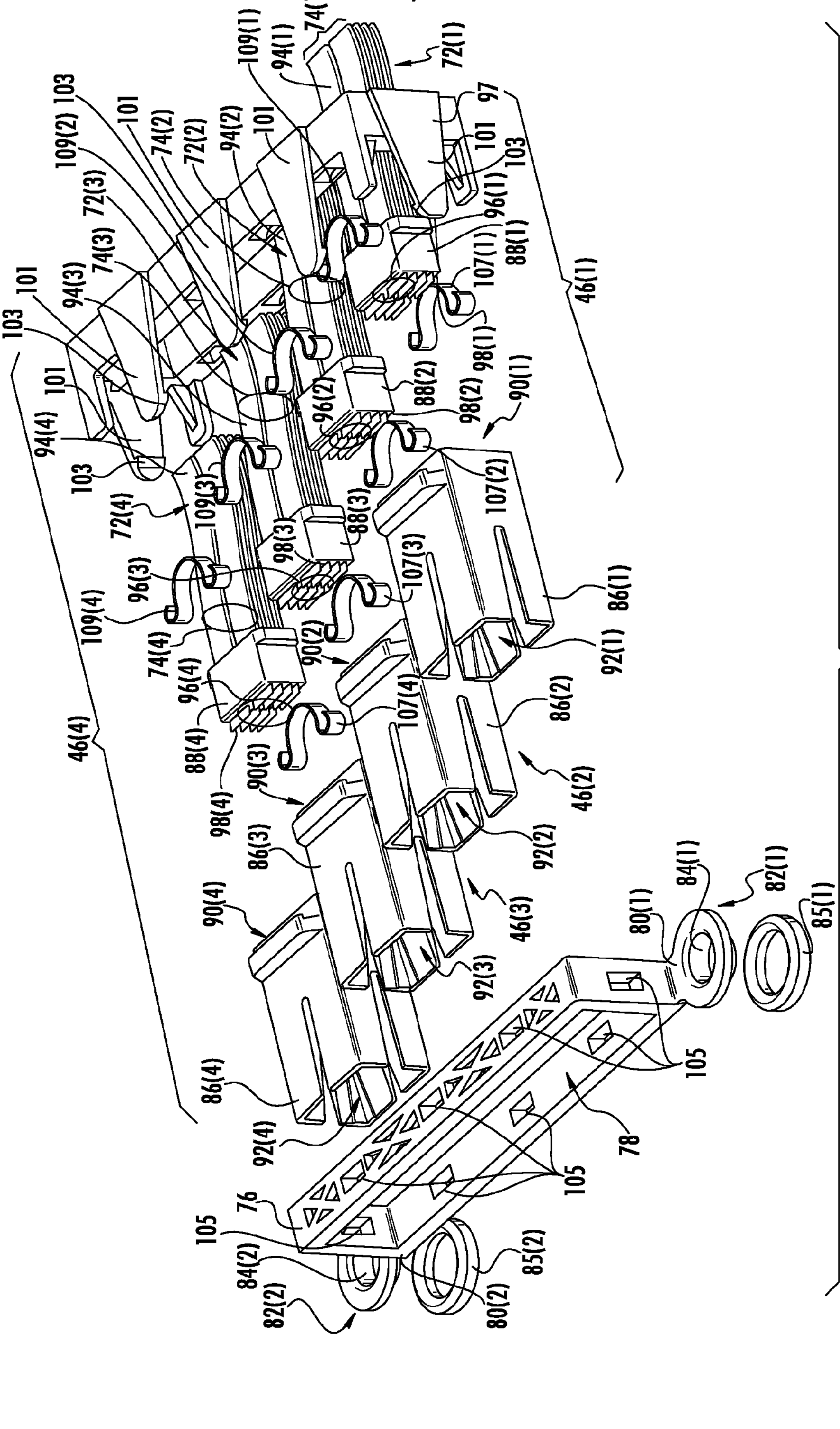

74(1)
72(1)
109(1)
94(1)
97
103
101
109(2)
74(2)
72(2)
94(2)
72(3)
96(1)
88(1)
107(1)
46(1)
74(3)
94(3)
98(1)
90(1)
88(2)
96(2)
98(2)
107(2)
94(4)
72(4)
109(3)
88(3)
98(3)
107(3)
86(1)
109(4)
96(3)
74(4)
90(2)
92(1)
96(4)
88(4)
107(4)
86(2)
46(4)
98(4)
90(3)
46(2)
86(3)
92(2)
90(4)
46(3)
92(3)
80(1)
84(1)
82(1)
85(1)
105
86(4)
92(4)
78
76
84(2)
82(2)
80(2)
85(2)

FIG. 8

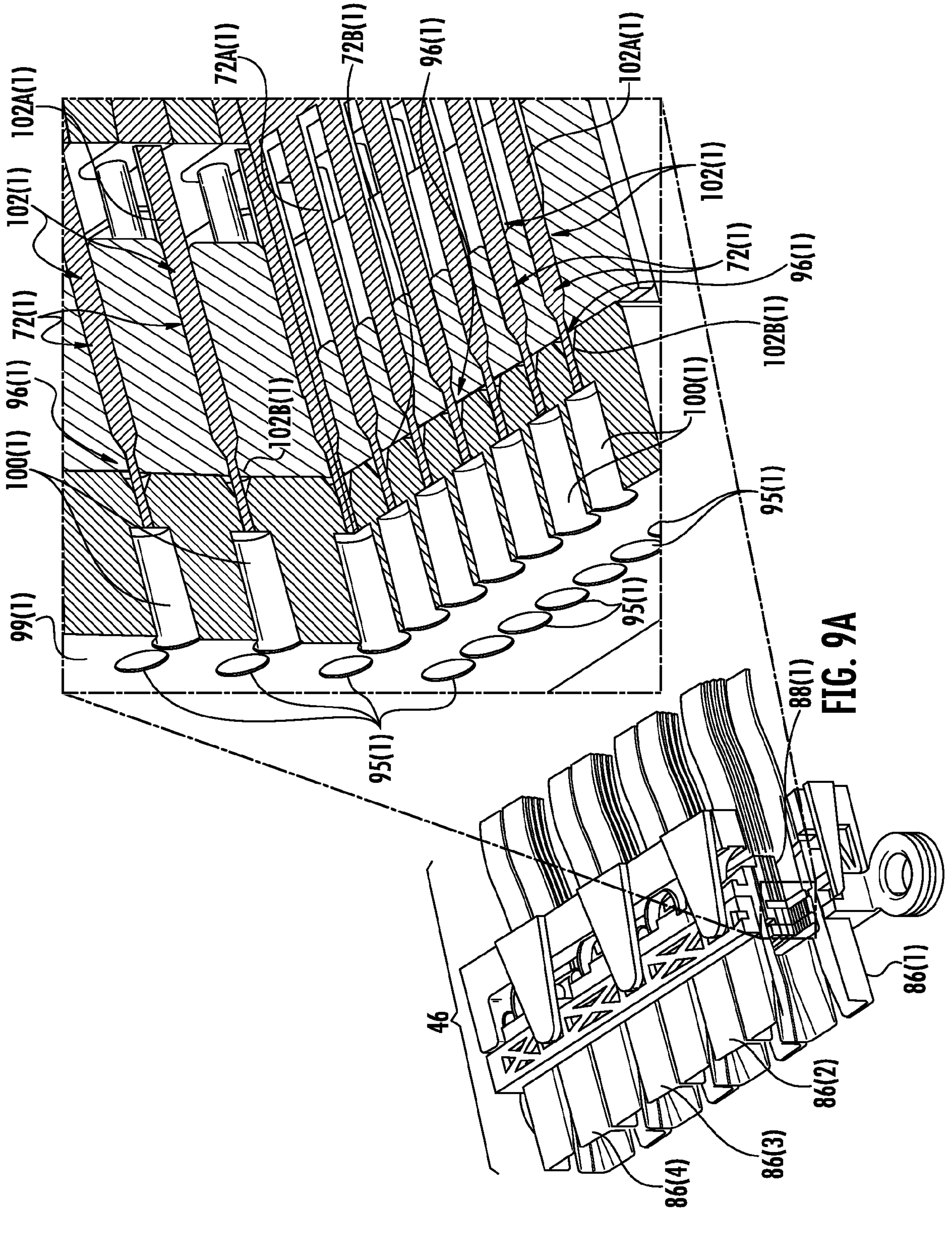

102A(1)
72A(1)
72B(1)
96(1)
102A(1)
102(1)
72(1)
96(1)
100(1)
102B(1)
99(1)
95(1)
100(1)
102B(1)
72(1)
96(1)
102(1)
46
88(1)
86(1)
86(2)
86(3)
86(4)

FIG. 9A

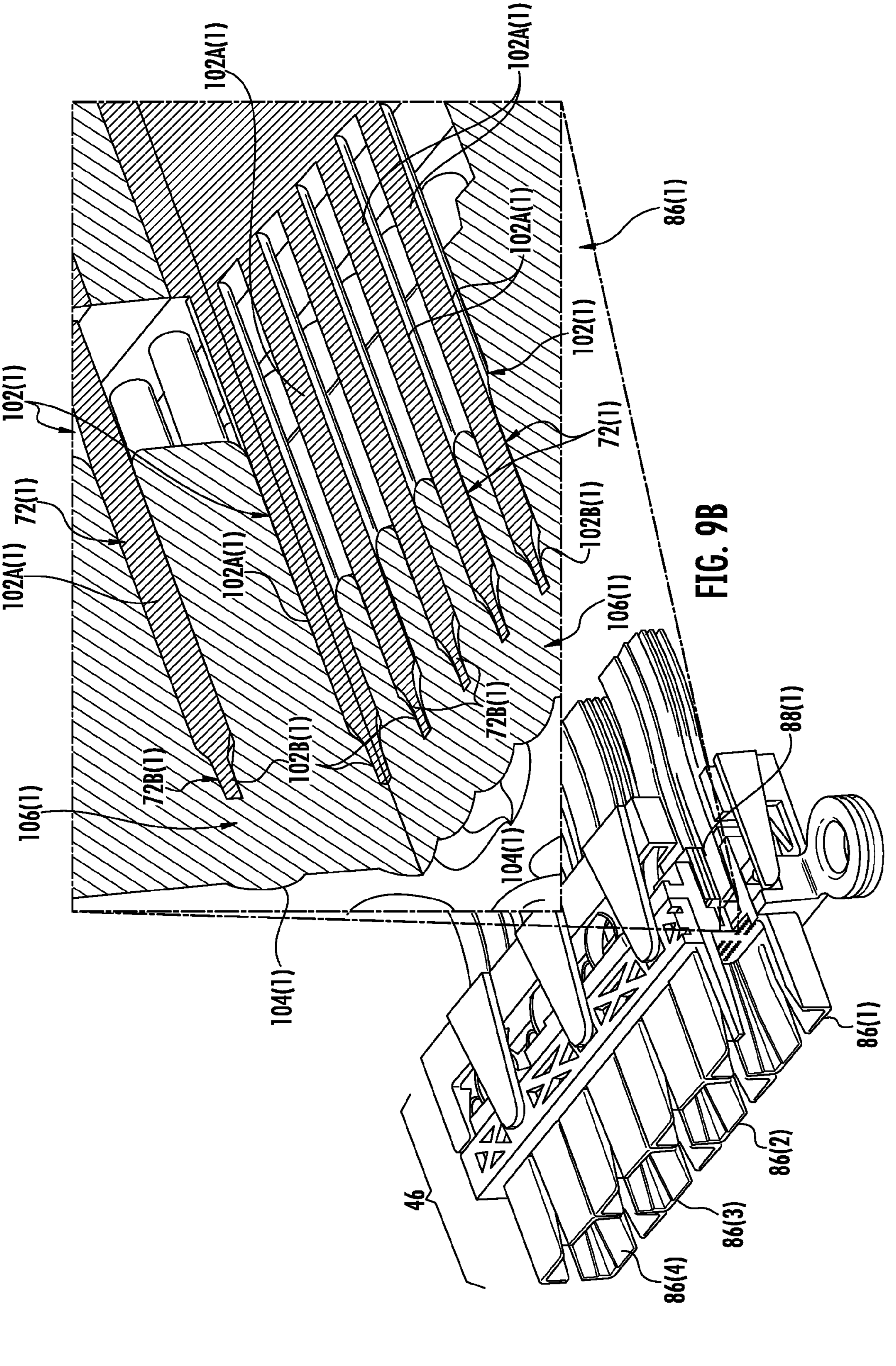

102A(1)
102A(1)
86(1)
102A(1)
102(1)
102(1)
72(1)
72(1)
102A(1)
102A(1)
102B(1)
106(1)
72B(1)
102B(1)
72B(1)
106(1)
88(1)
104(1)
104(1)
86(1)
86(2)
86(3)
86(4)
46

