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(54) **HEAT EXCHANGER WITH INTERNAL SLOTTED MANIFOLD**

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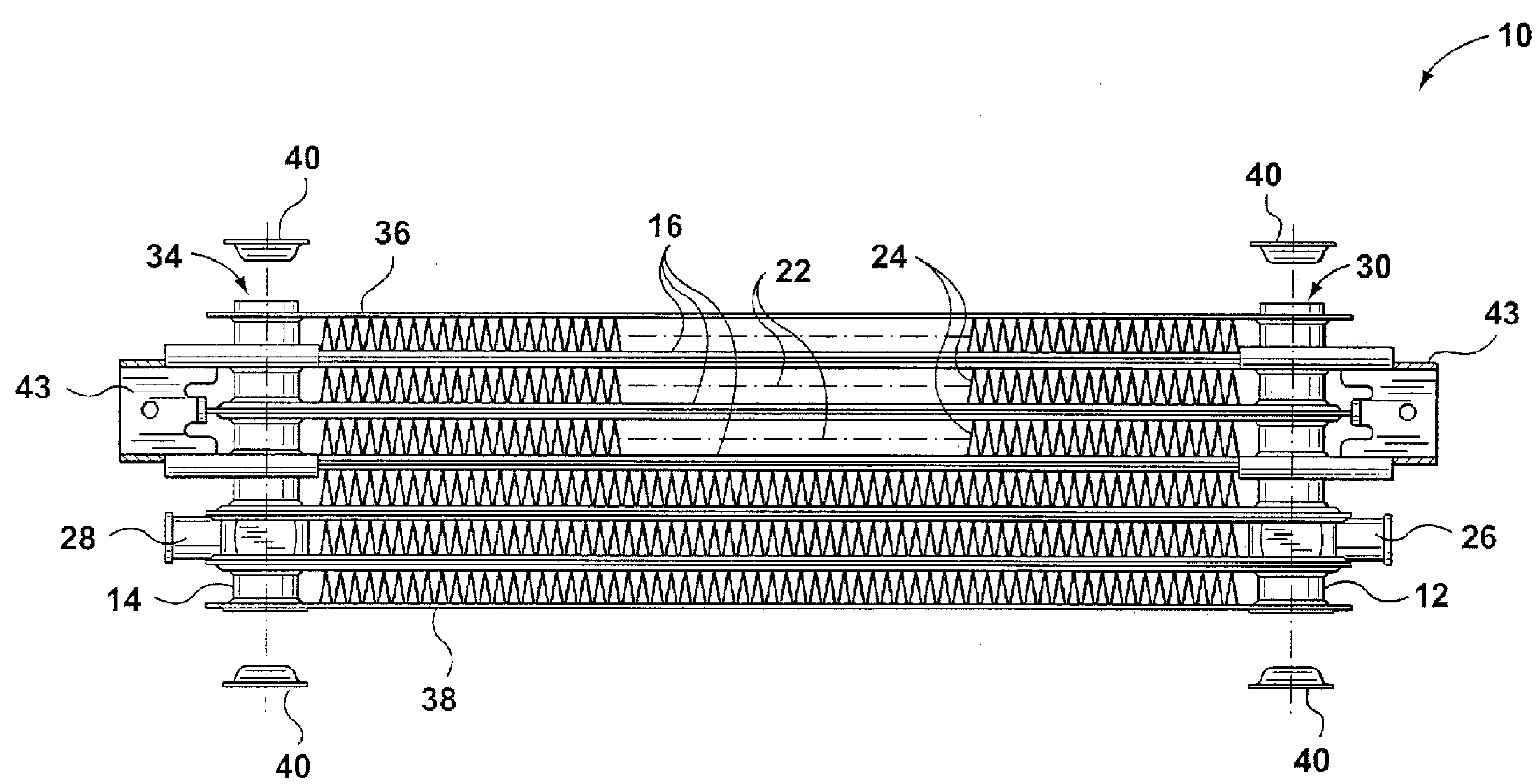
(57) **ABSTRACT**

A heat exchanger that includes a manifold tube having a plurality of spaced apart openings formed through its wall in flow communication with a flow passageway, and a plurality of stacked flat tube elements each including a first plate and a second plate defining a flow channel therebetween, the plates each being provided with an aperture therethrough, the apertures in the first and second plates being substantially in alignment with each other. The manifold tube is received through the apertures in the first and second plates of each of the flat tube elements with each of the spaced apart openings in flow communication with the flow channel of a respective one of the flat tube elements. During assembly, the wall of the manifold tube is radially enlarged so that an outer surface of the manifold tube engages an inner surface surrounding the aperture in each of the first and second plates to secure the flat tube elements to the manifold tube. Also provided is a stacked plate heat exchanger having a manifold tube with an error proofing hole for ensuring a baffle cup is in place in the manifold tube, and a stacked plate heat exchanger having a manifold tube and a port fixture having an annular flow way in communication with a flow passage in the manifold tube through a plurality of radially spaced openings through the manifold tube.