FIG. 9B

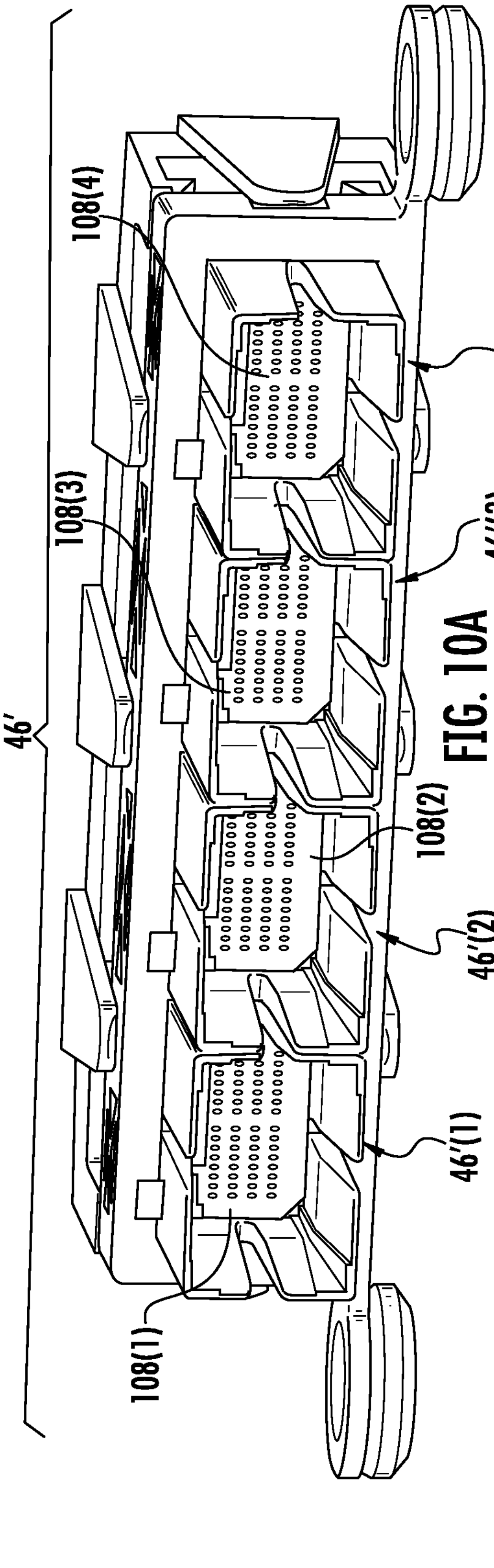


FIG. 10A

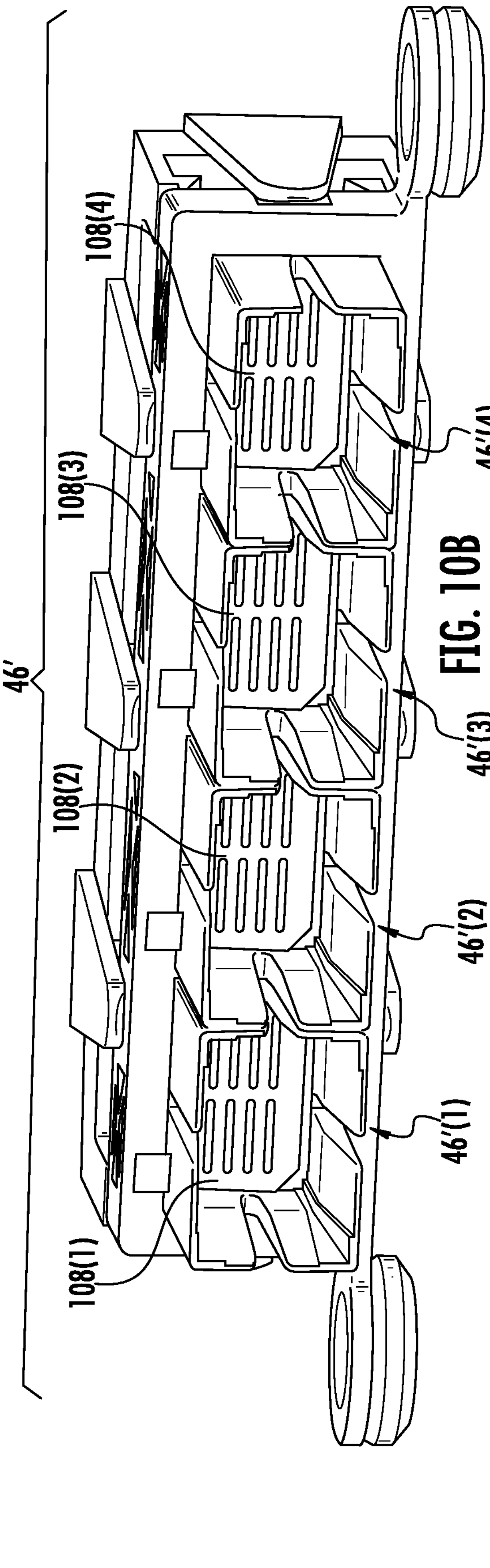


FIG. 10B

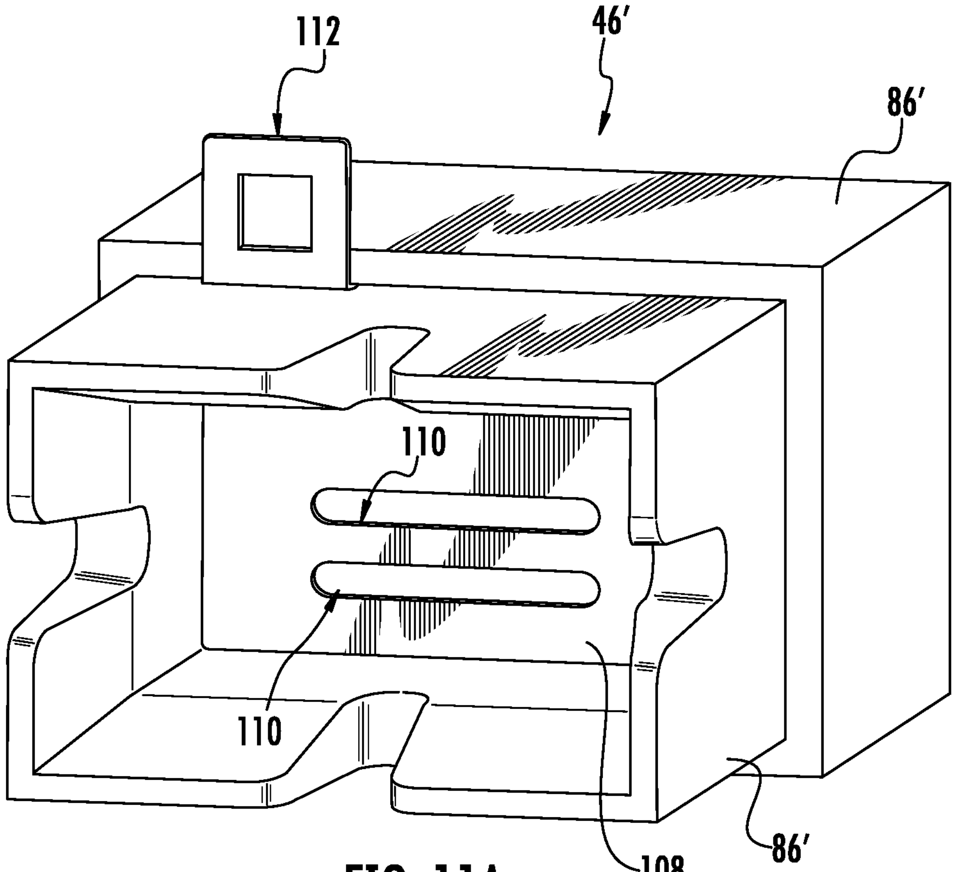


FIG. 11A

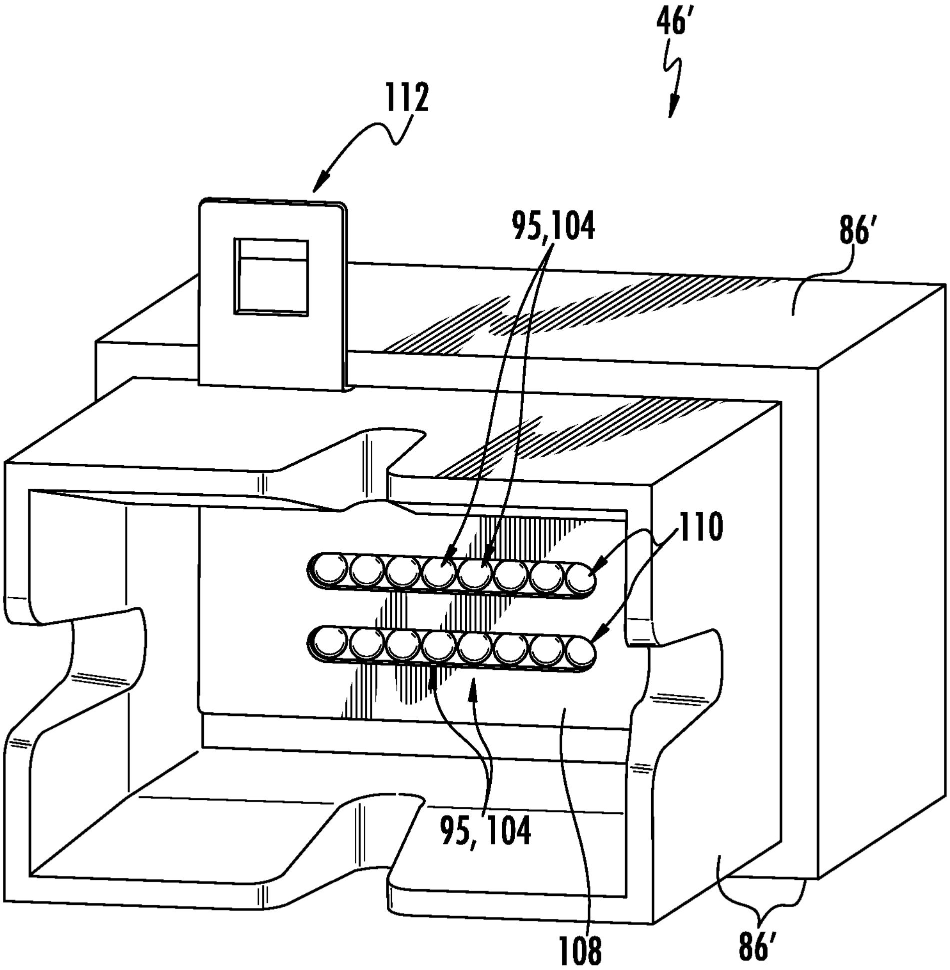


FIG. 11B

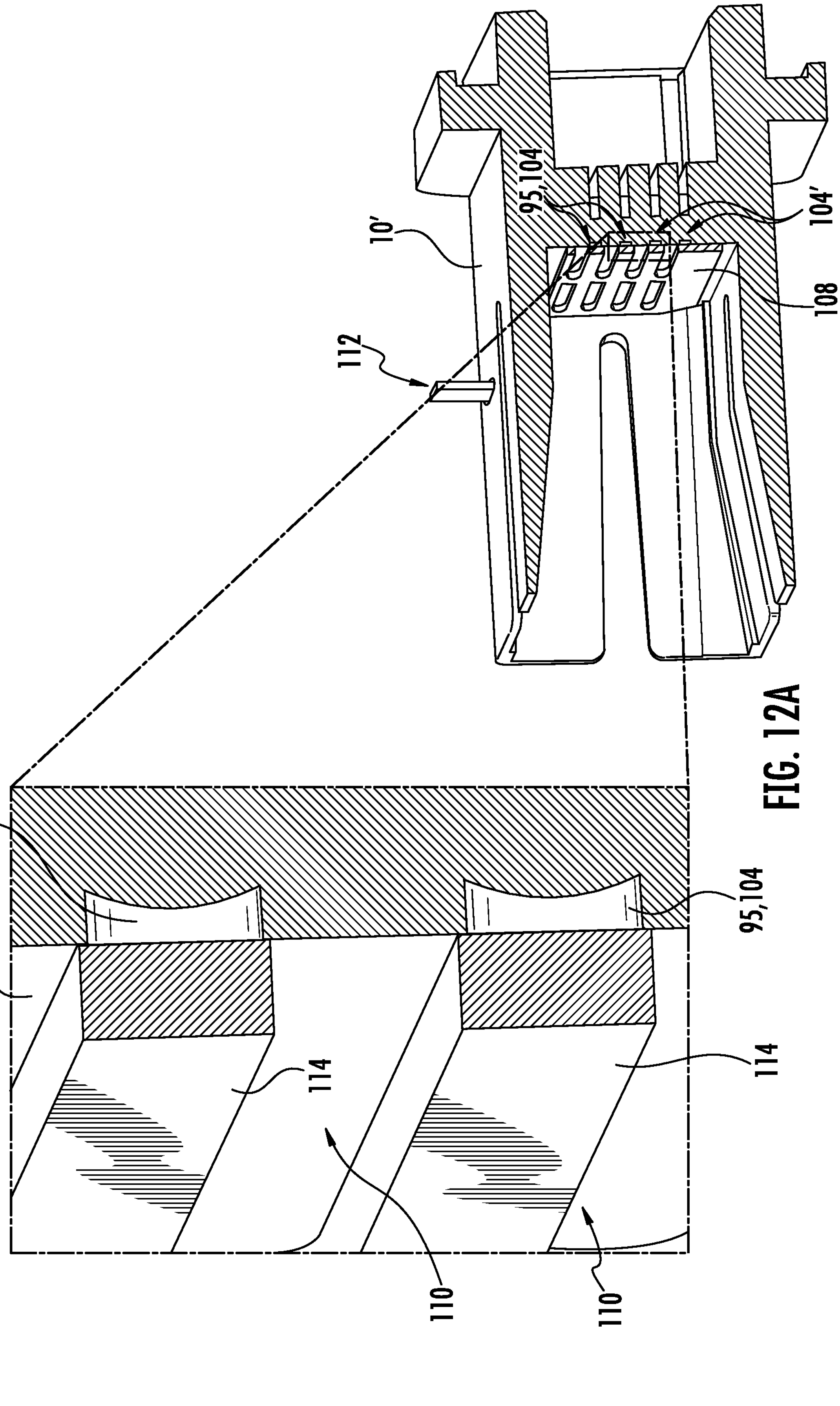


FIG. 12A

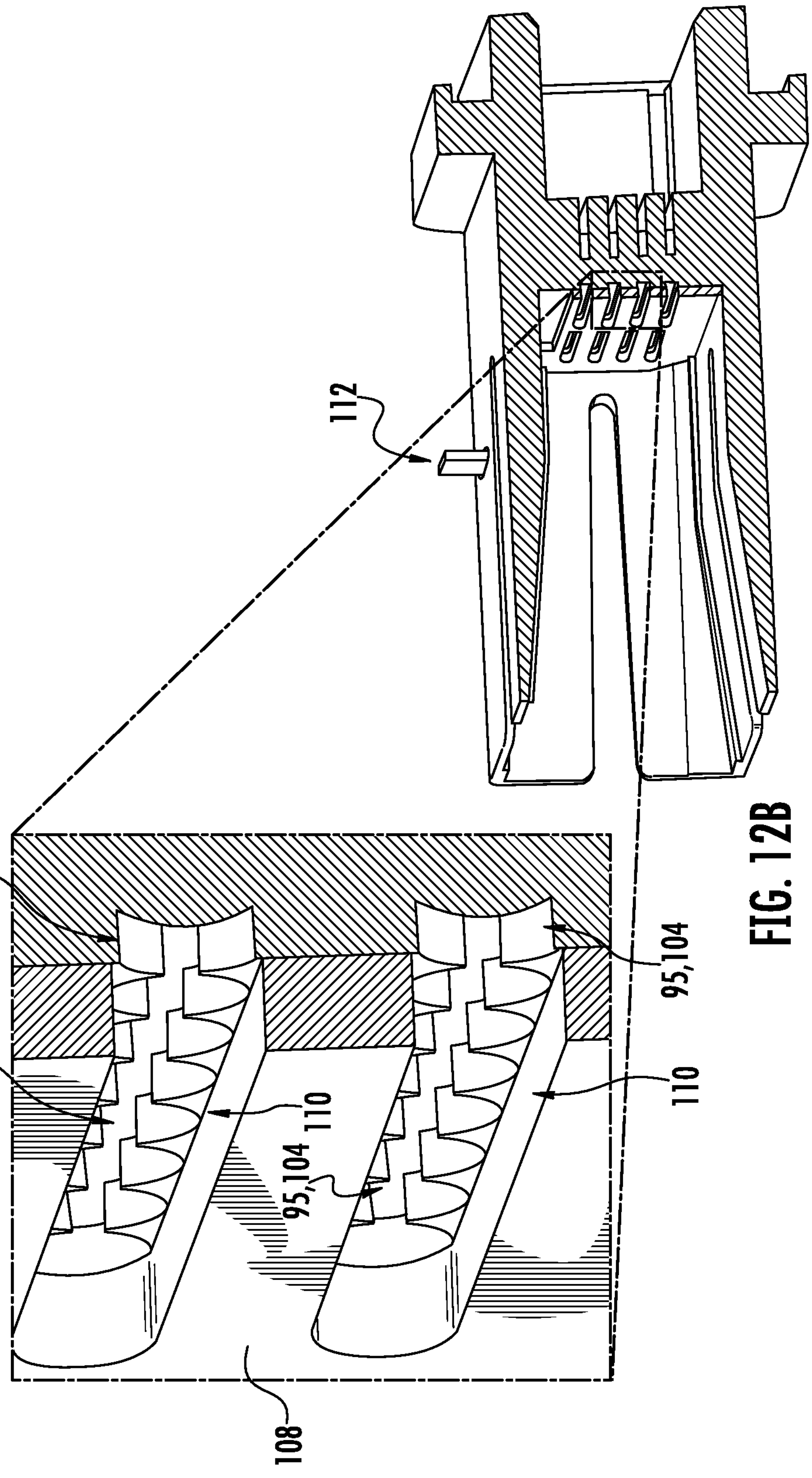


FIG. 12B

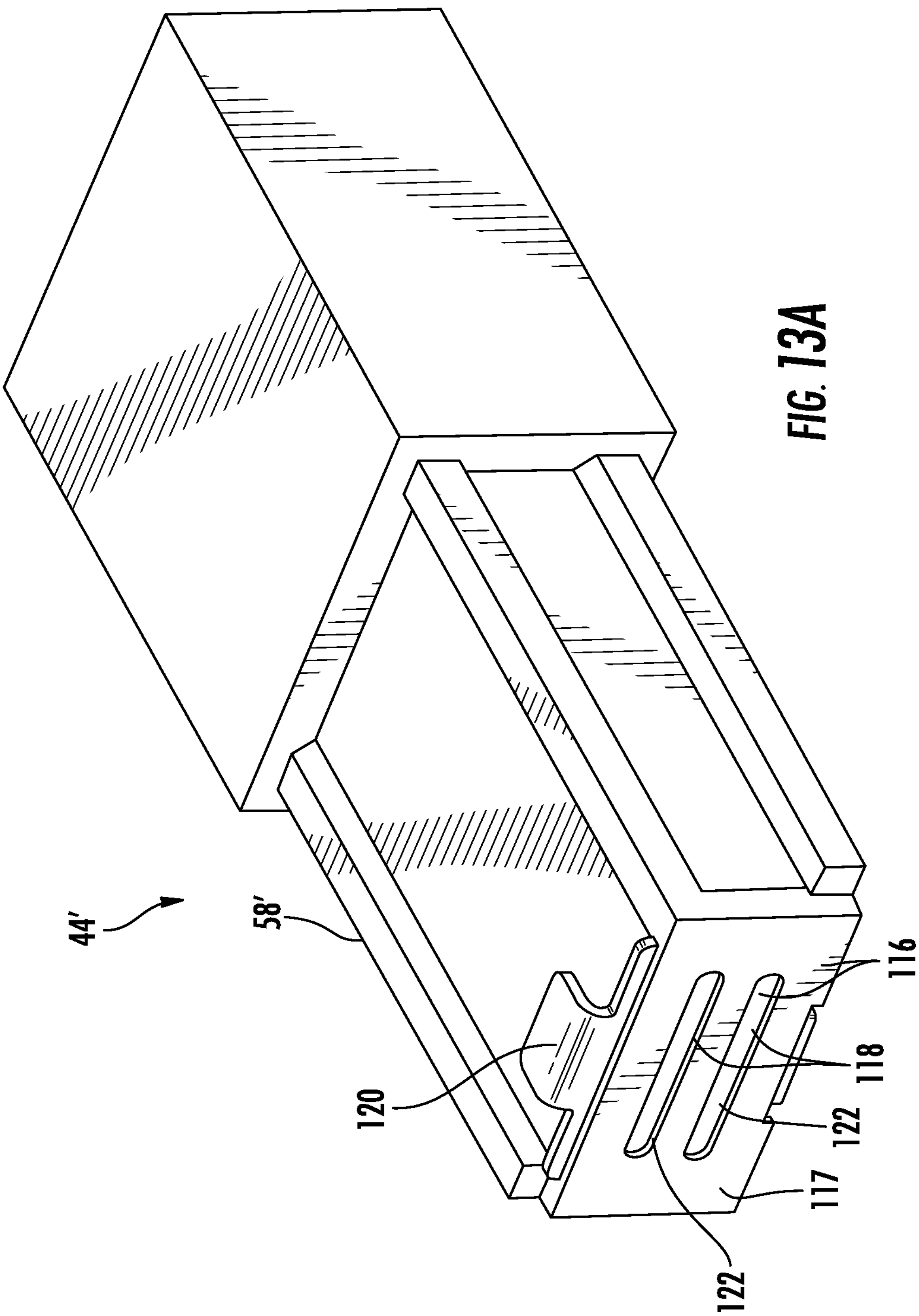


FIG. 13A

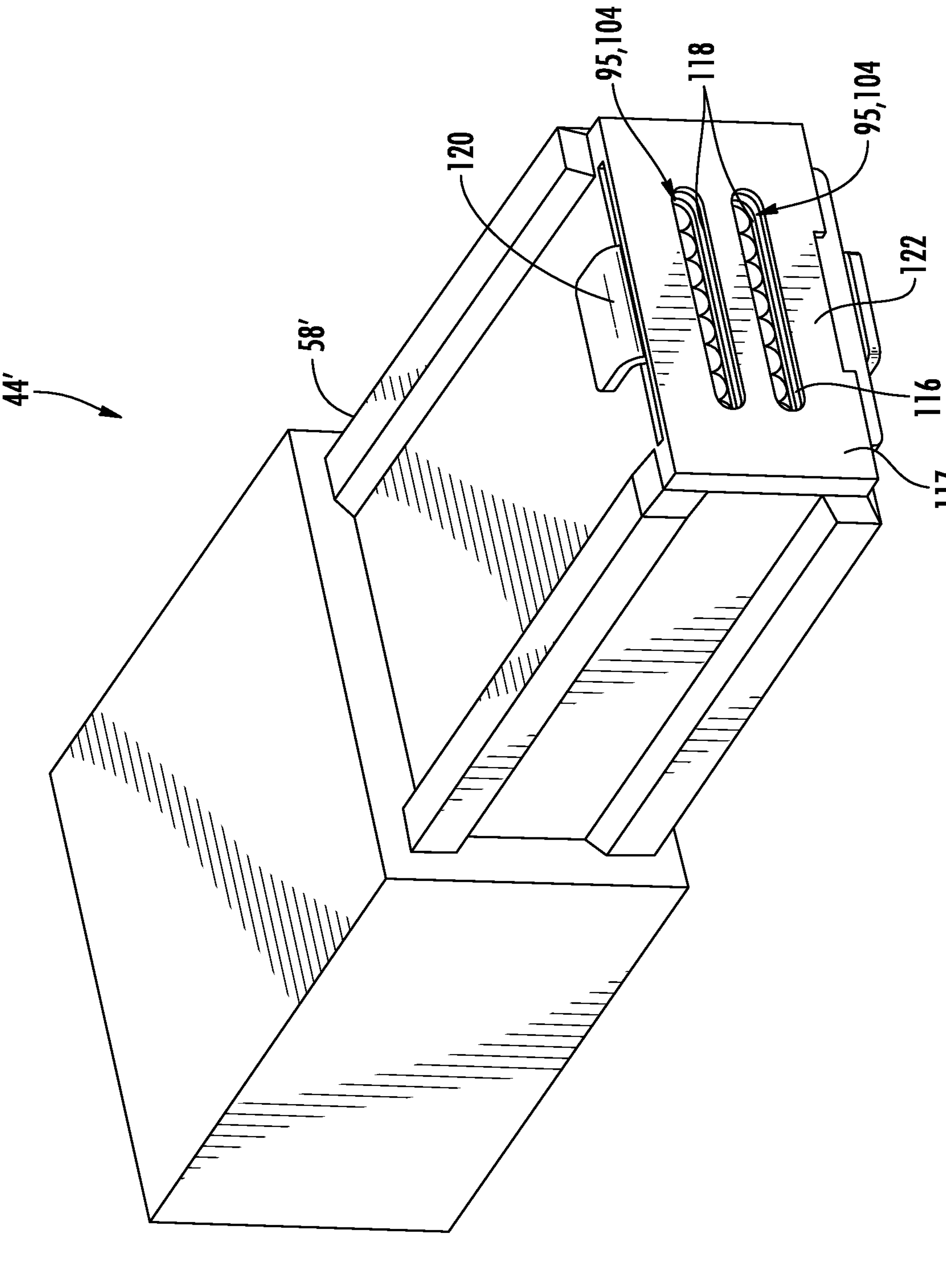


FIG. 13B

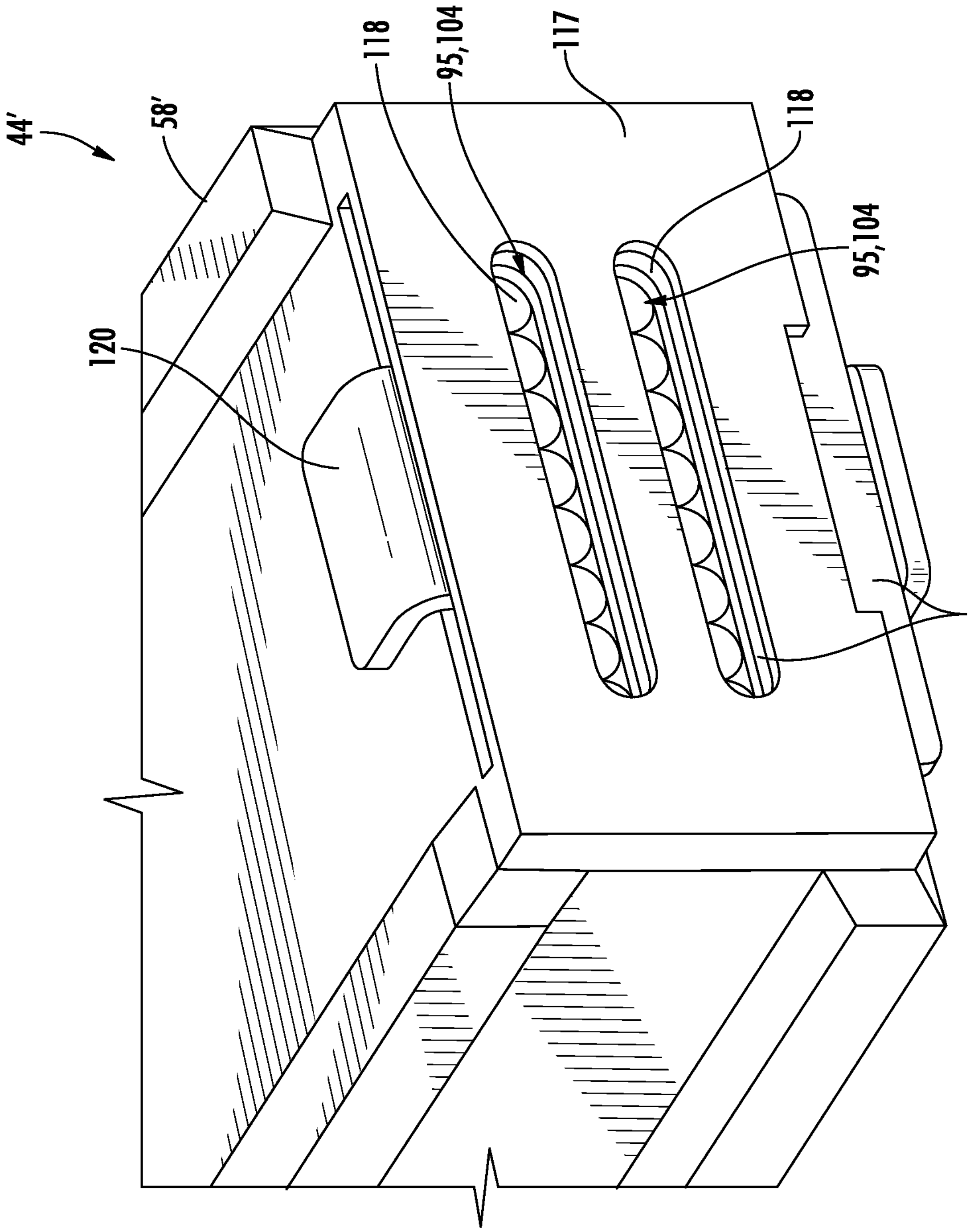


FIG. 13C

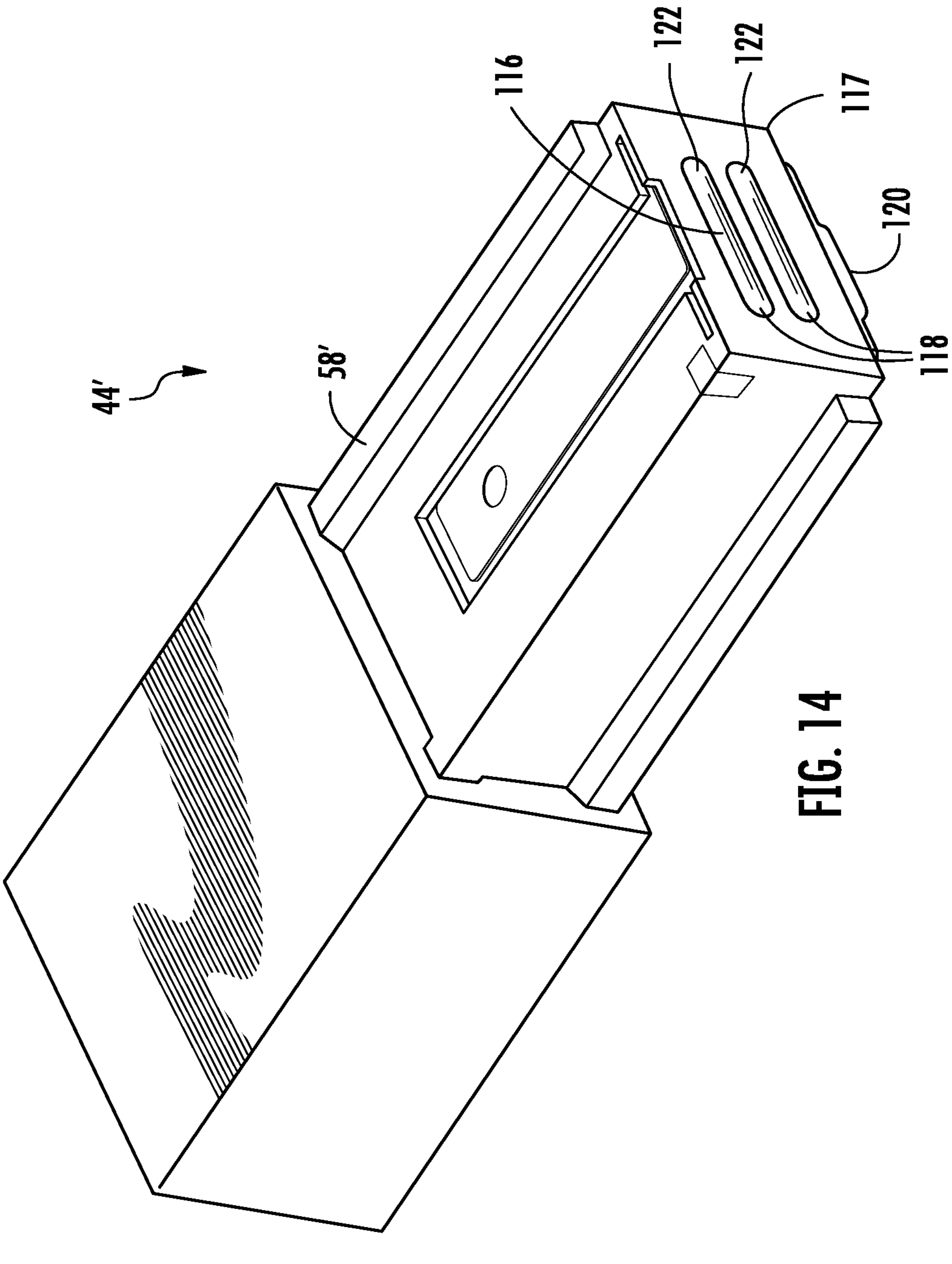


FIG. 14

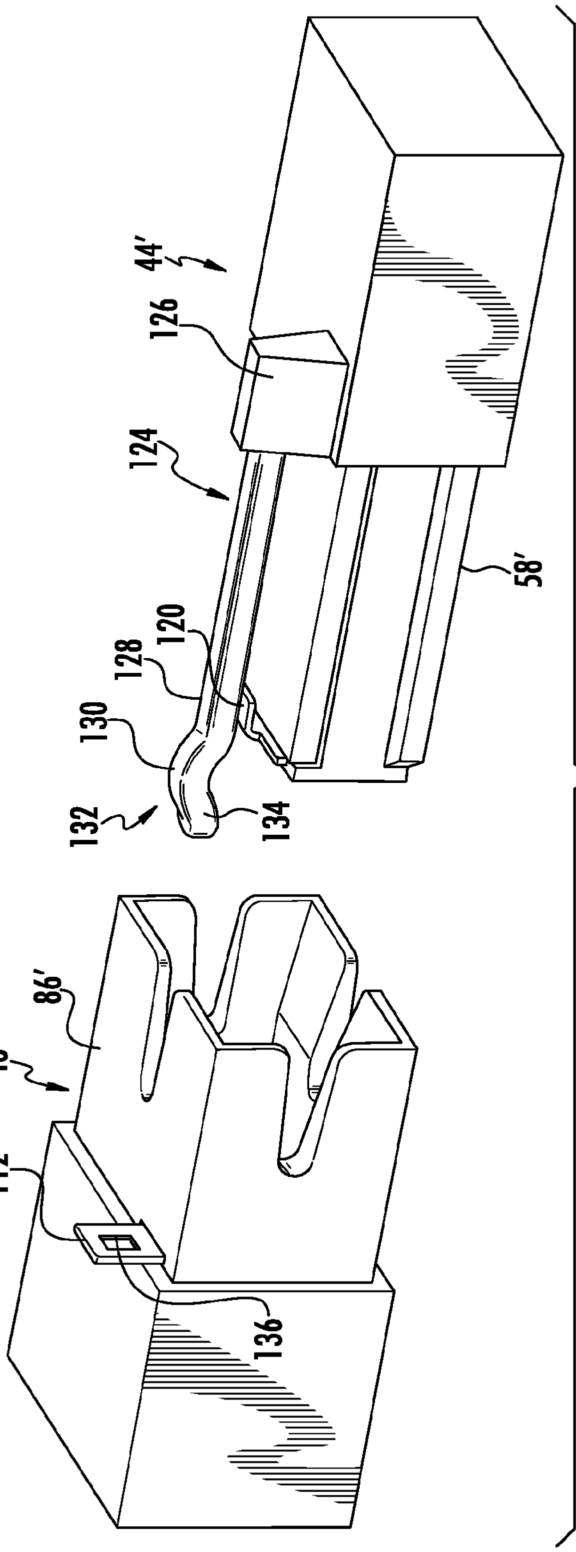


FIG. 15A

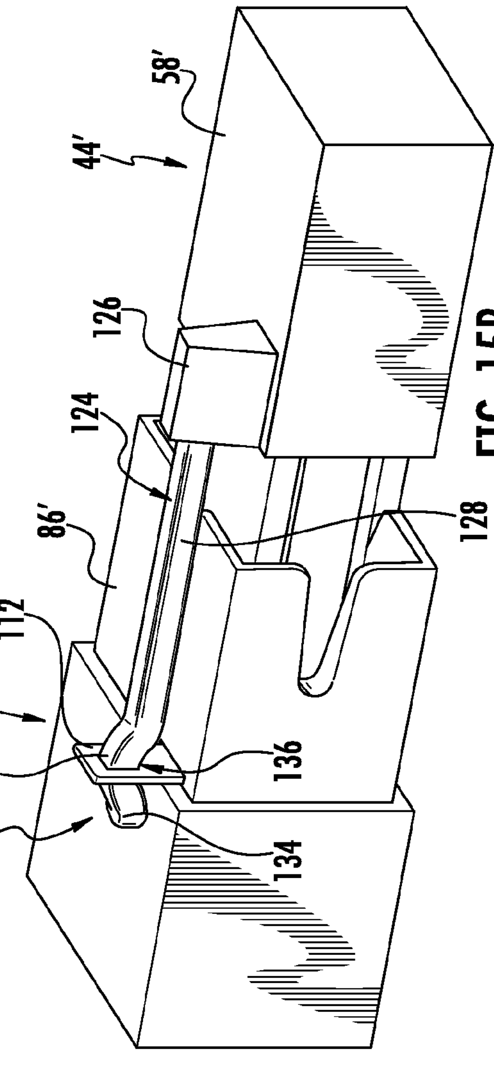


FIG. 15B

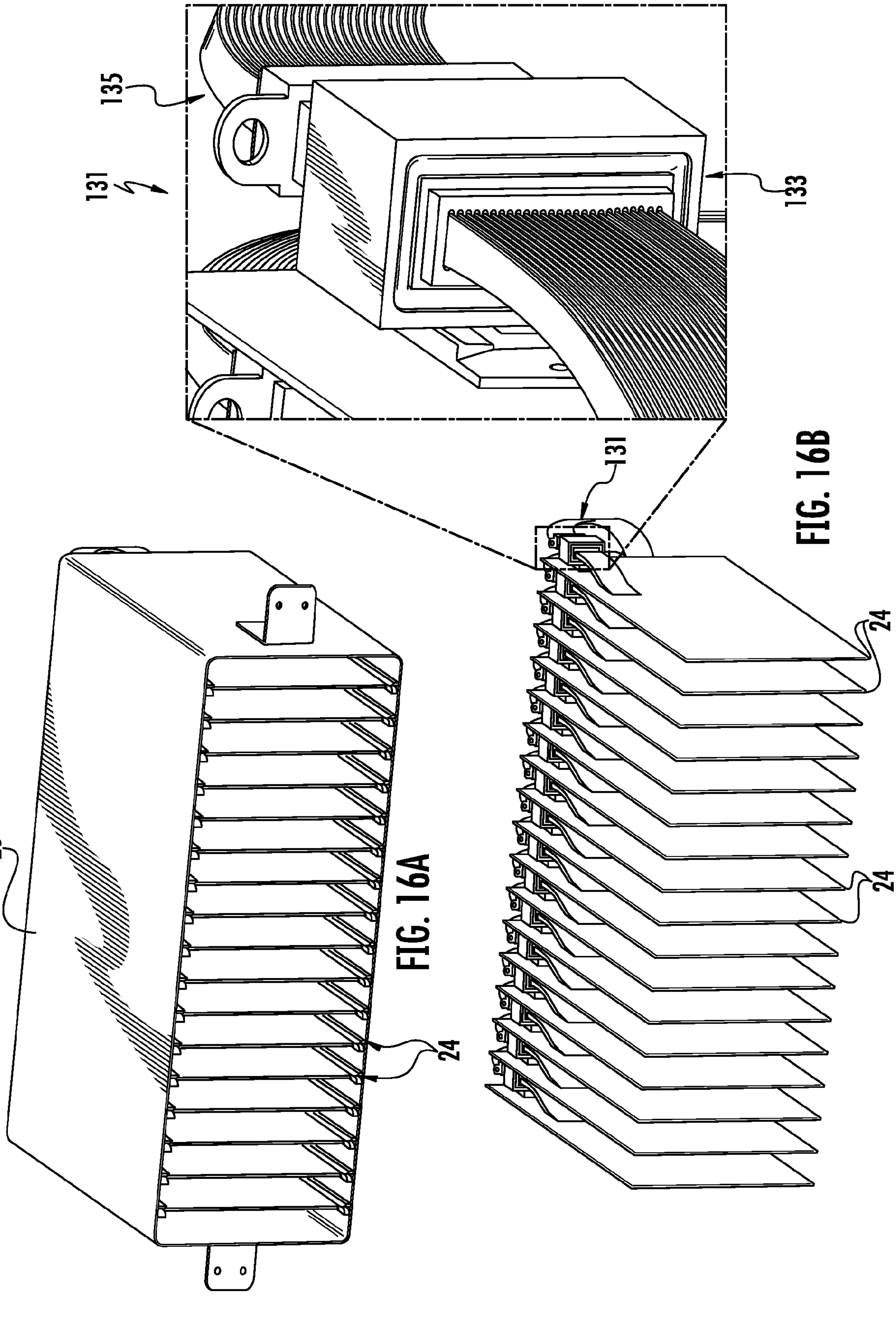


FIG. 16A

FIG. 16B

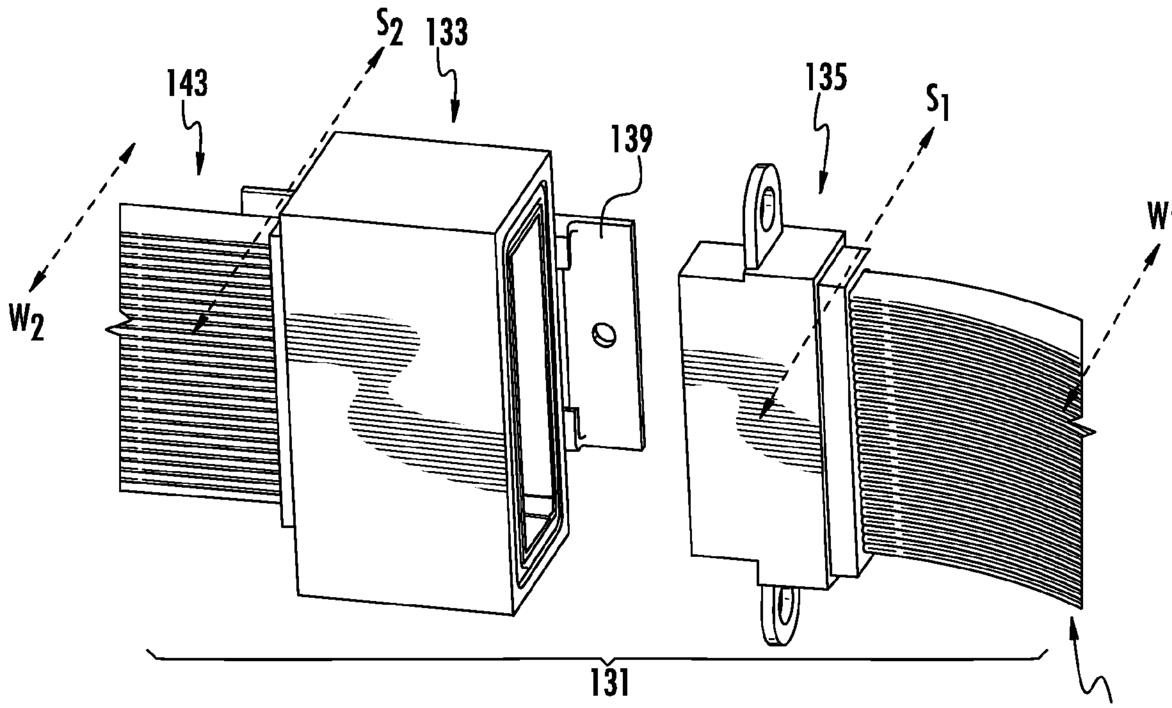


FIG. 17A

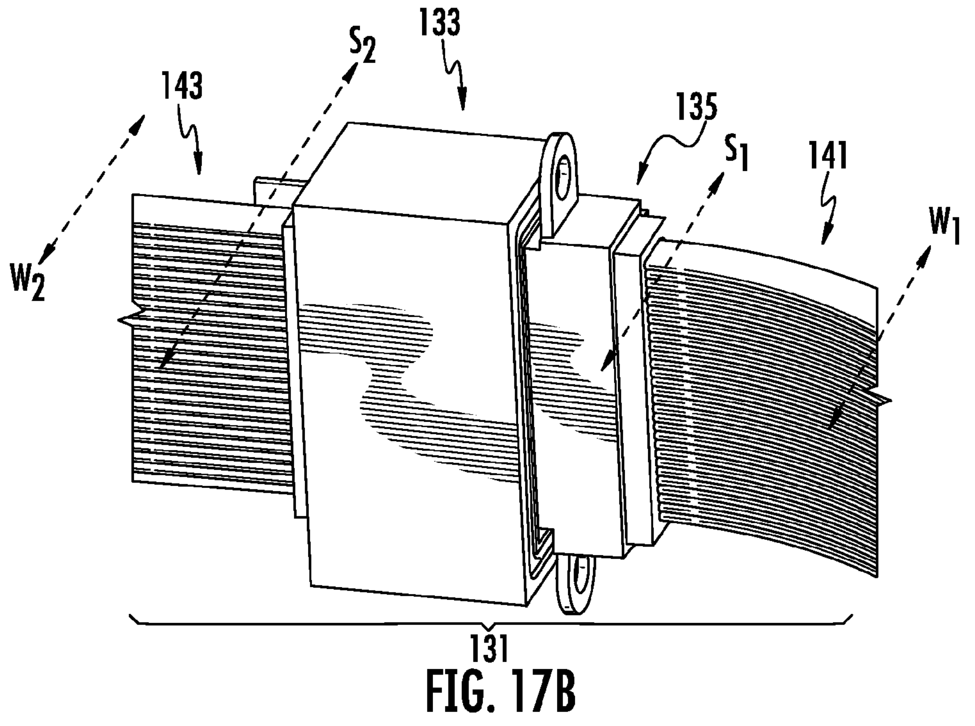


FIG. 17B

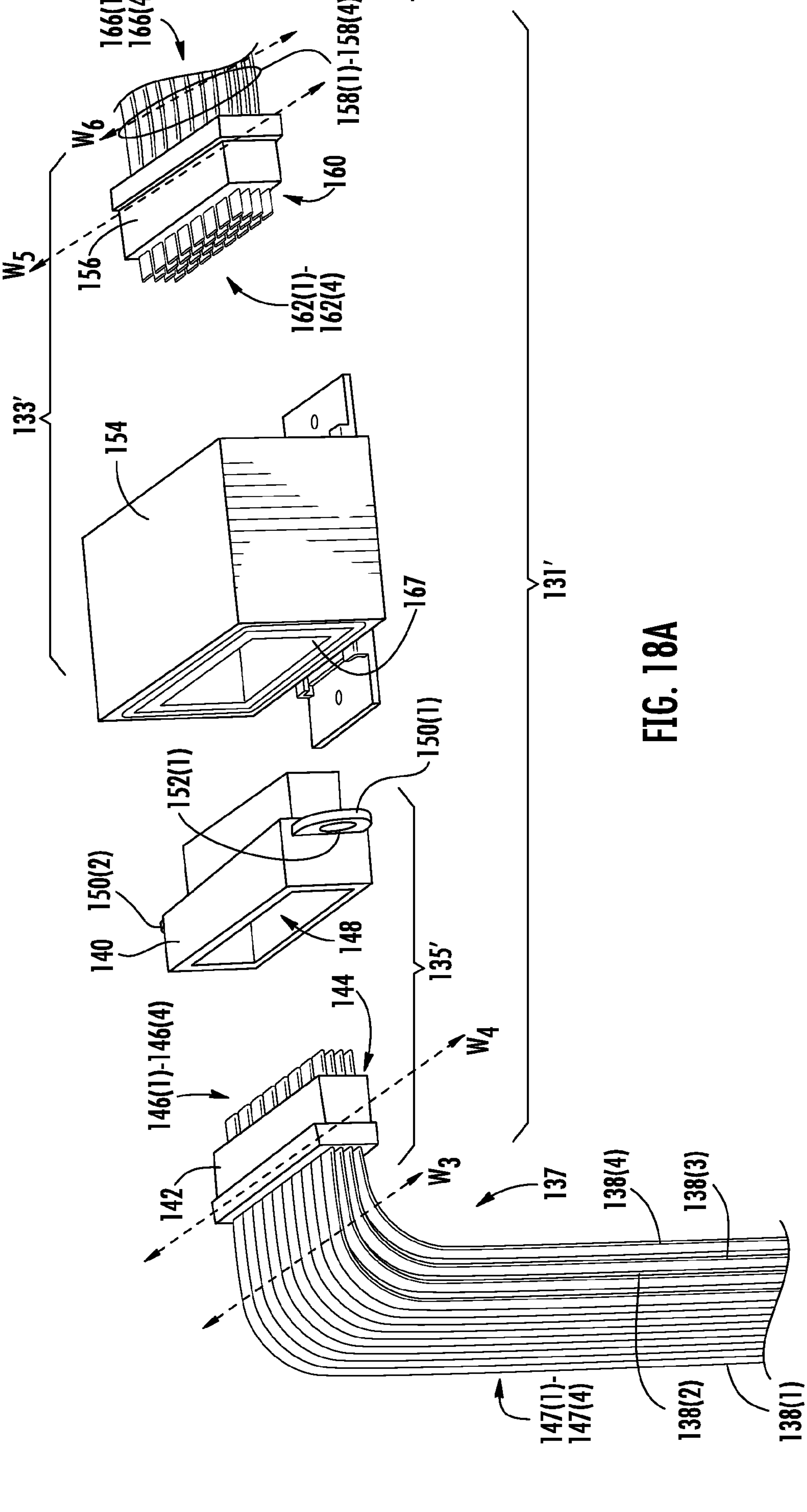

166(1)-
166(4)
158(1)-158(4)
W6
160
W5
156
162(1)-
162(4)
133'