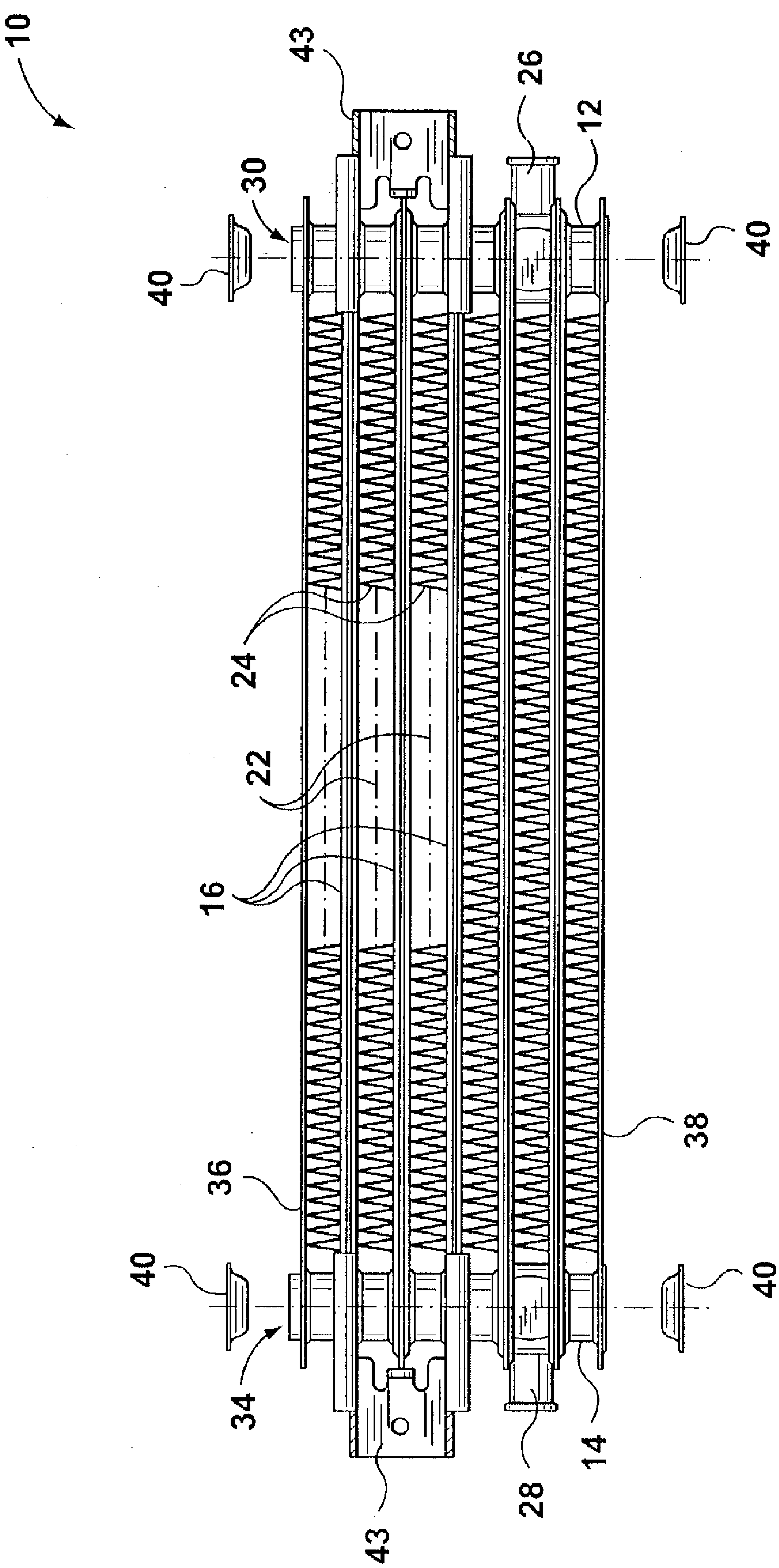


FIG. 1

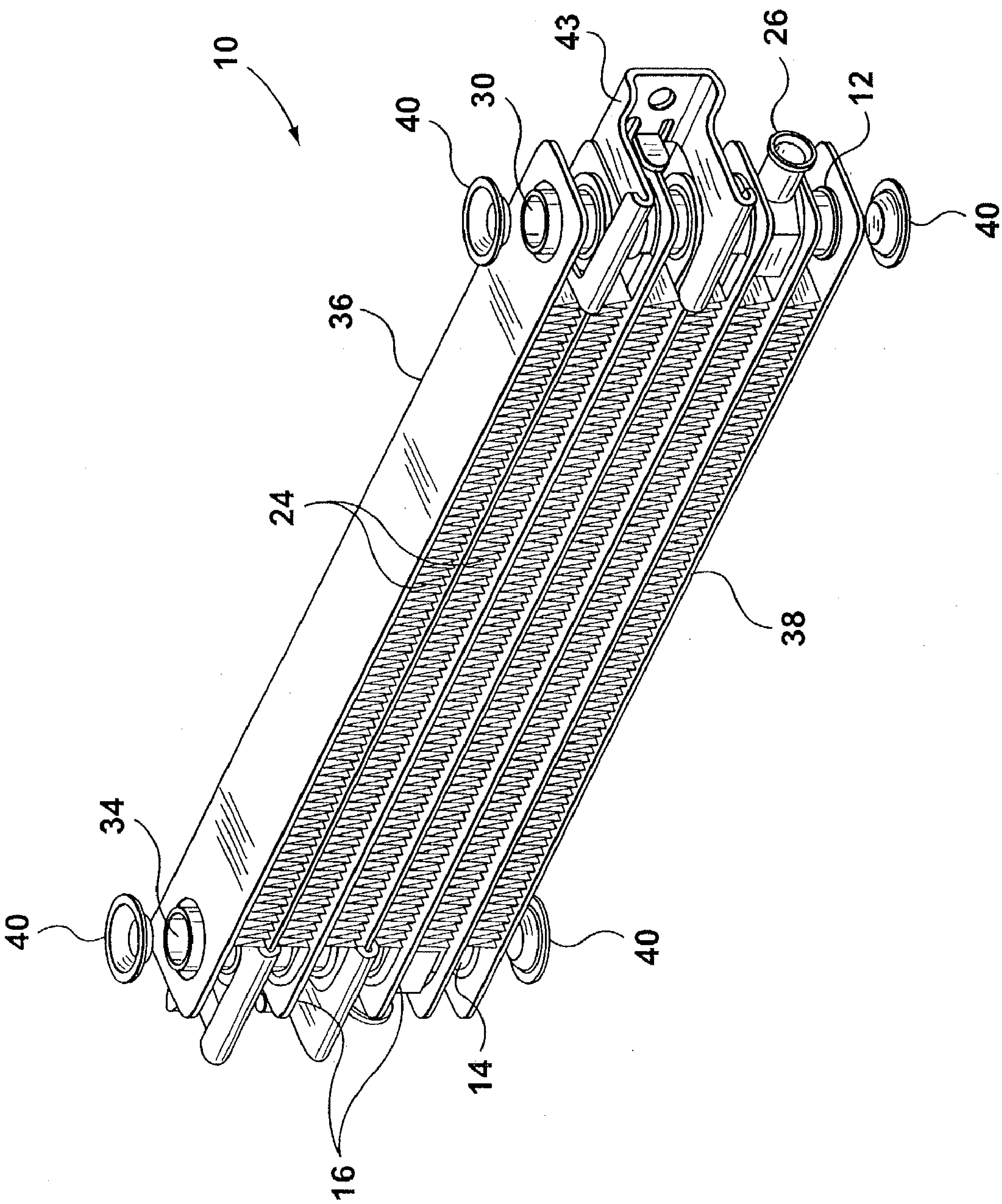
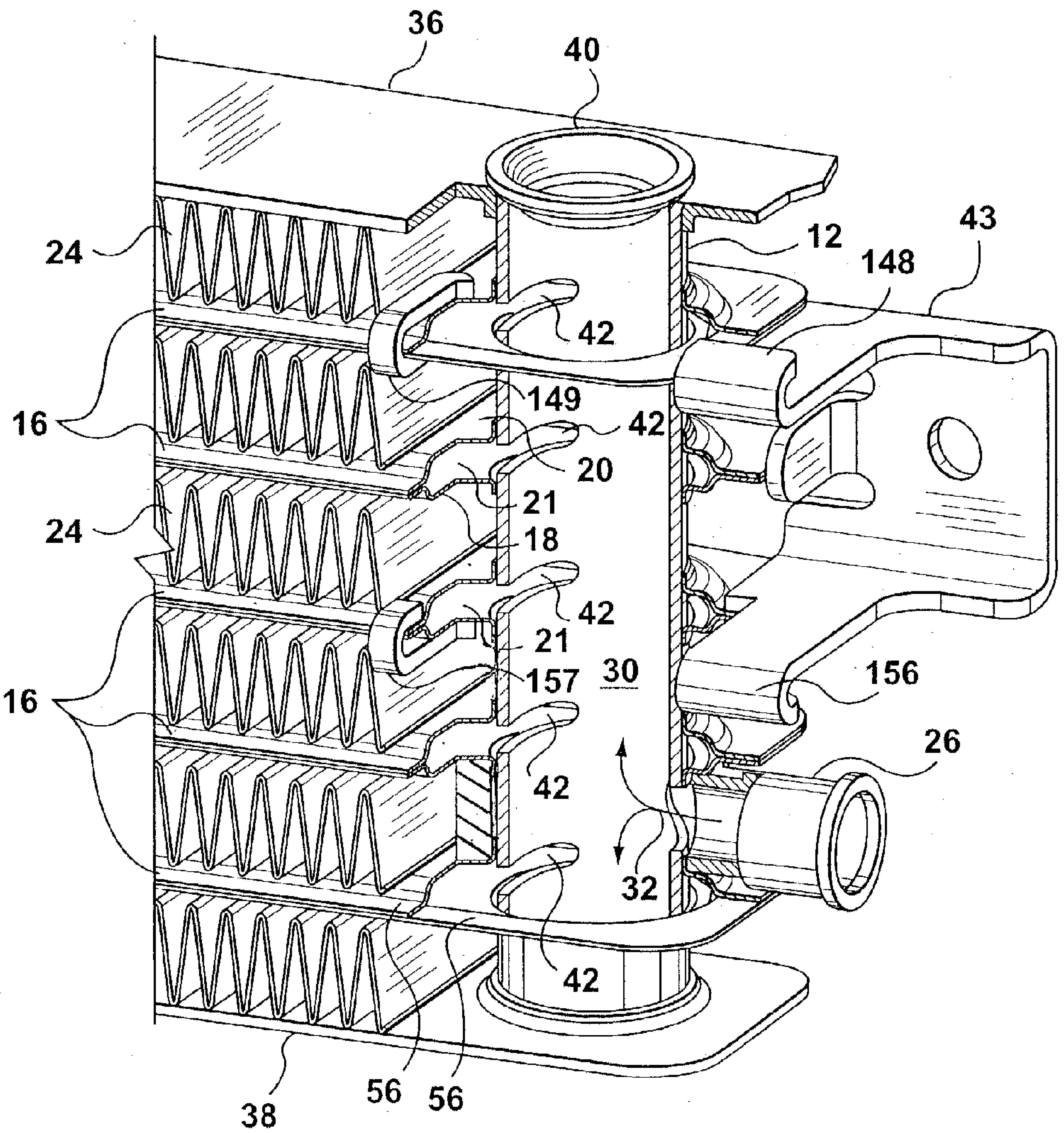


FIG. 2


36
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12
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148
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149
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FIG. 3