154
167
131'
150(1)
152(1)
150(2)
140
148
135'
144
146(1)-146(4)
W4
142
W3
137
138(4)
138(3)
147(1)-
147(4)
138(2)
138(1)

FIG. 18A

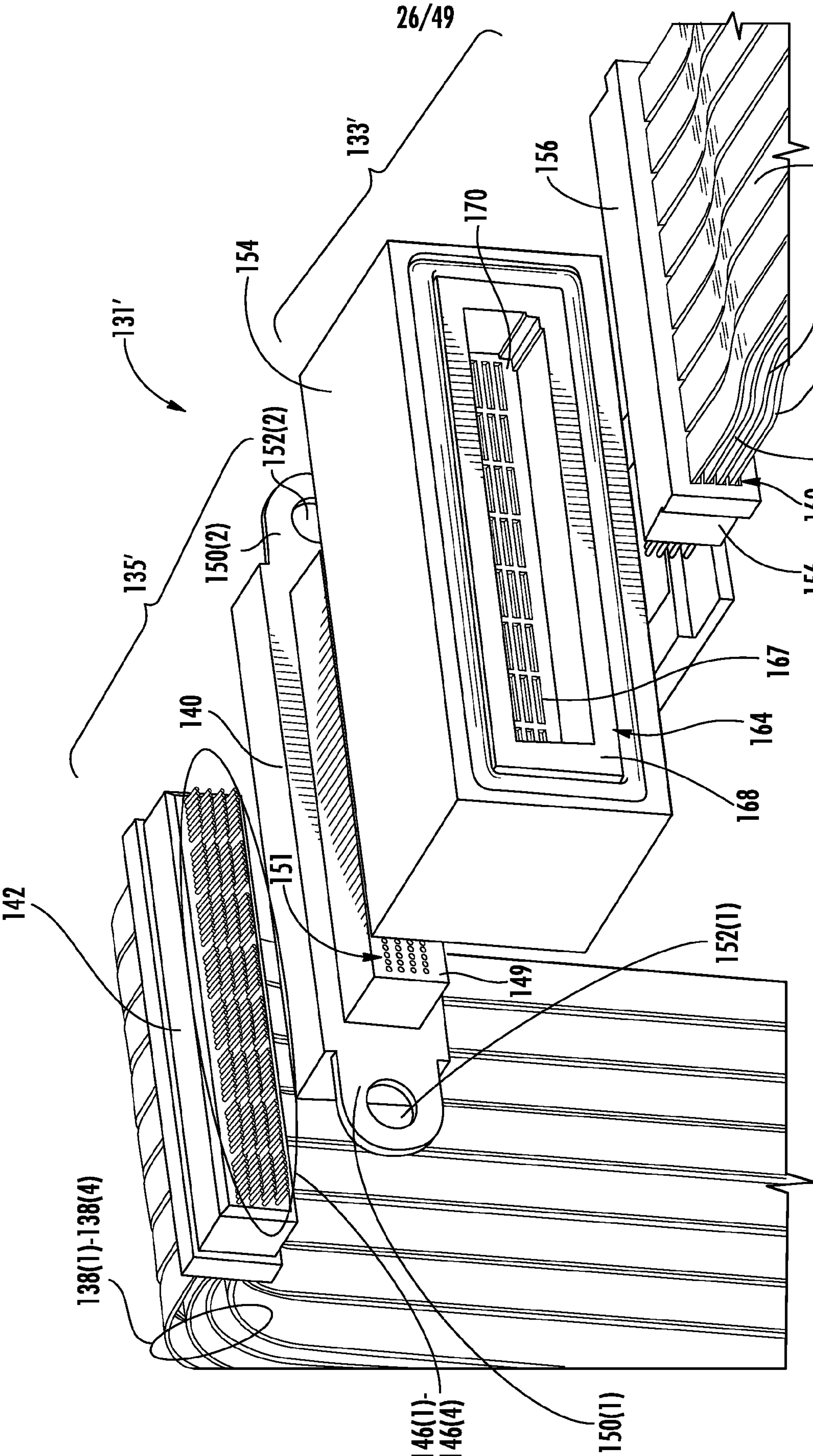

131′
133′
135′
154
170
156
156
158(1)
158(3)
158(4)
158(2)
160
167
164
168
140
151
152(2)
150(2)
142
149
152(1)
138(1)-138(4)
146(1)-146(4)
150(1)

FIG. 18B

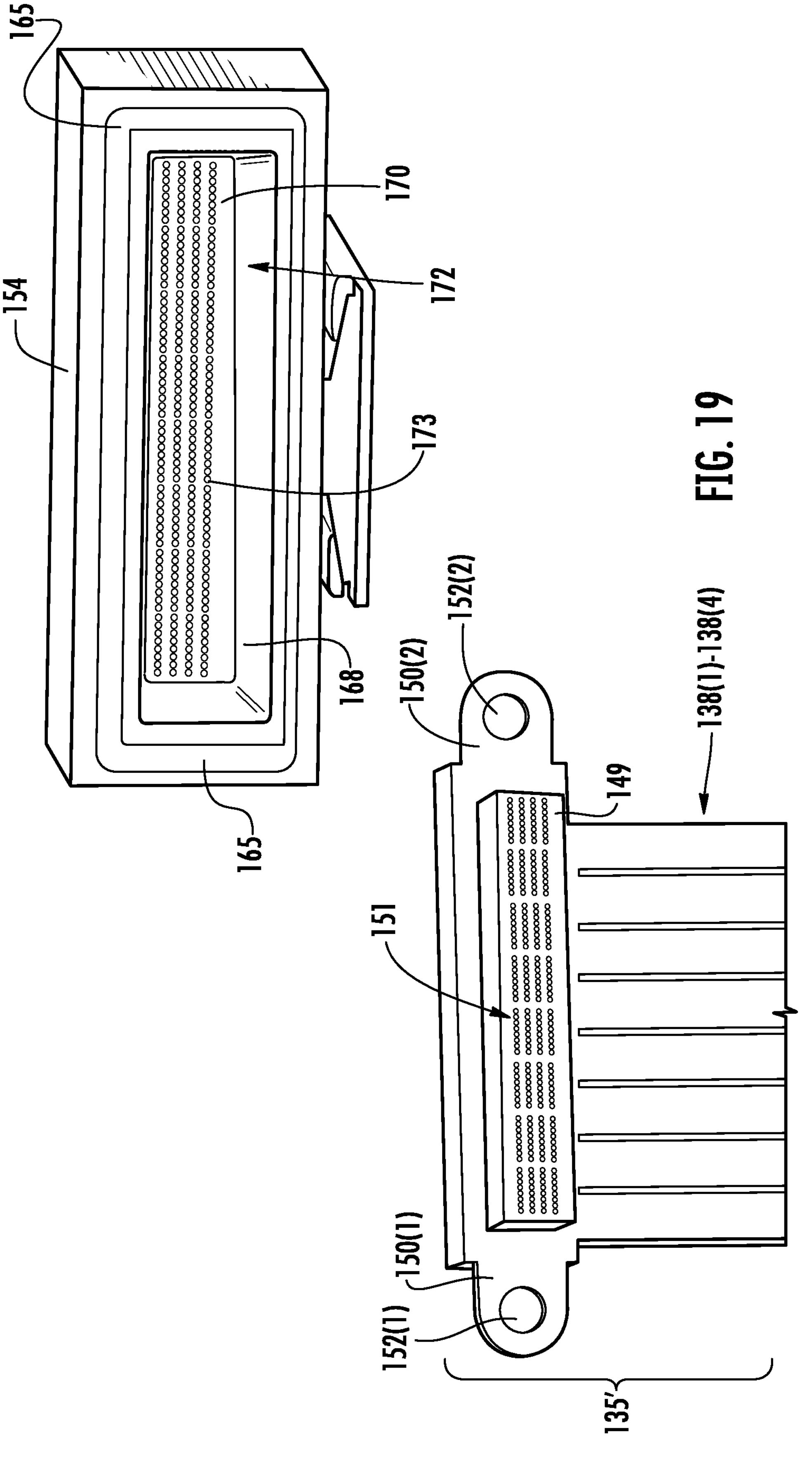

165
170
172
154
173
168
165
152(2)
150(2)
138(1)-138(4)
149
151
150(1)
152(1)
135'

FIG. 19

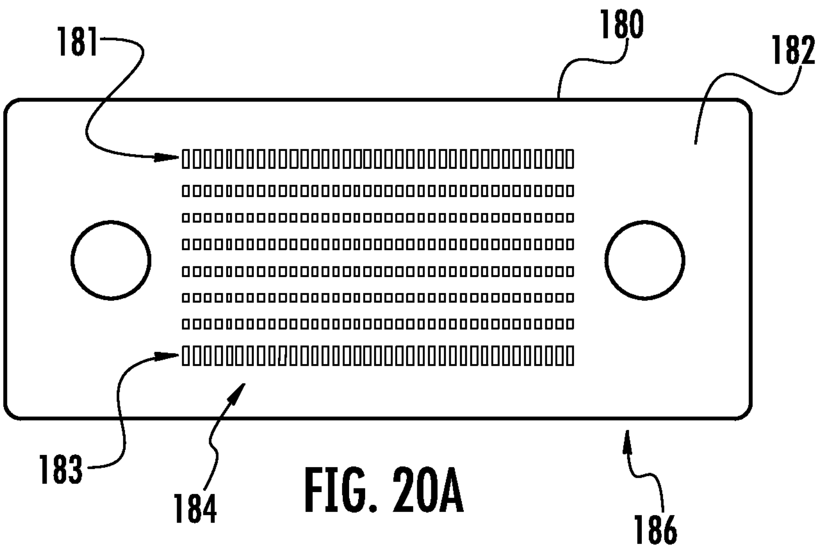


FIG. 20A

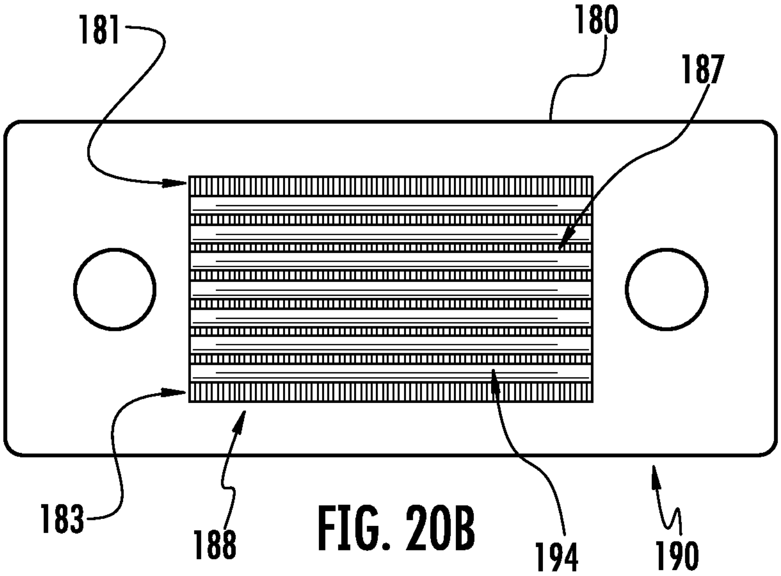


FIG. 20B

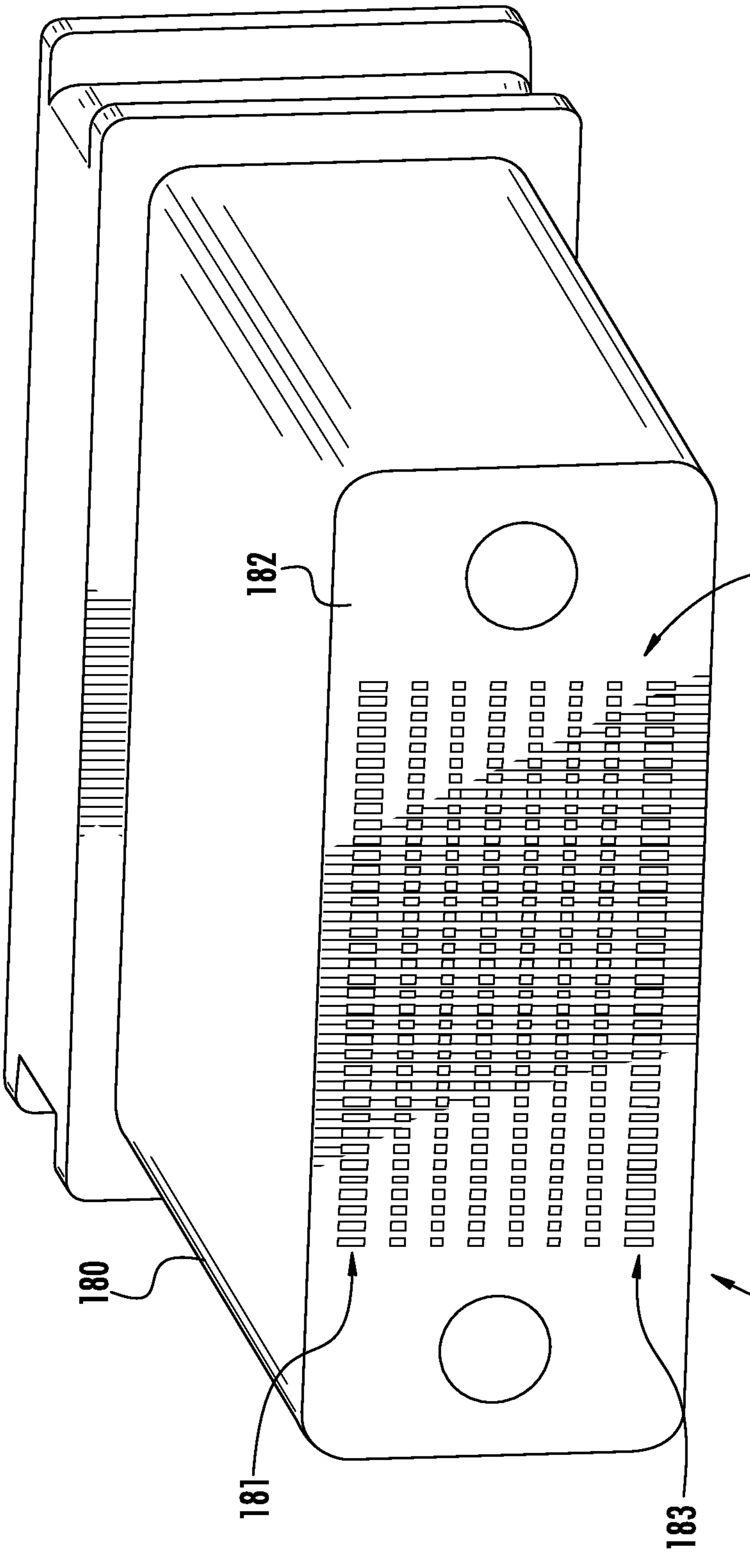


FIG. 21A

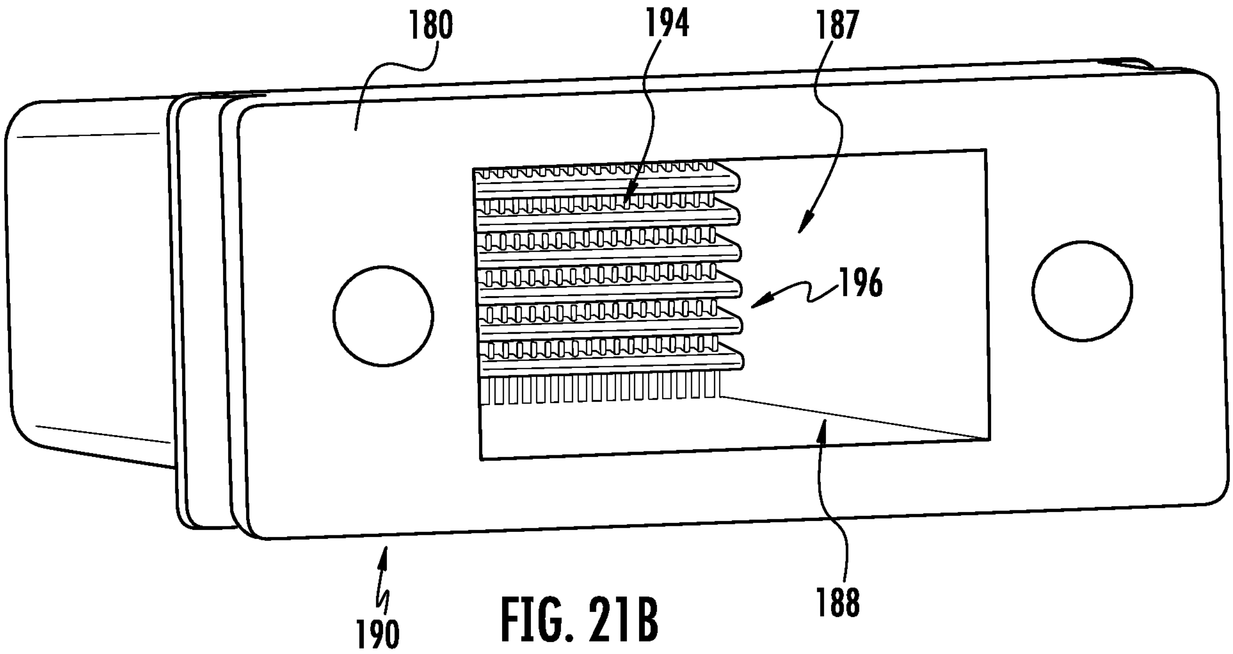


FIG. 21B

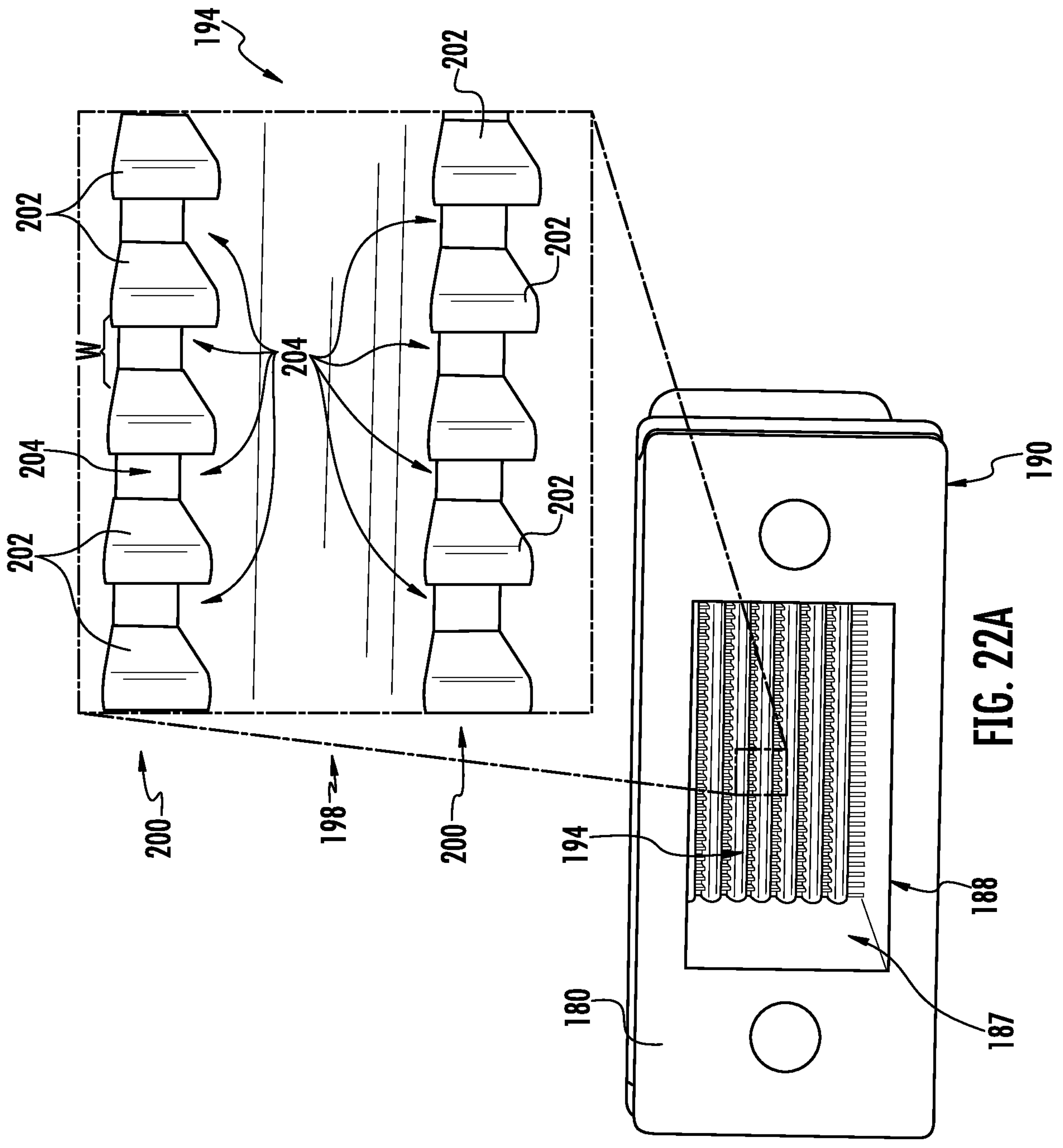


FIG. 22A

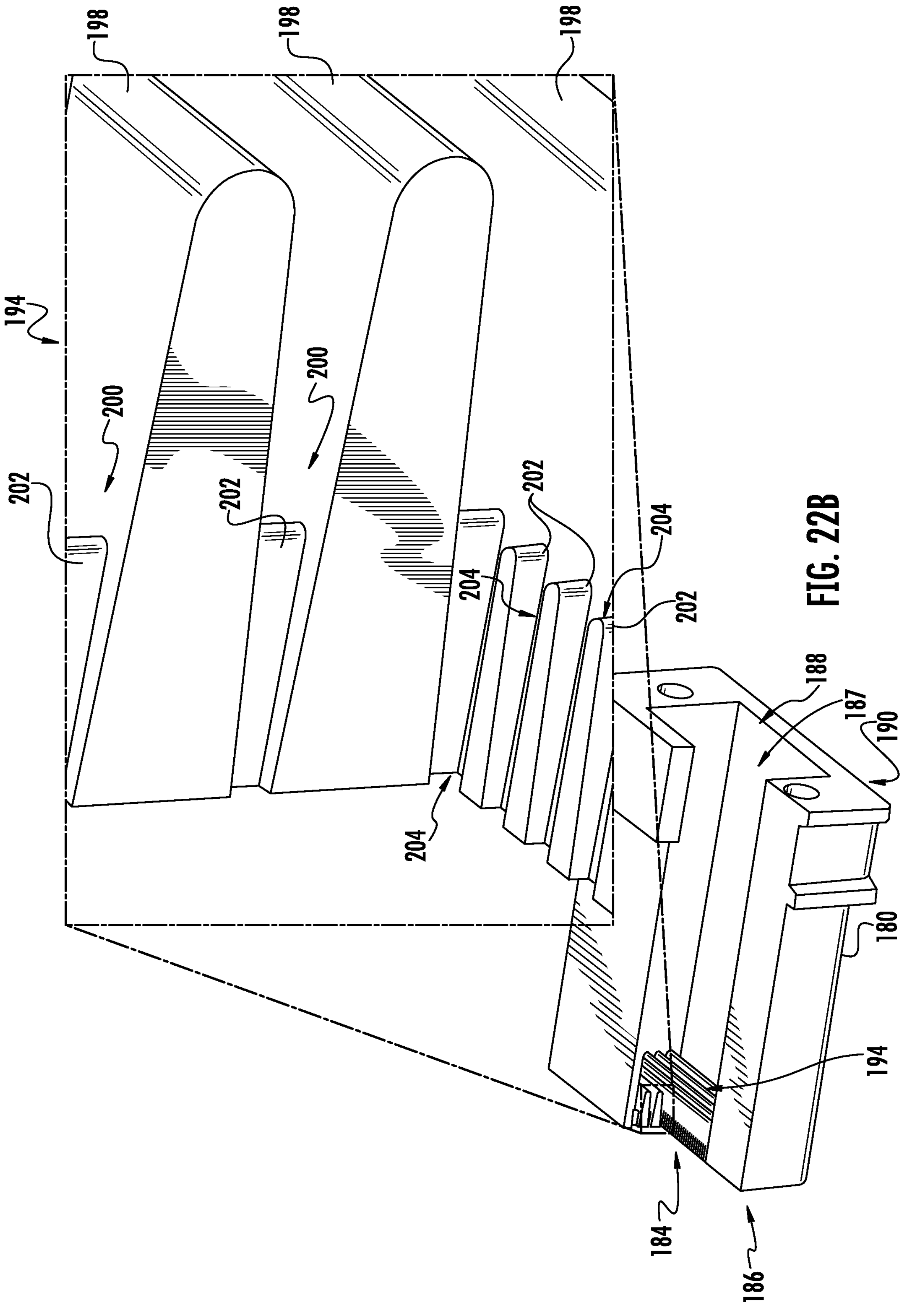

198
198
198
194
200
200
202
202
202
204
204
202
204
188
187
190
180
194
184
186

FIG. 22B