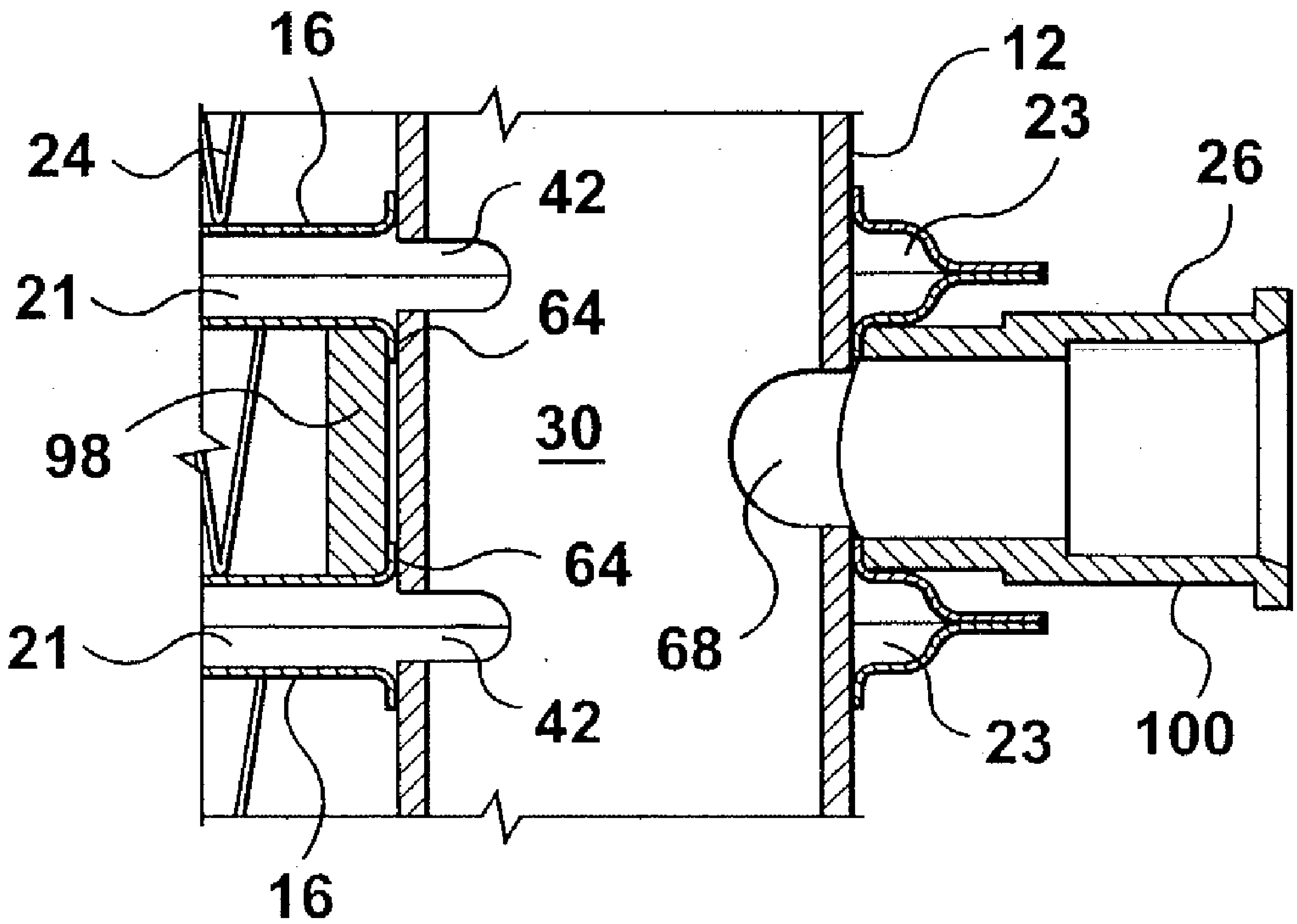
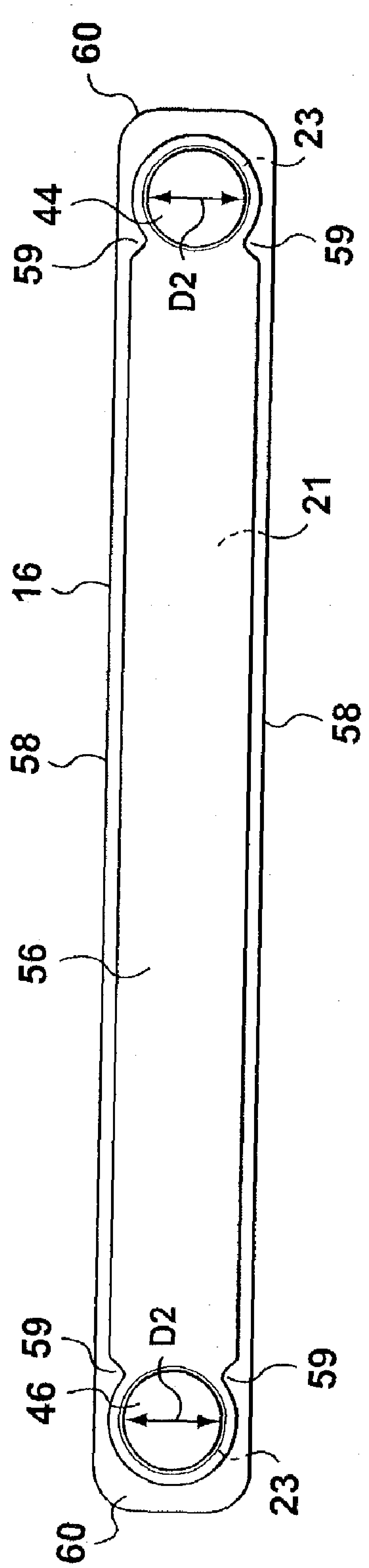


FIG. 3A


60
23
44
59
59
D2
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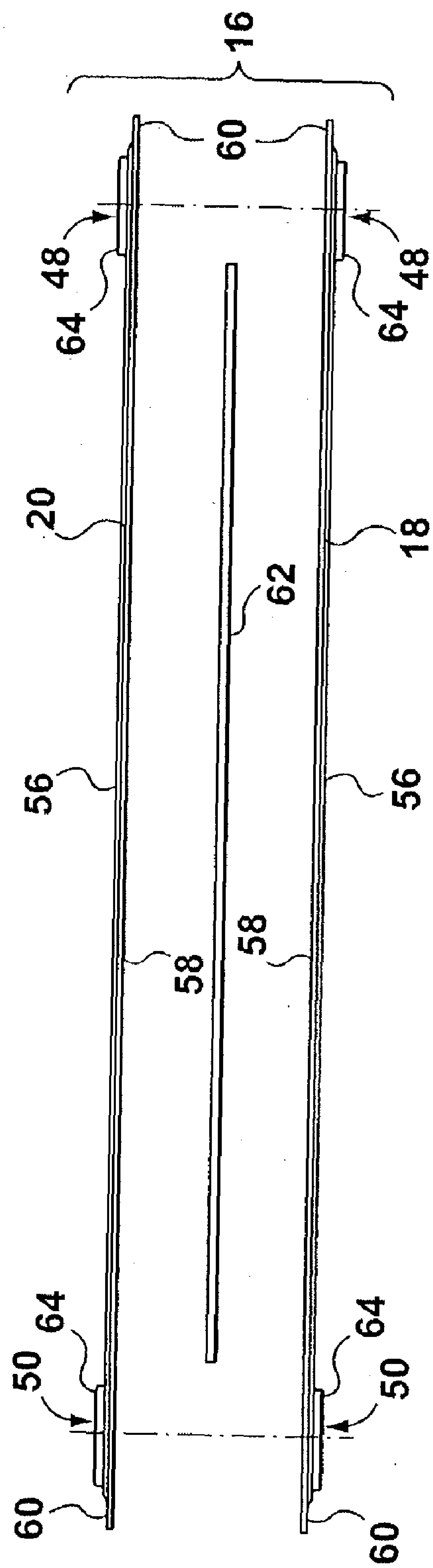
16
58
58
56
59
D2
59
46
23
60

FIG. 4


16
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48
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62
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64
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60
60