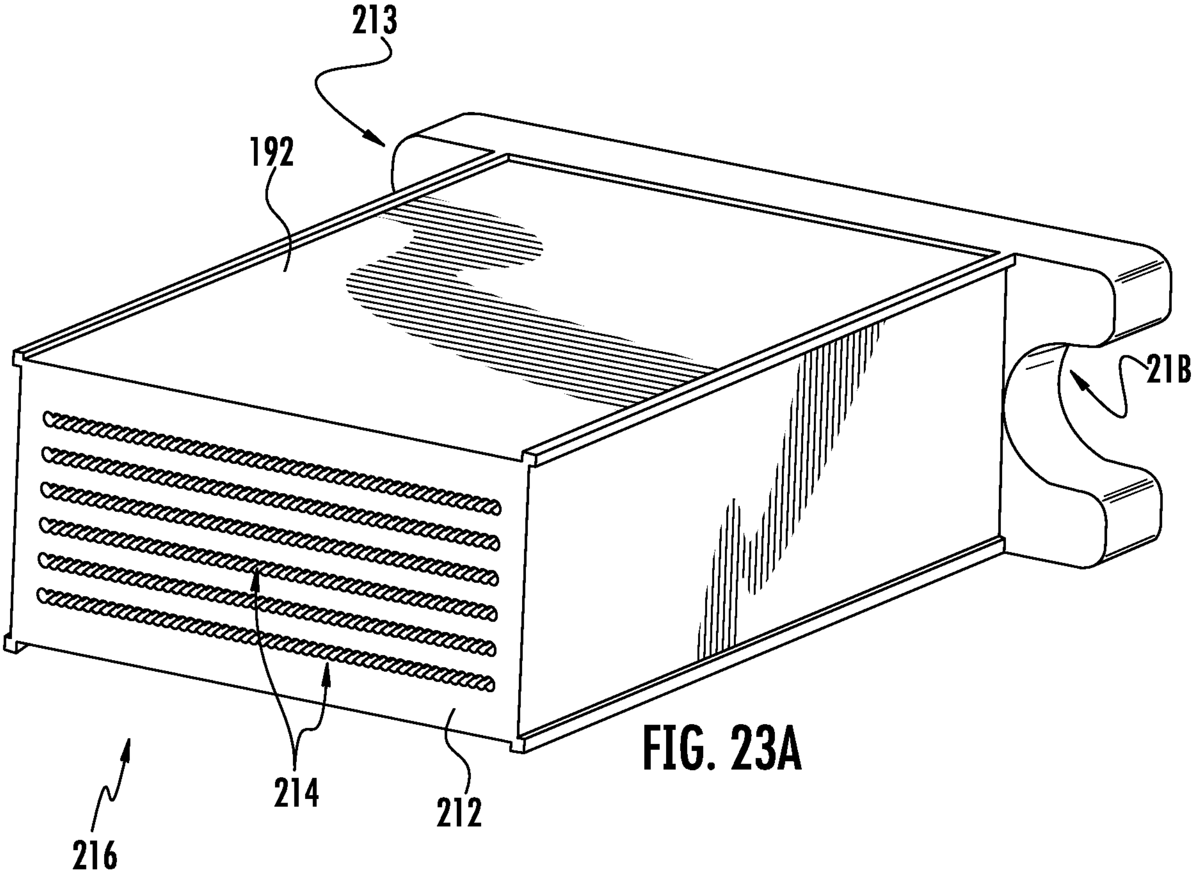


FIG. 23A

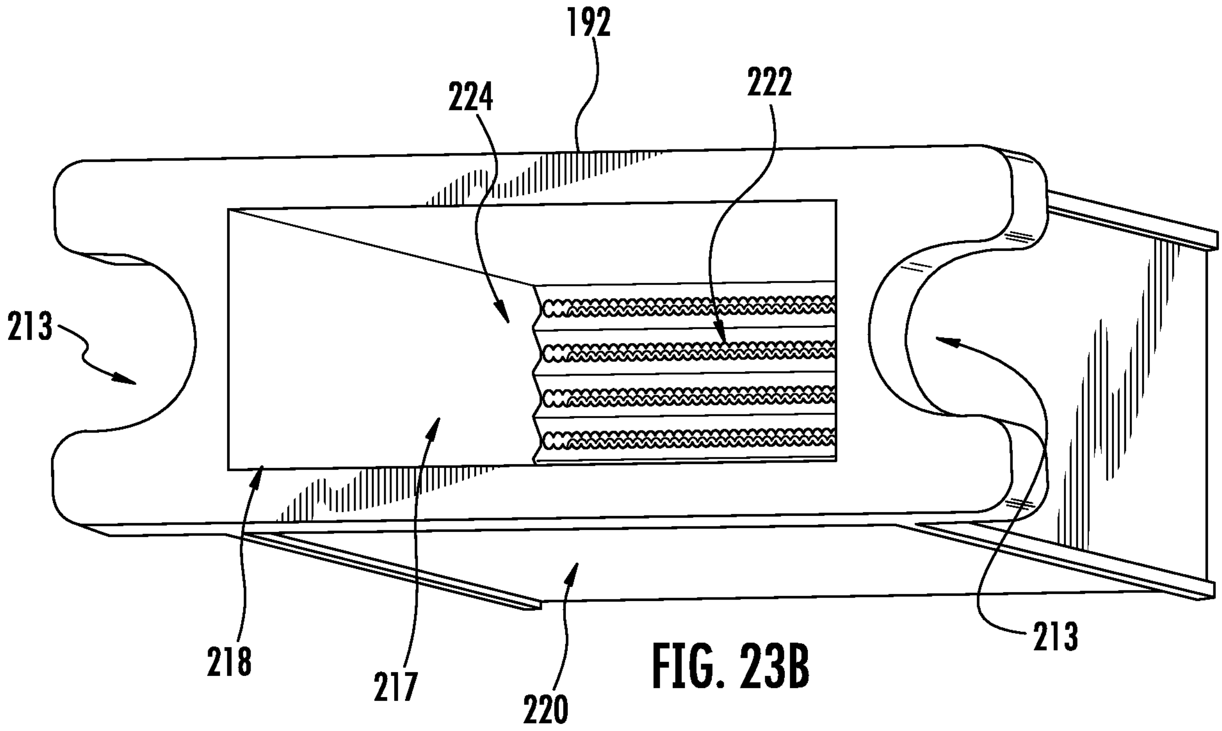


FIG. 23B

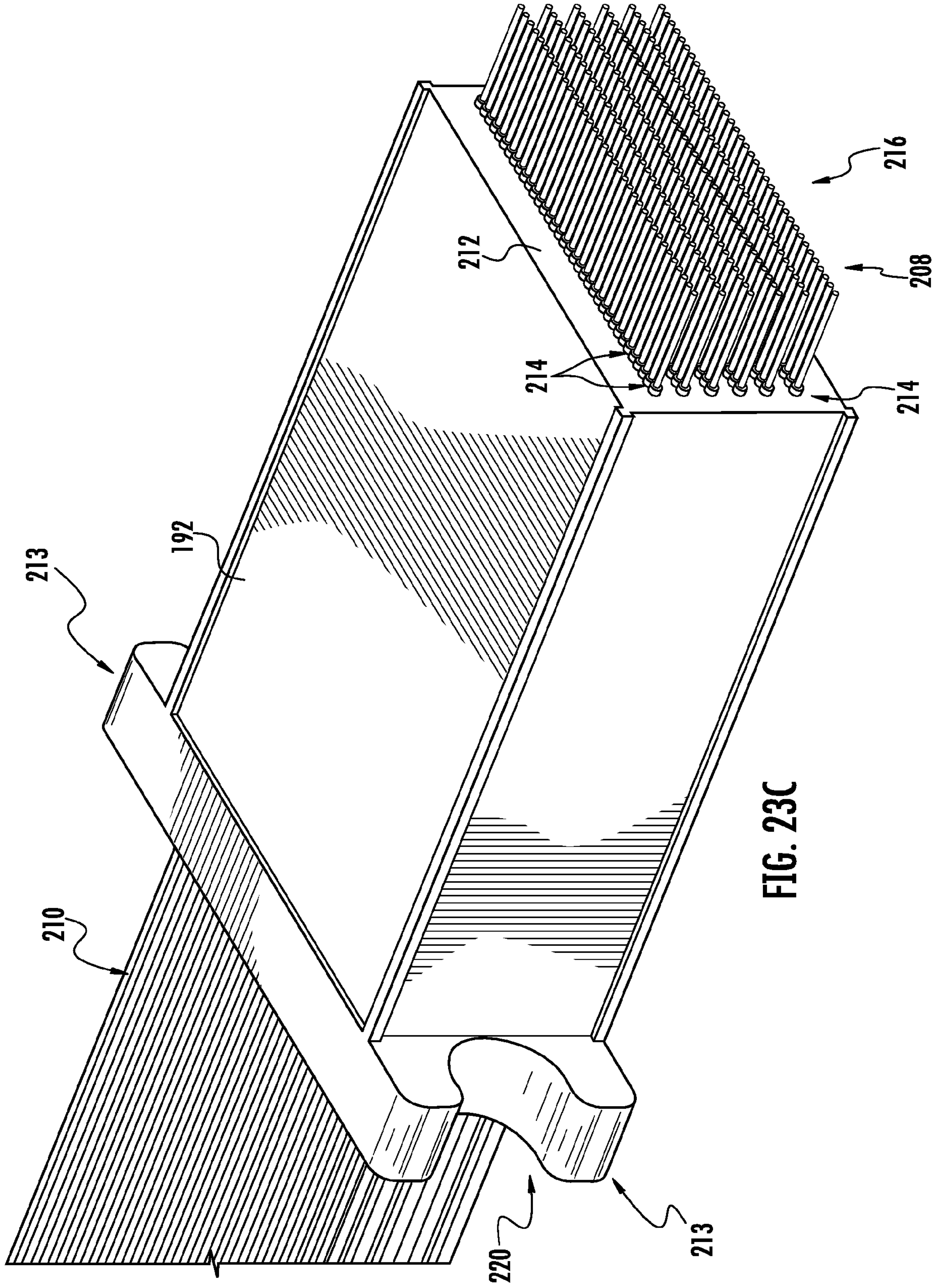


FIG. 23C

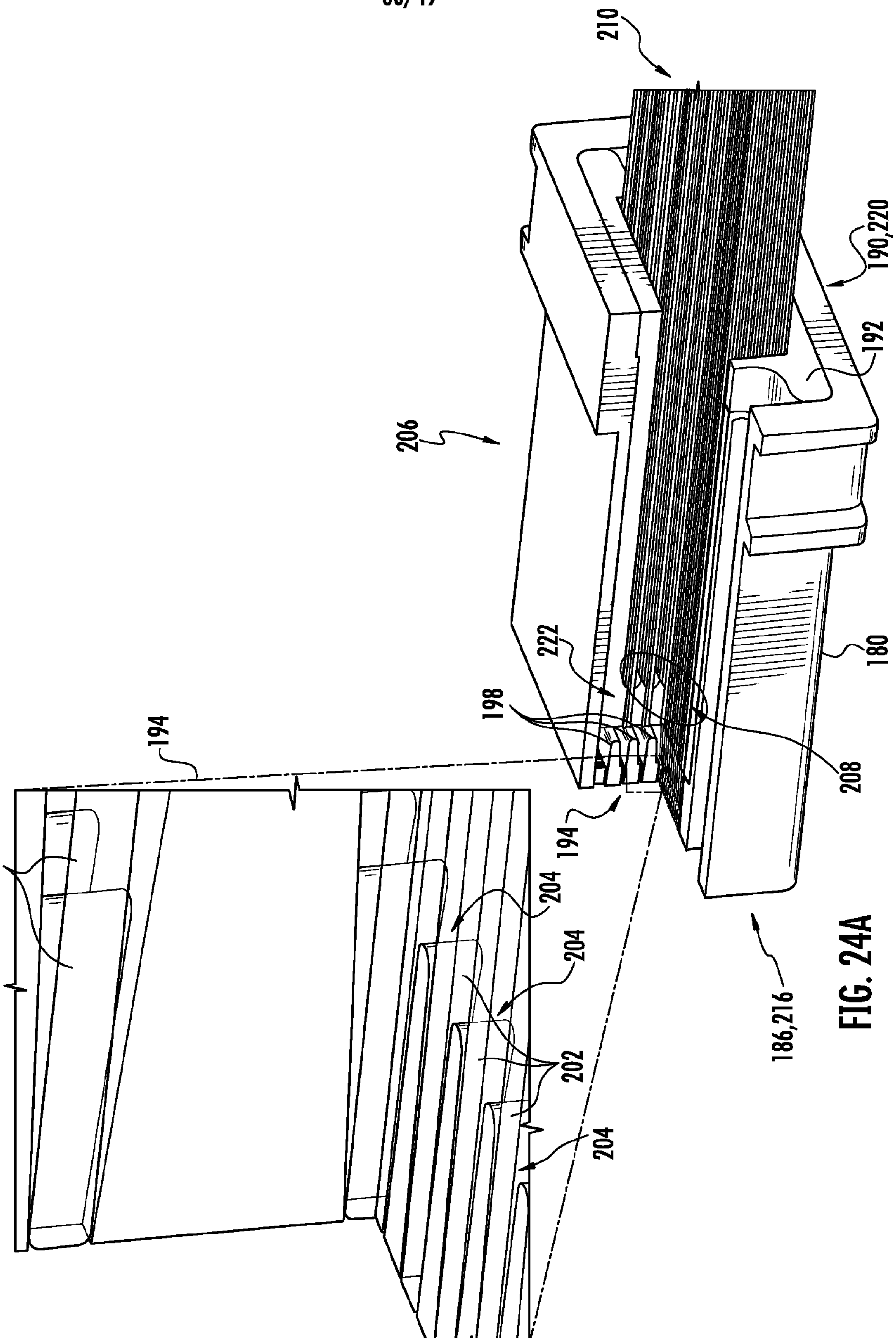
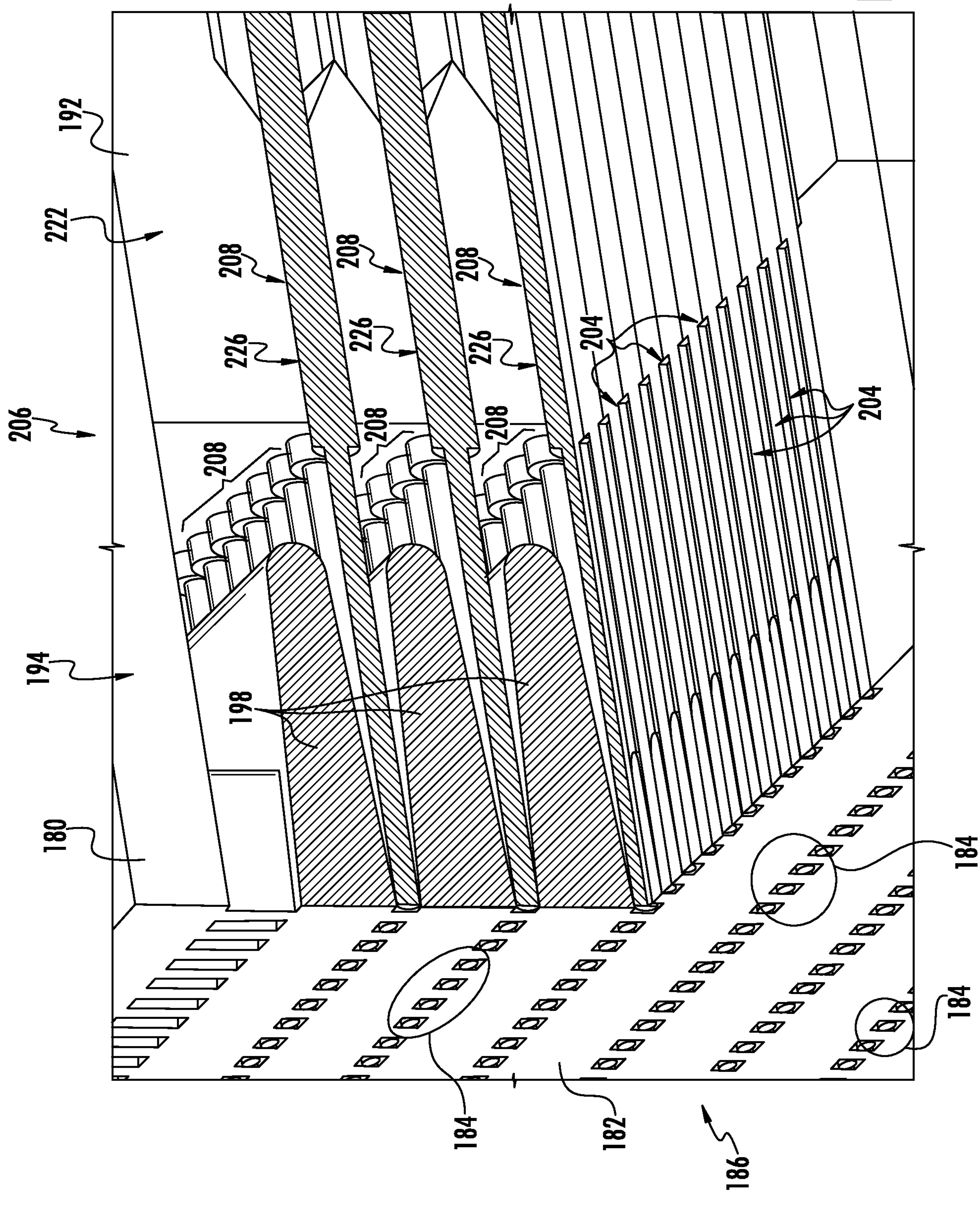

210
206
190,220
192
222
198
194
180
208
194
202
204
204
202
204
186,216

FIG. 24A

FIG. 24B


192
222
206
194
180
208
208
208
226
226
226
208
208
208
204
204
198
184
184
184
182
186