FIG. 5

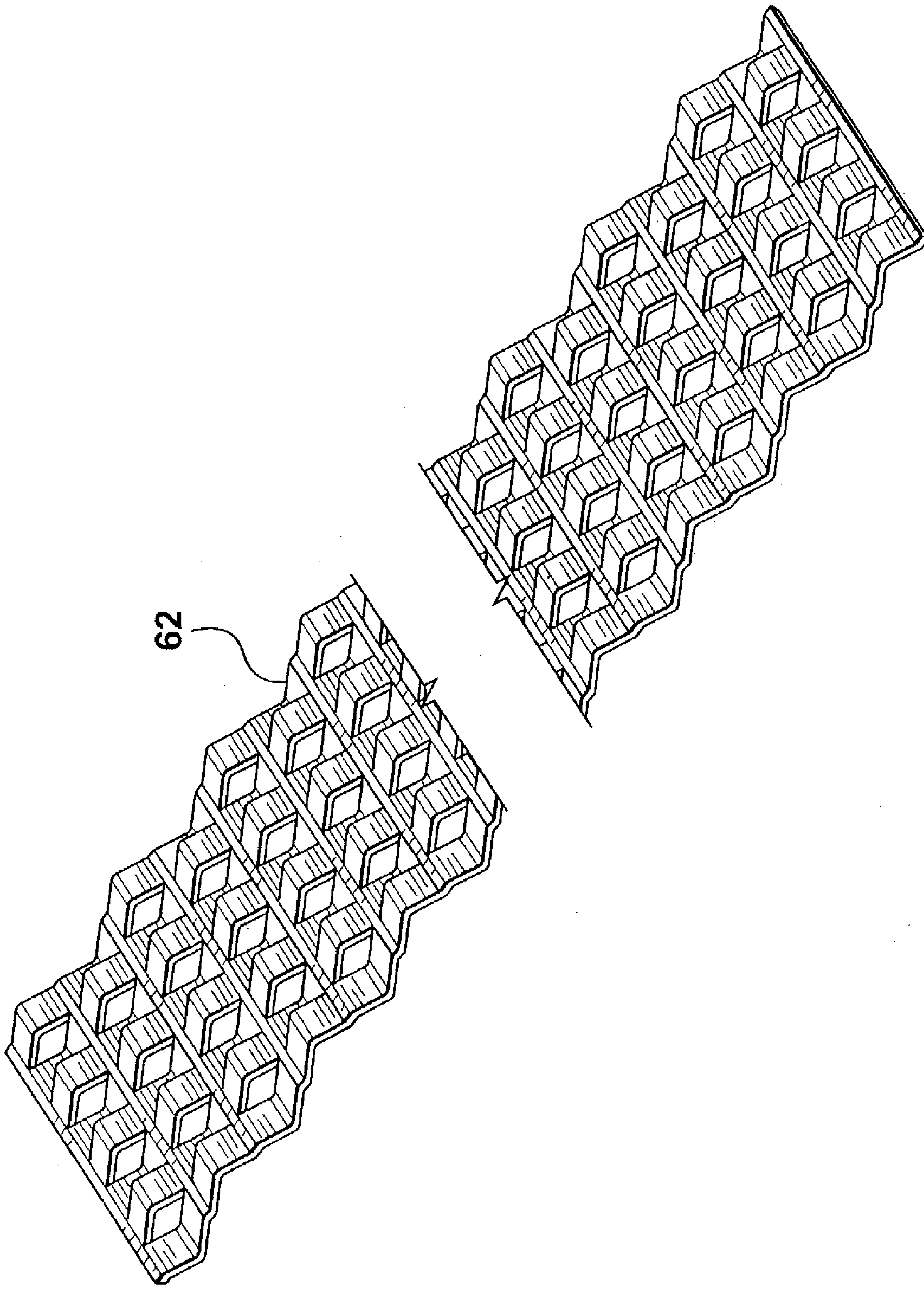

FIG. 6

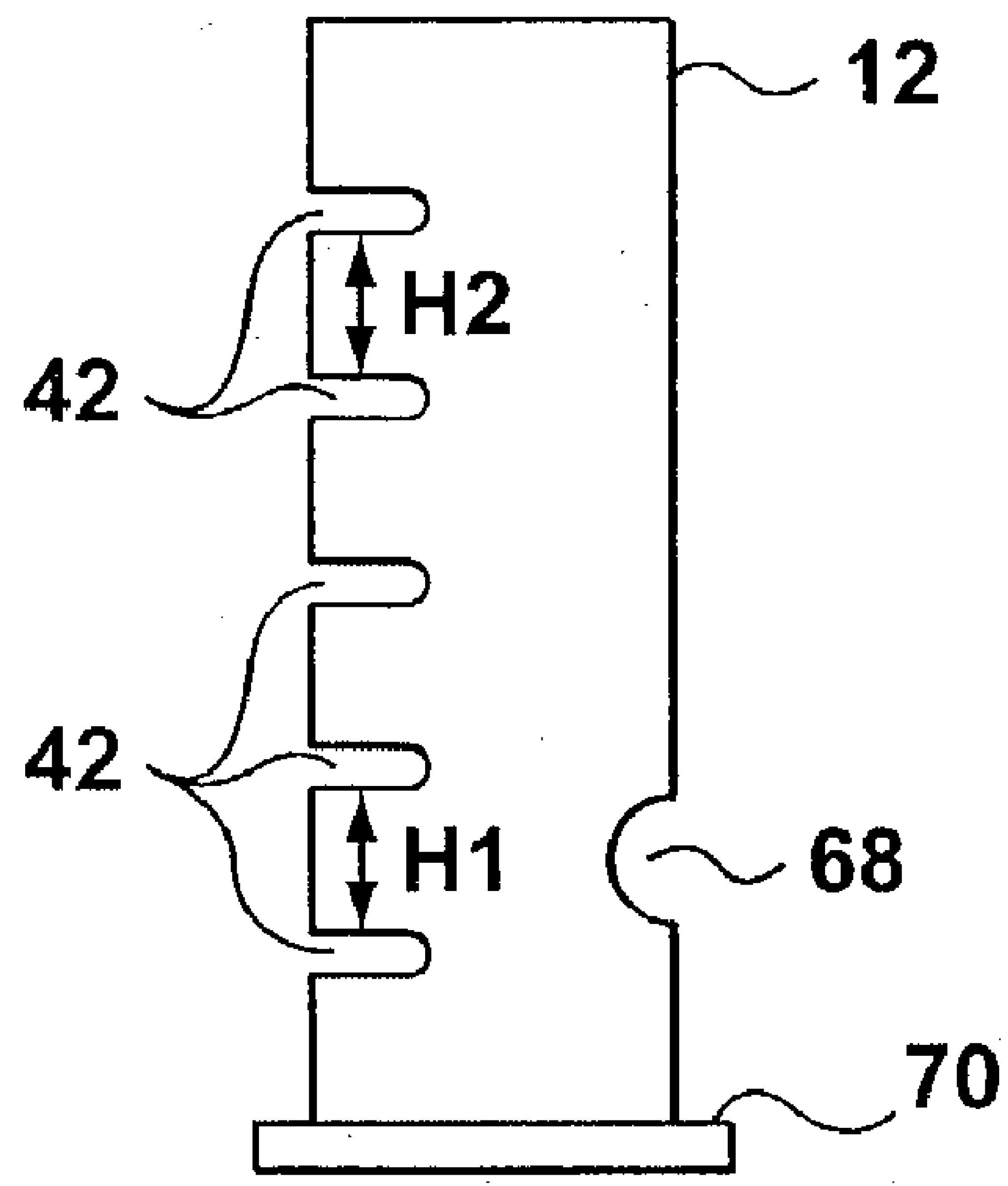

FIG. 7

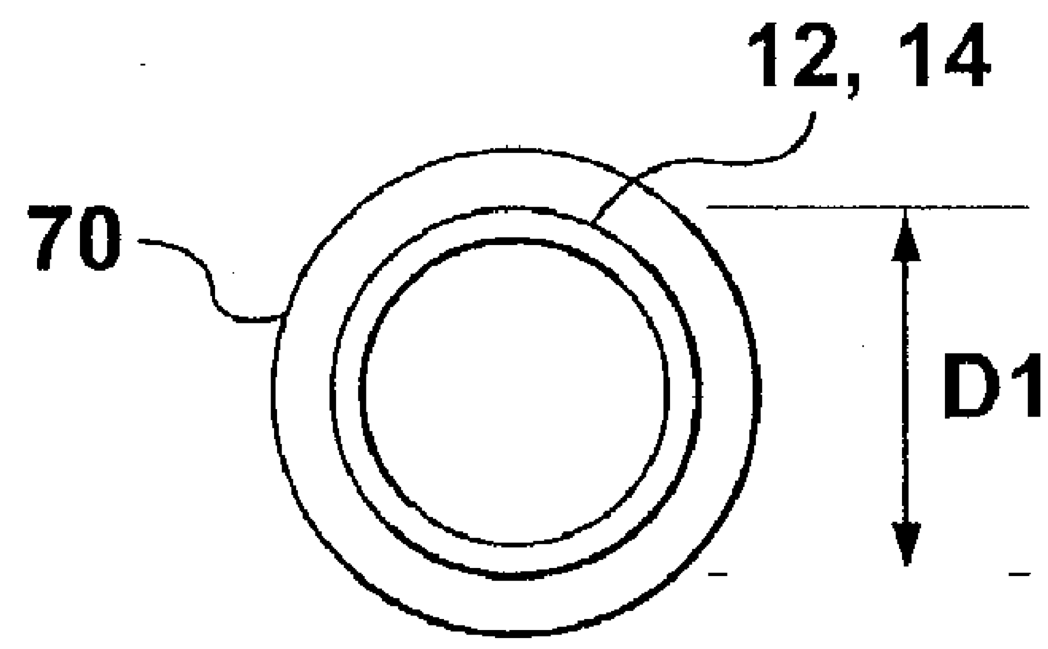

FIG. 8

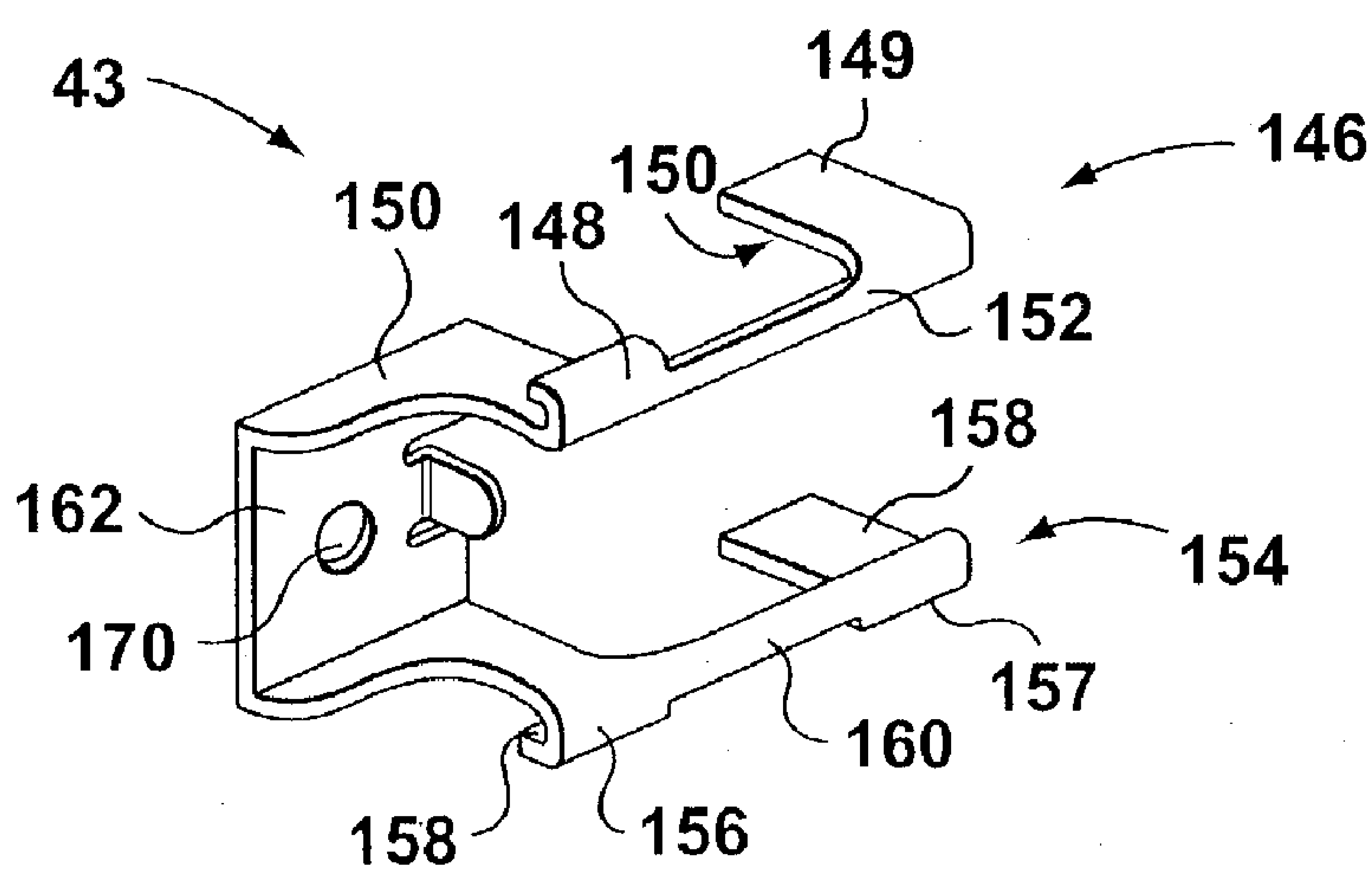

FIG. 9

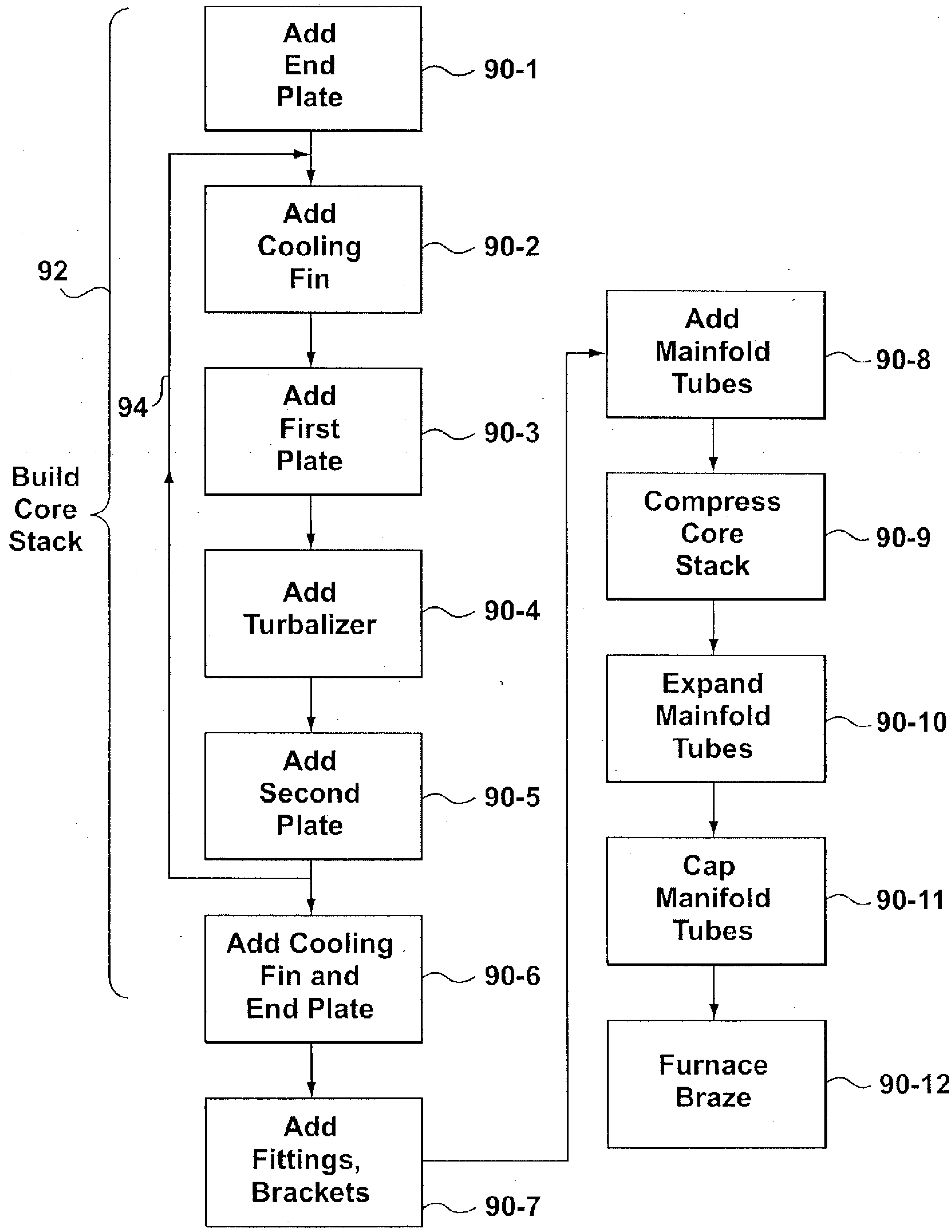
Add End Plate
90-1
Add Cooling Fin
90-2
Add First Plate
90-3
Add Turbalizer
90-4
Add Second Plate
90-5
Add Cooling Fin and End Plate
90-6
Add Fittings, Brackets
90-7
Add Mainfold Tubes
90-8
Compress Core Stack
90-9
Expand Mainfold Tubes
90-10
Cap Manifold Tubes
90-11
Furnace Braze
90-12
92
94
Build Core Stack