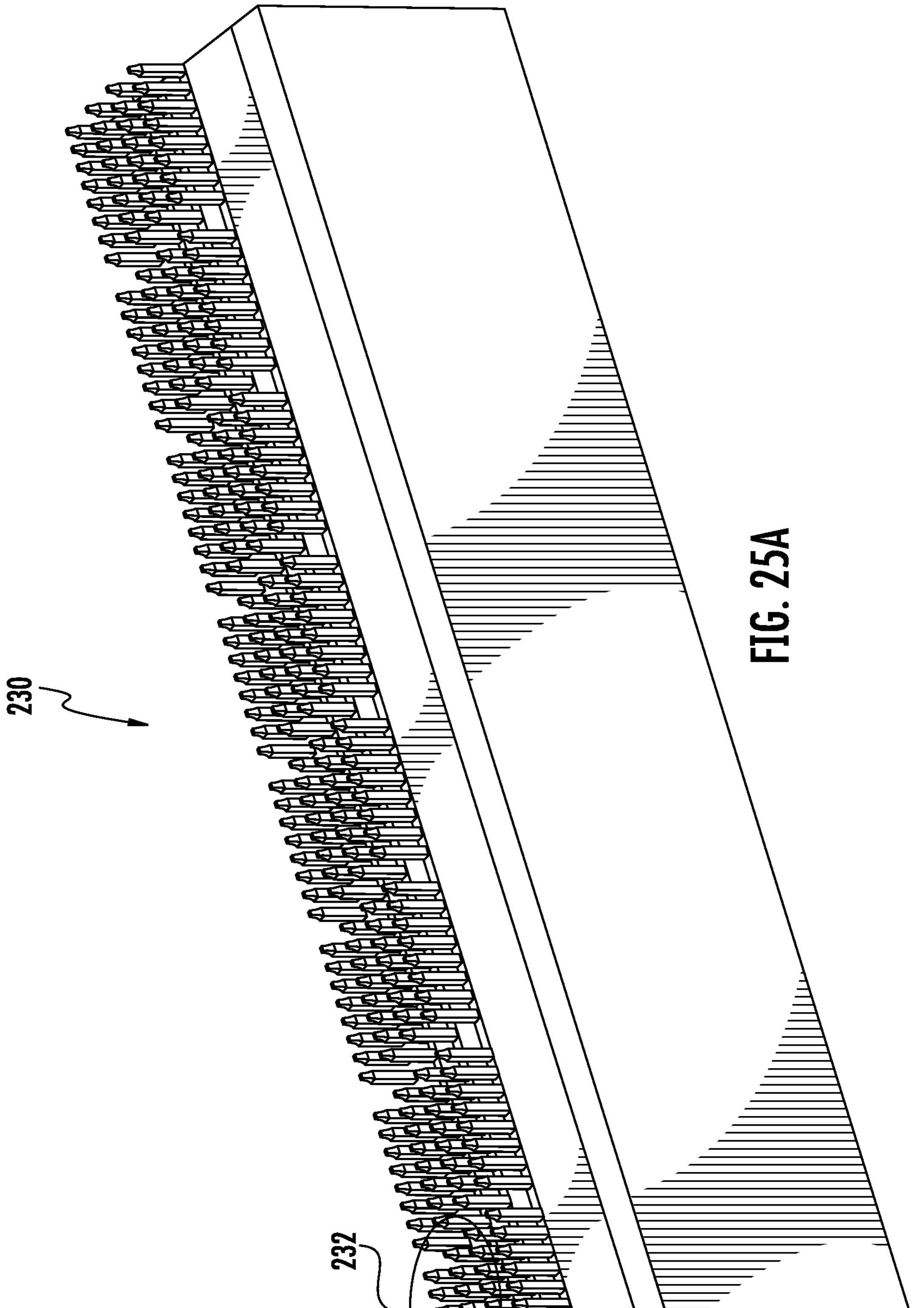


FIG. 25A

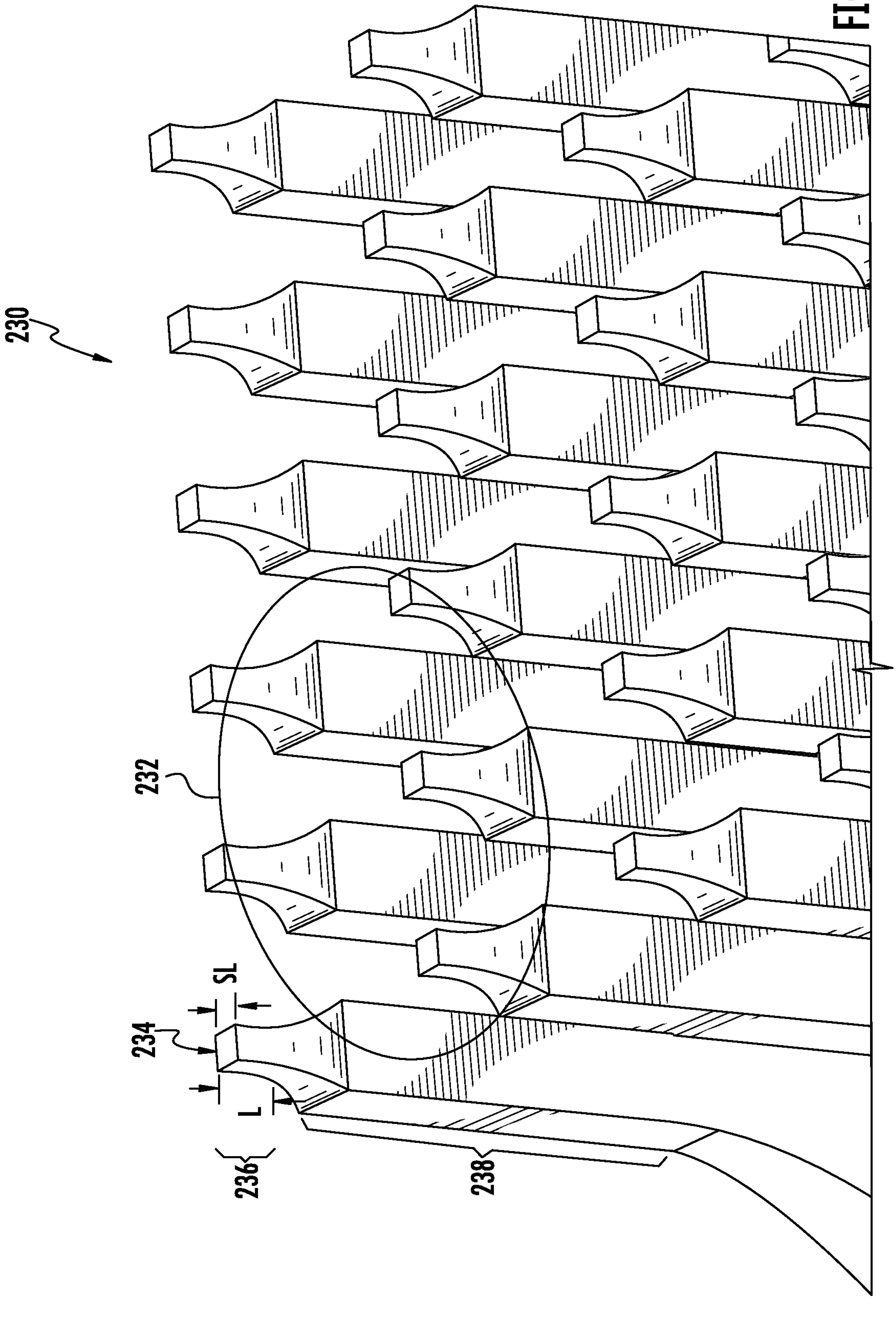


FIG. 25B

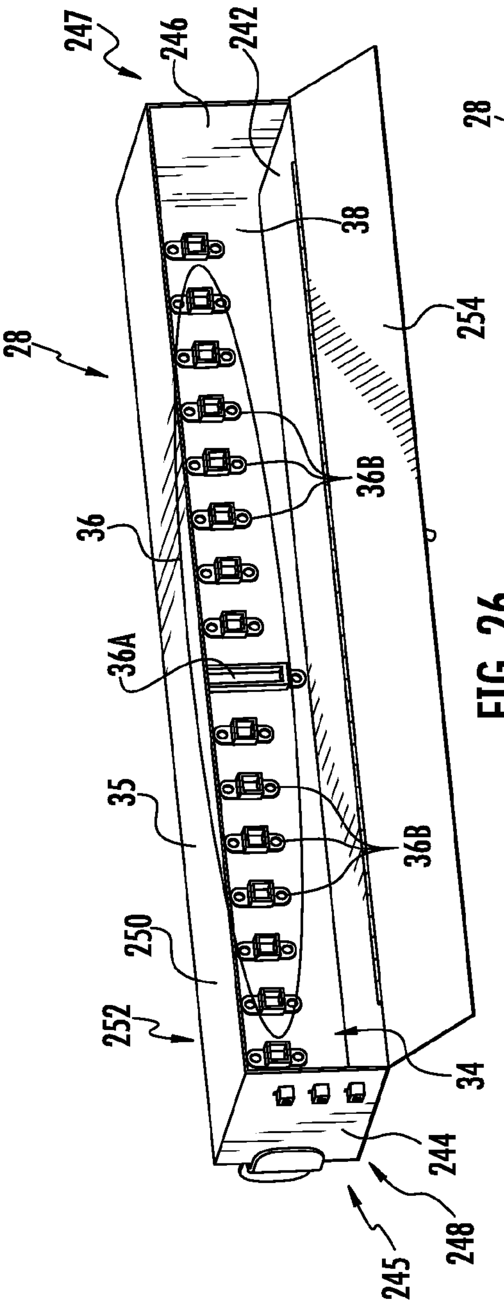

28
247
246
242
38
254
36B
36
36A
35
250
252
34
244
248
245

FIG. 26

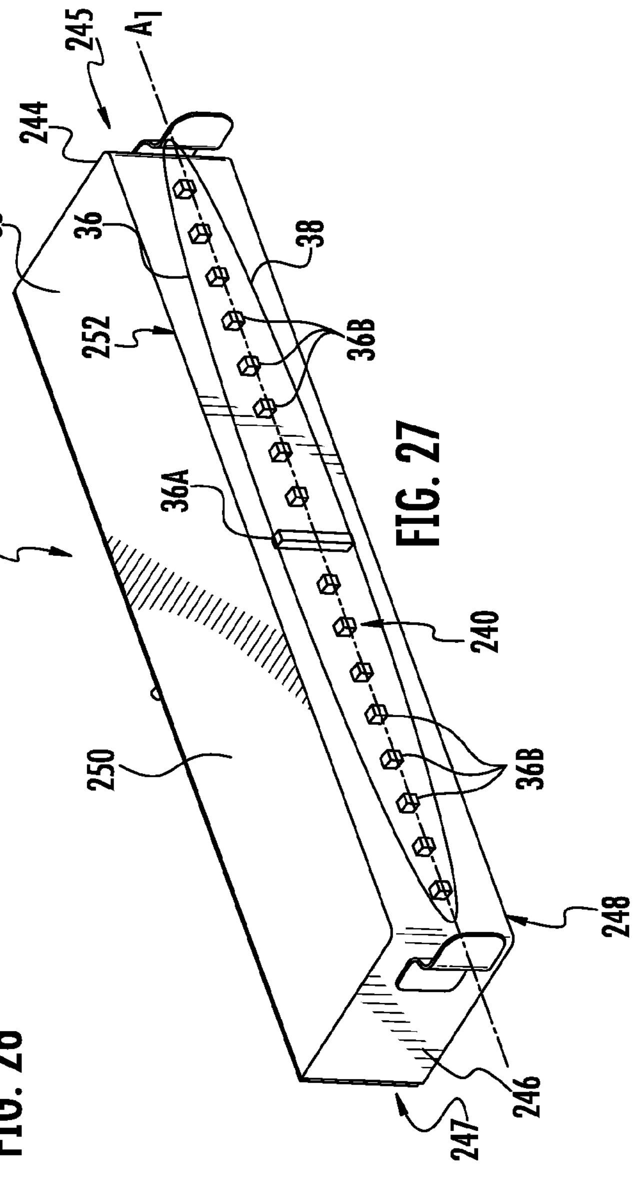

245
A1
244
35
36
38
252
36B
36A
28
240
250
248
246
247

FIG. 27

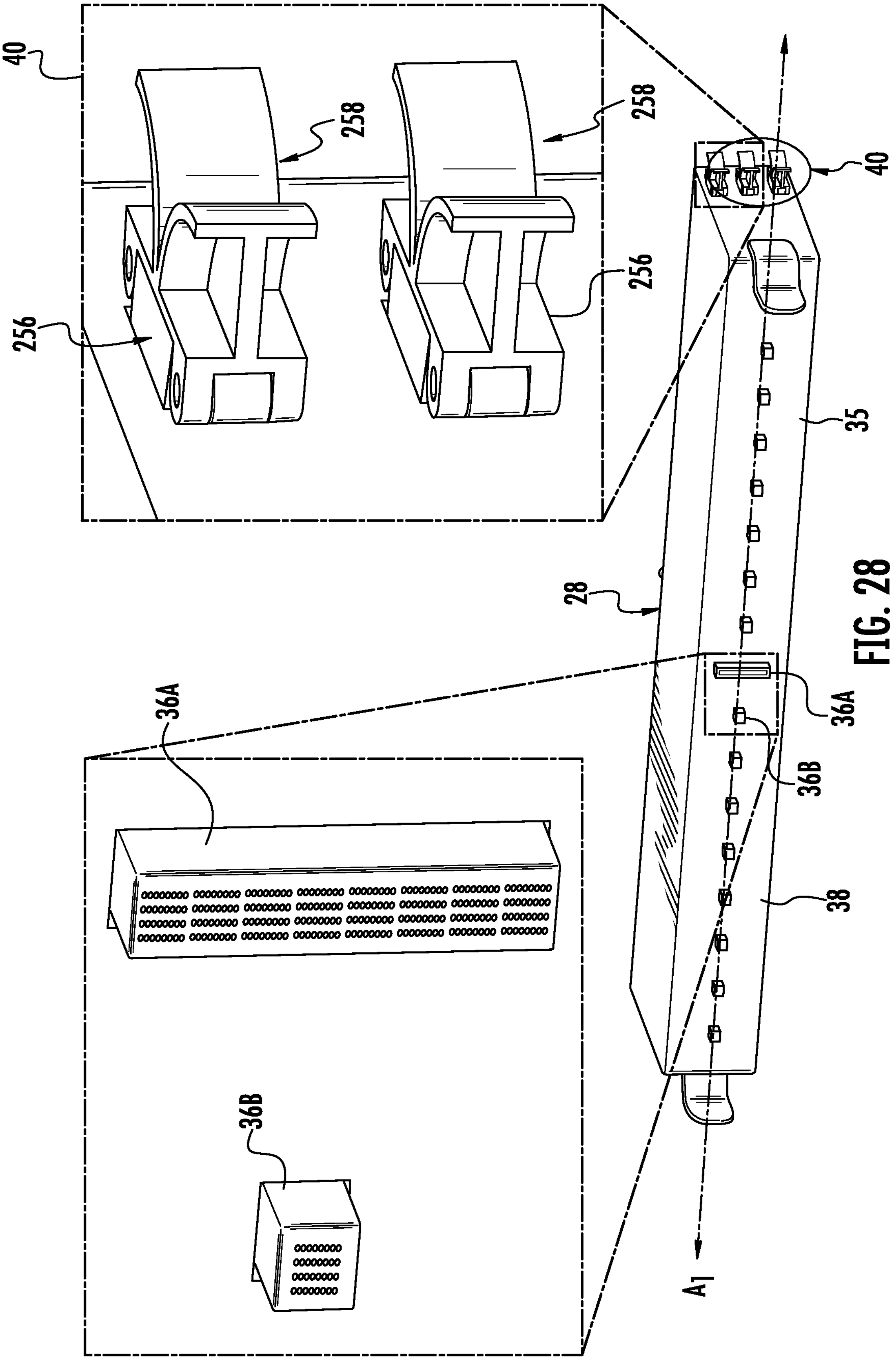


FIG. 28

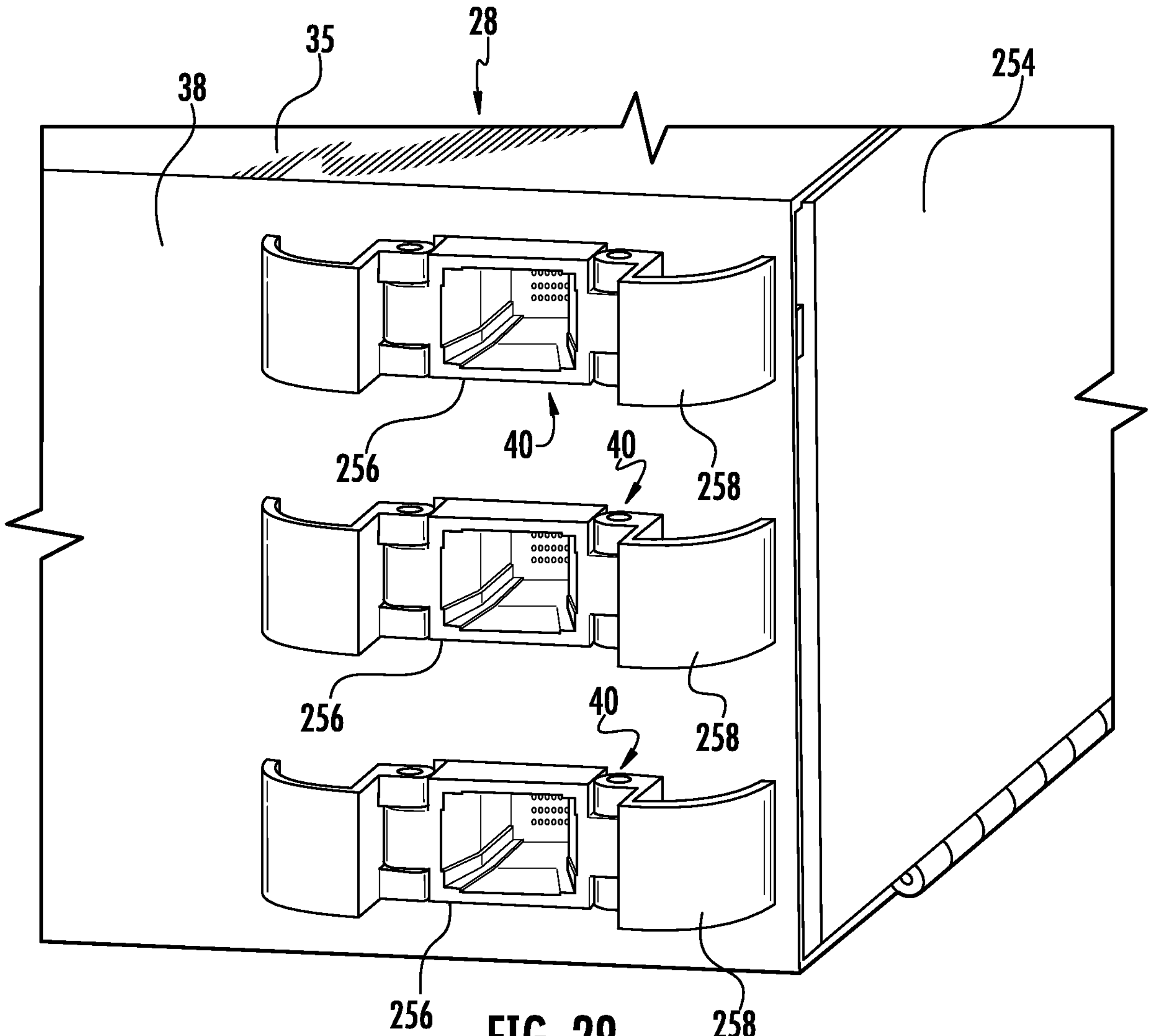


FIG. 29

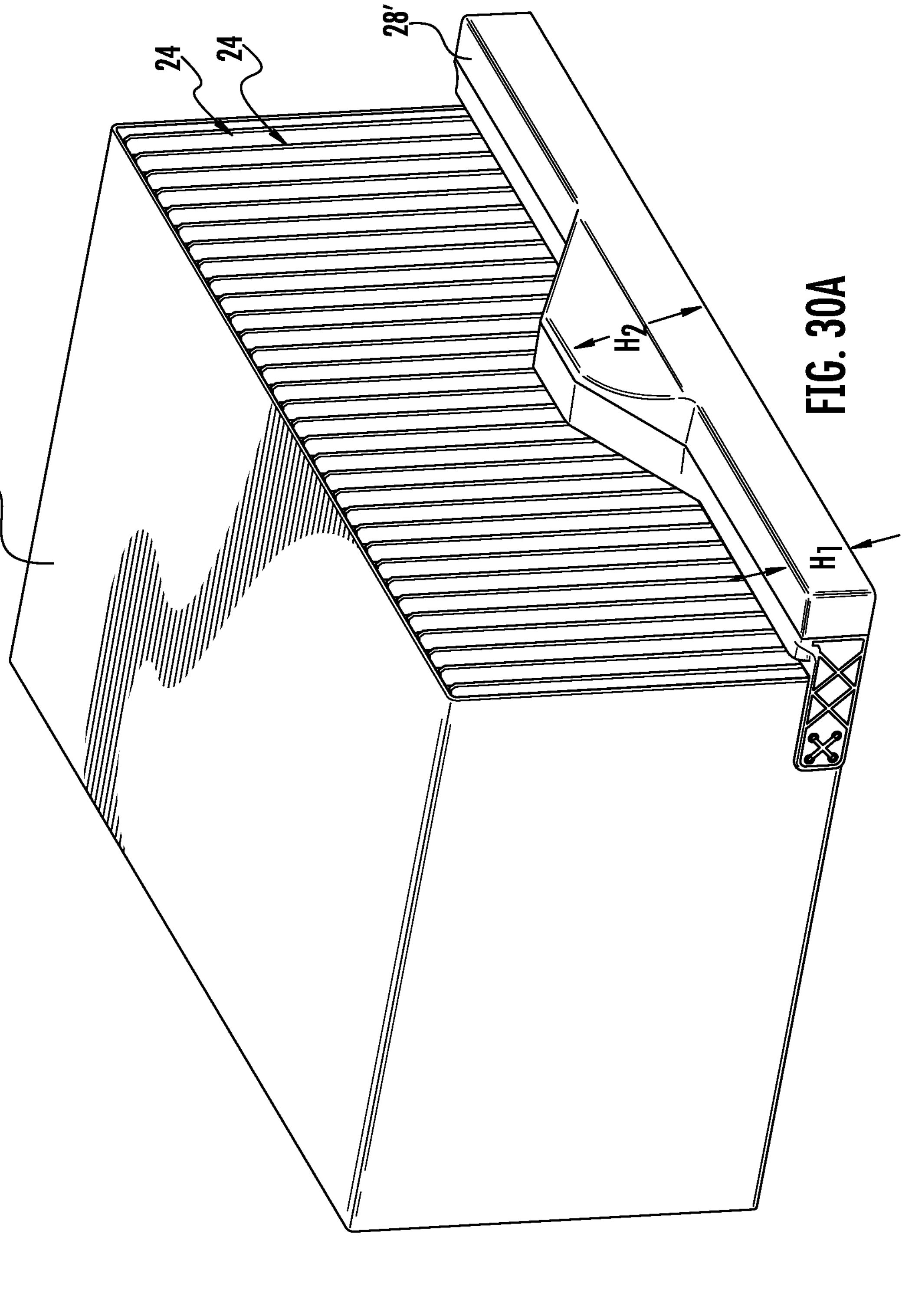


FIG. 30A

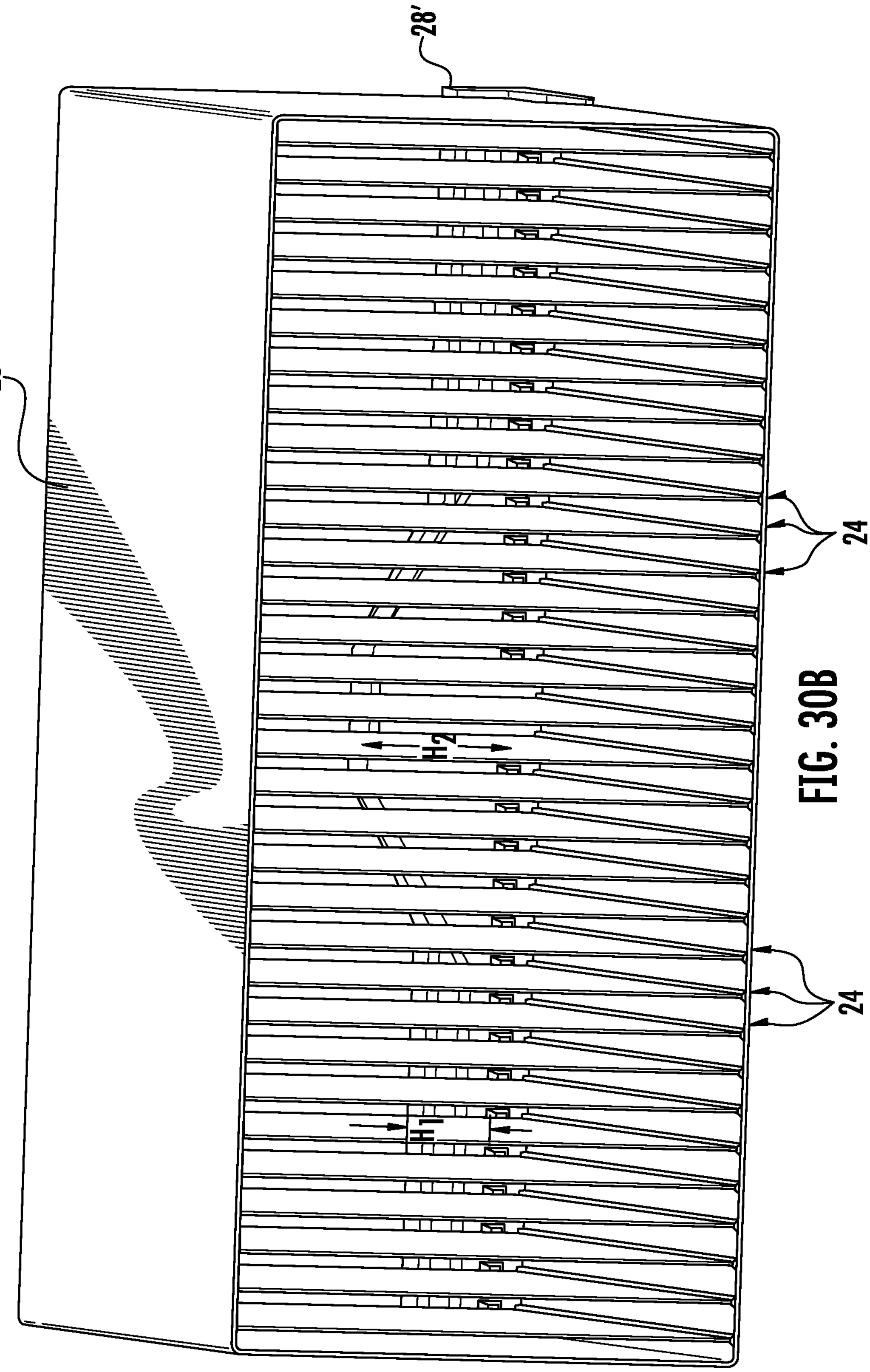


FIG. 30B

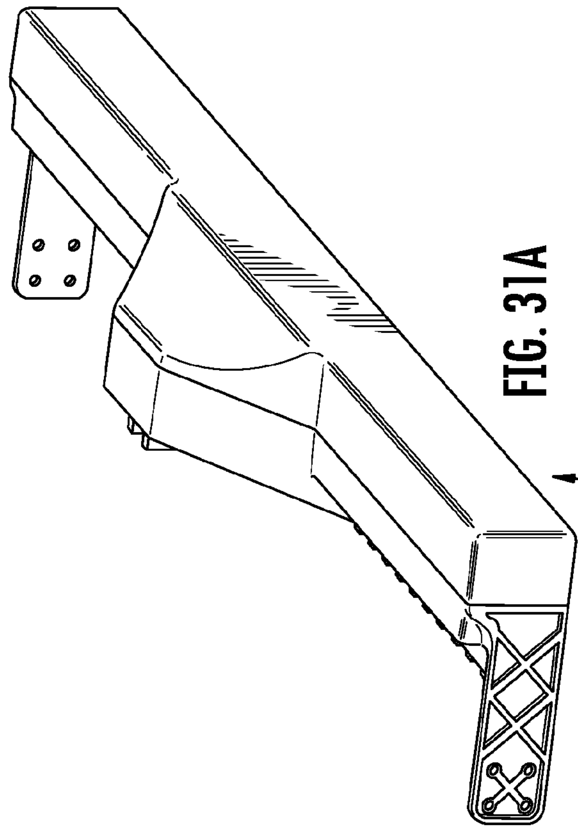


FIG. 31A

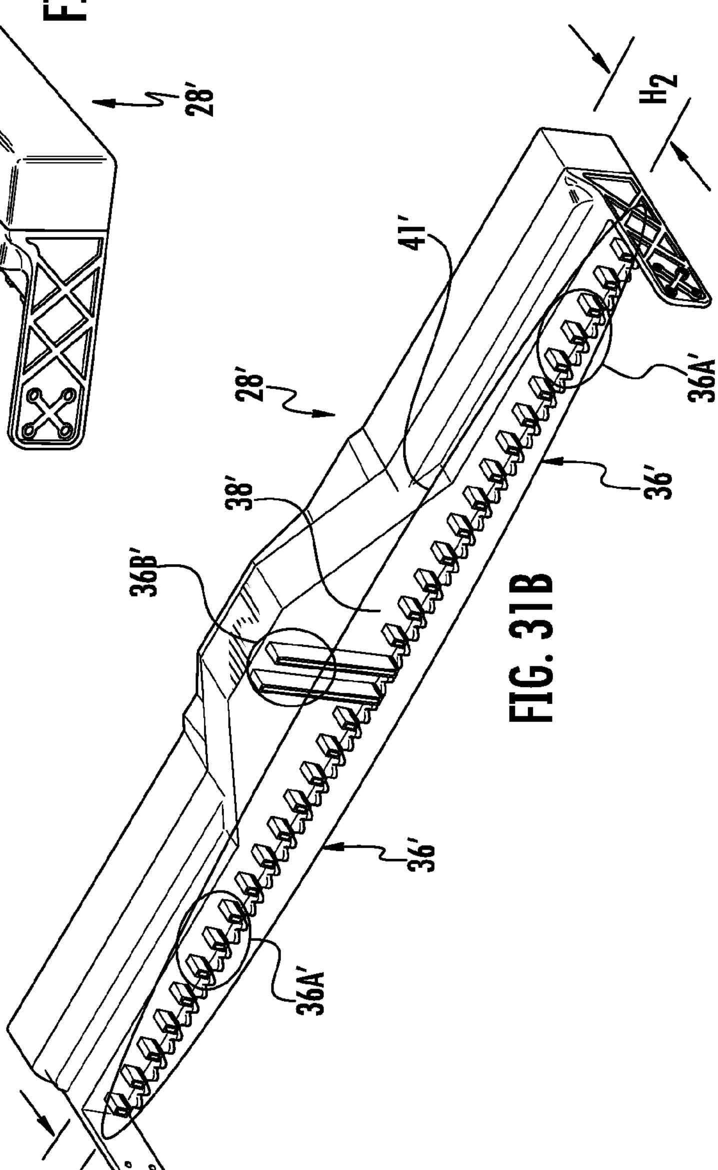


FIG. 31B

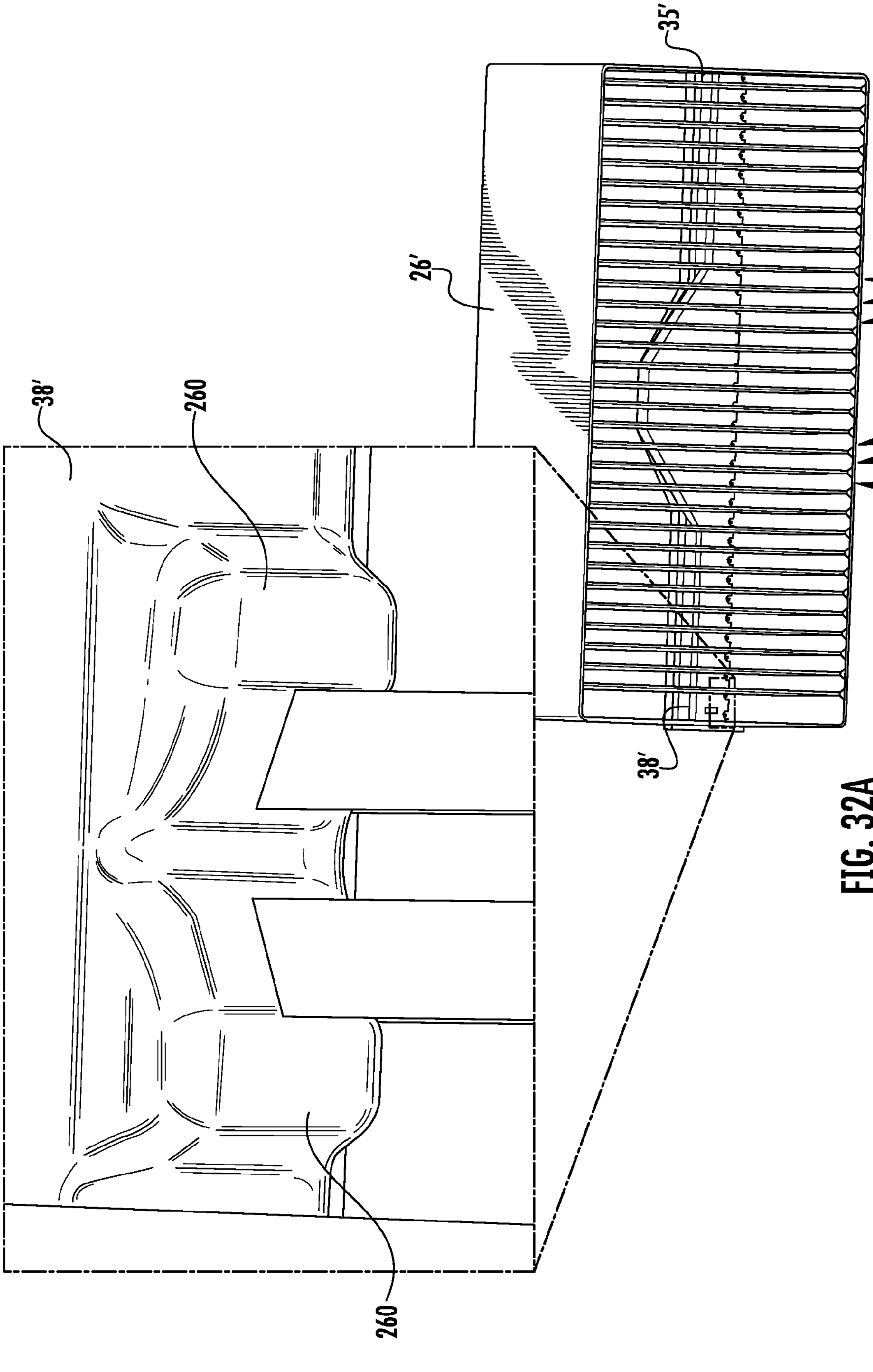


FIG. 32A

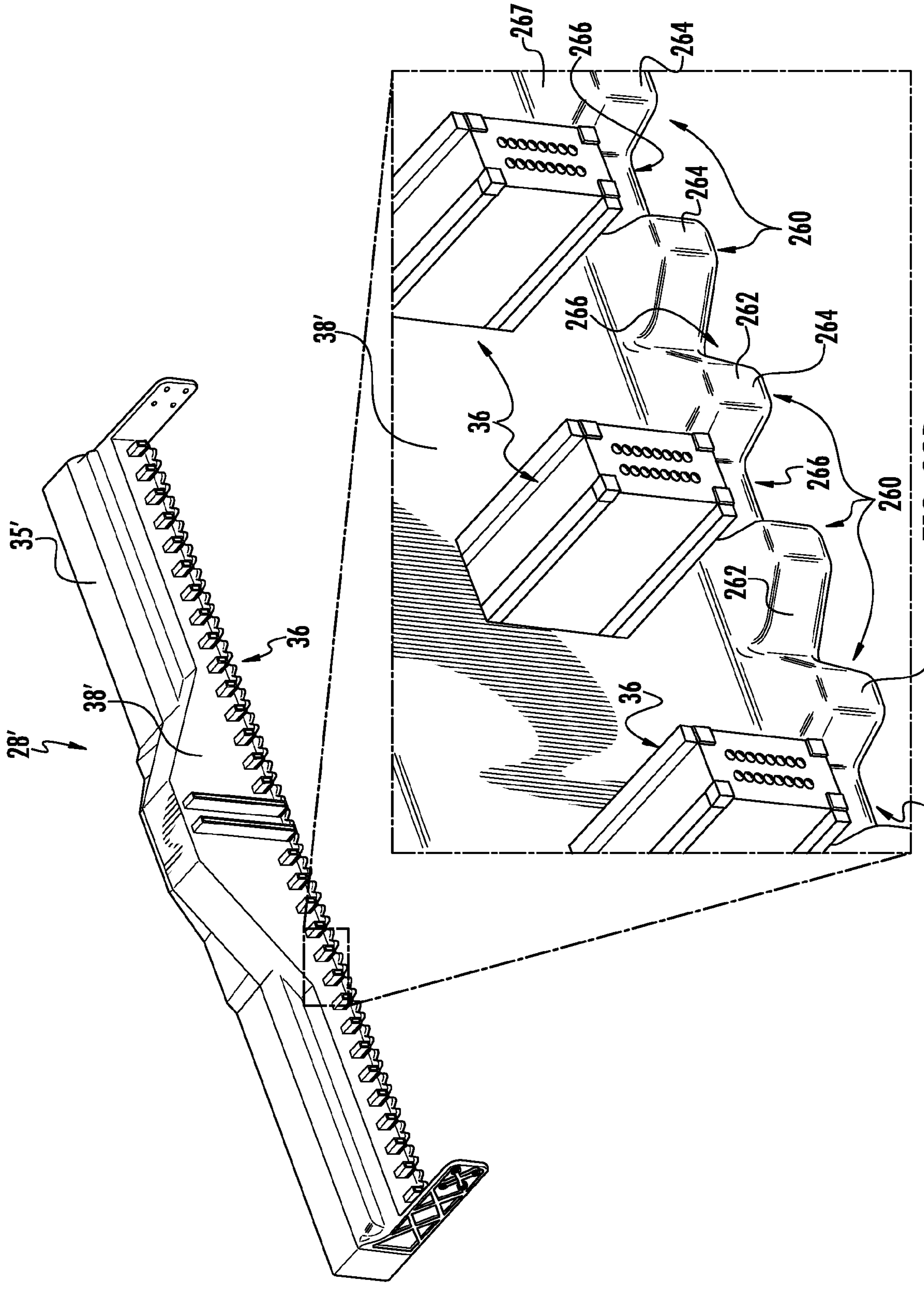


FIG. 32B

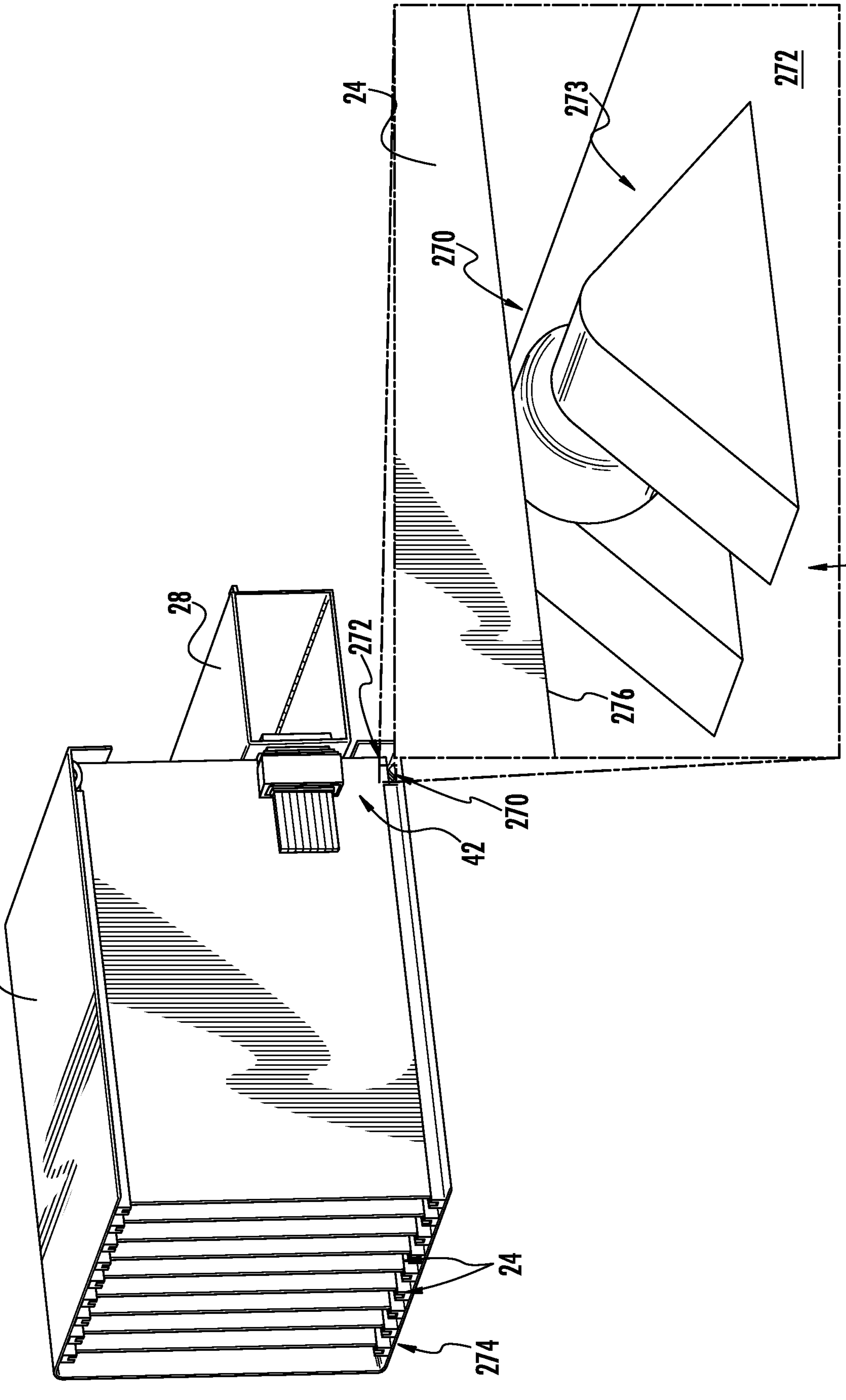


FIG. 33

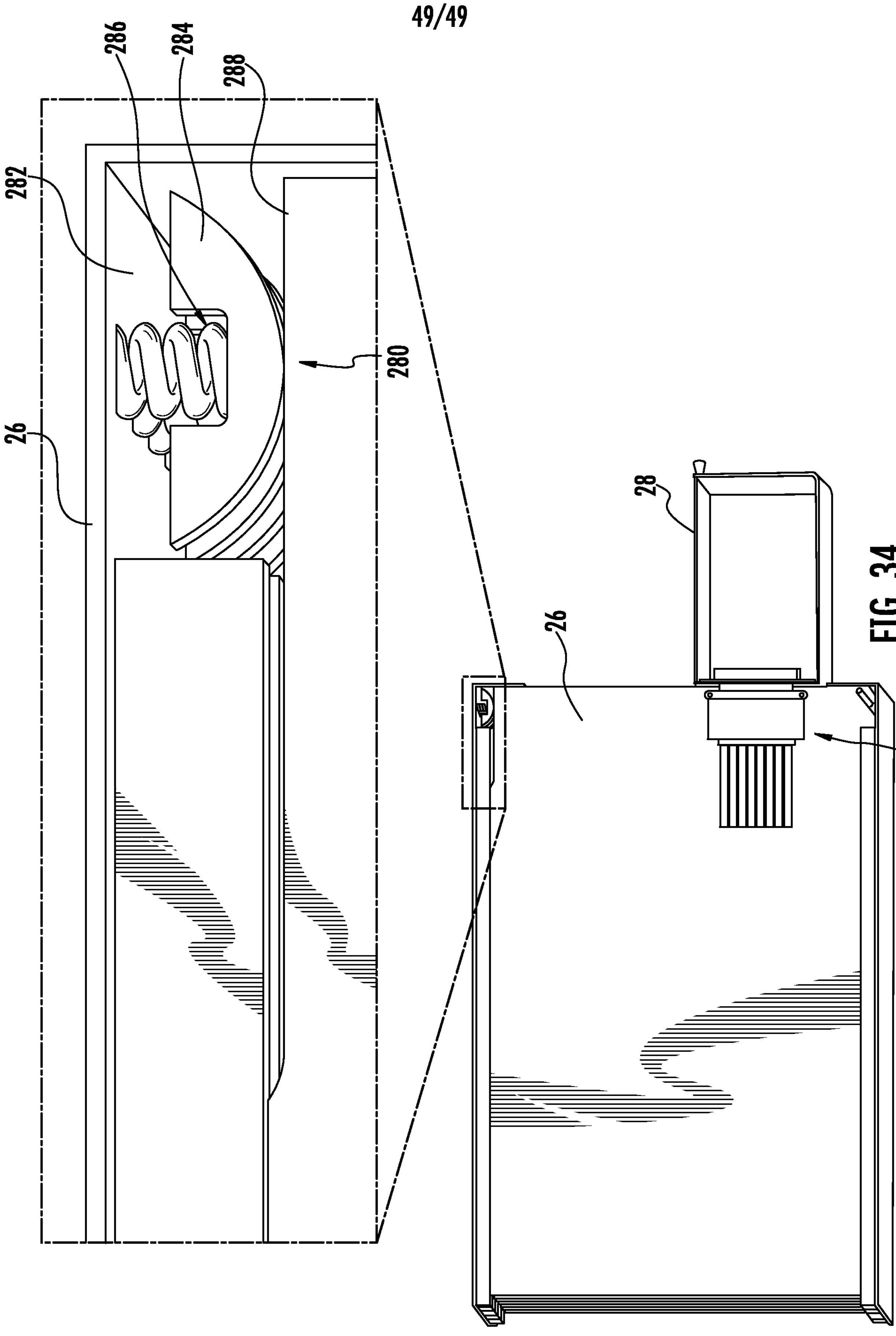


FIG. 34