FIG. 10

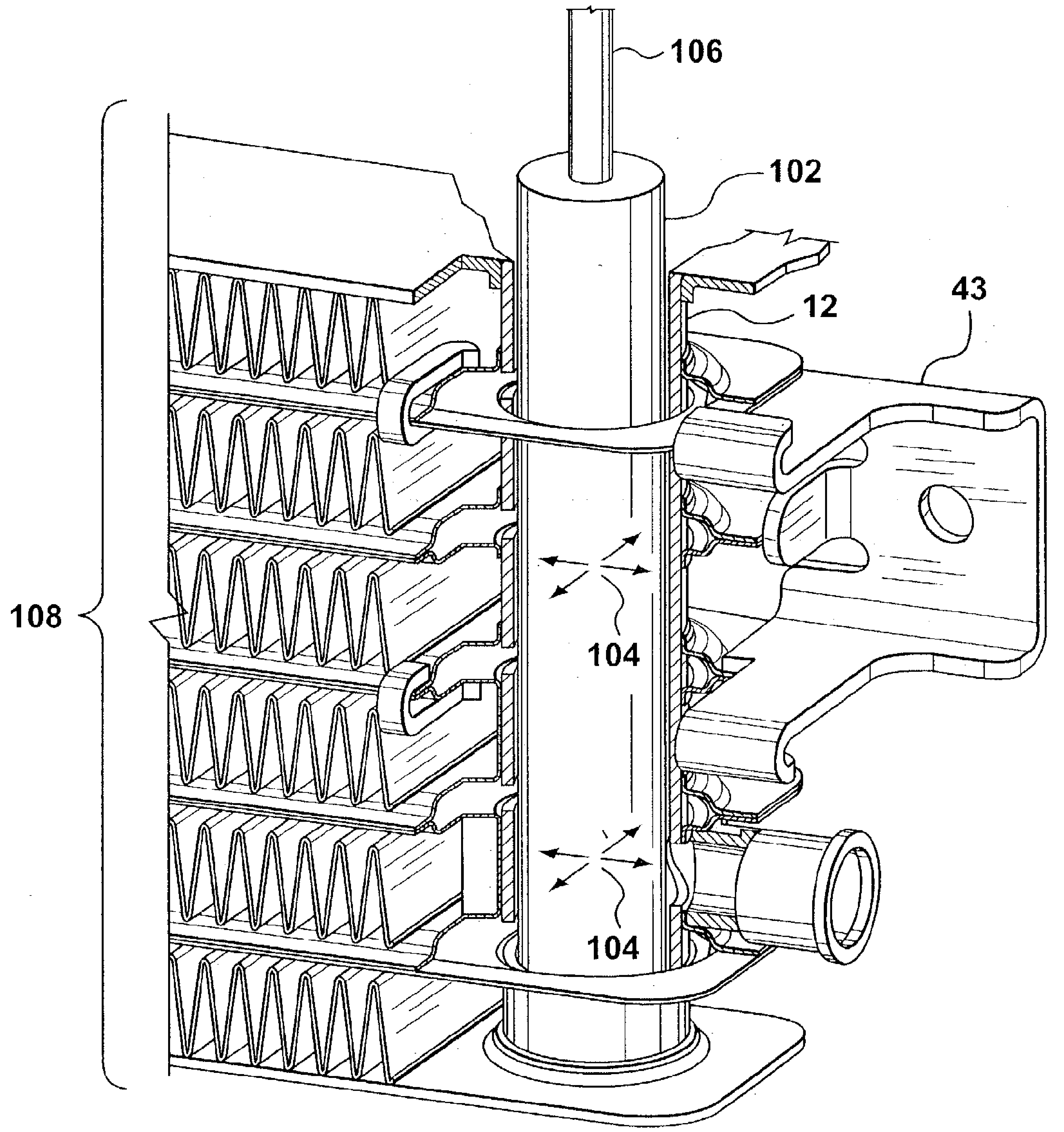

FIG. 11

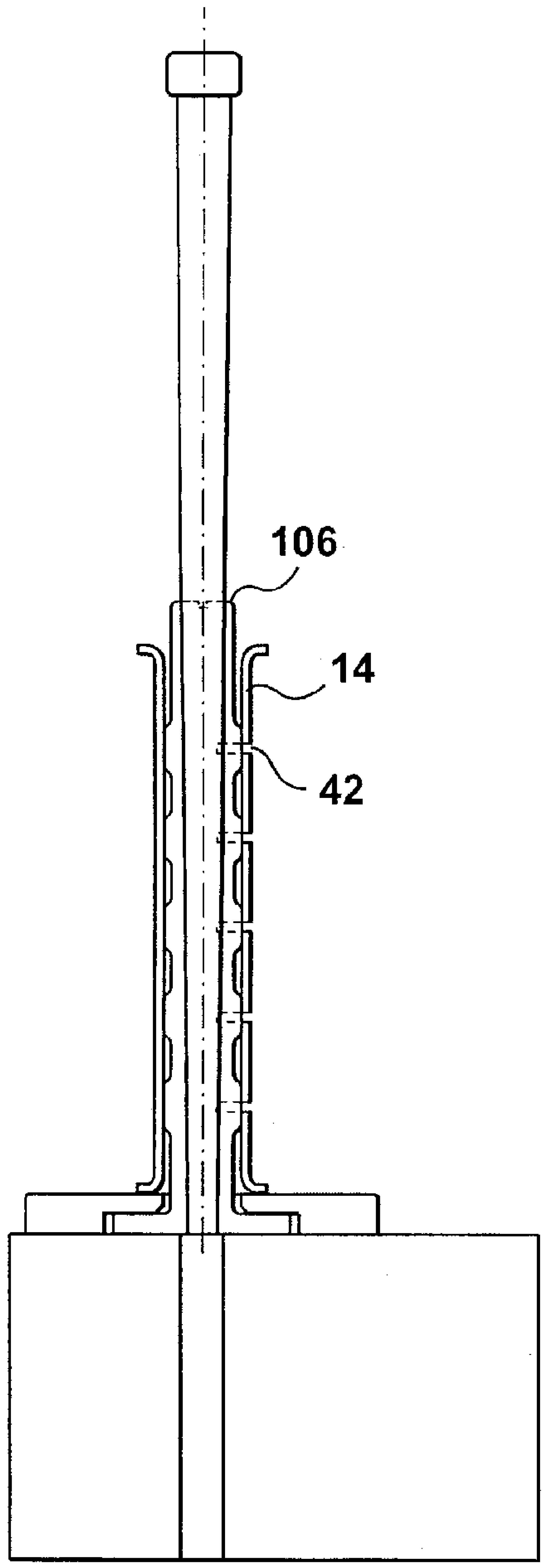

FIG. 12A

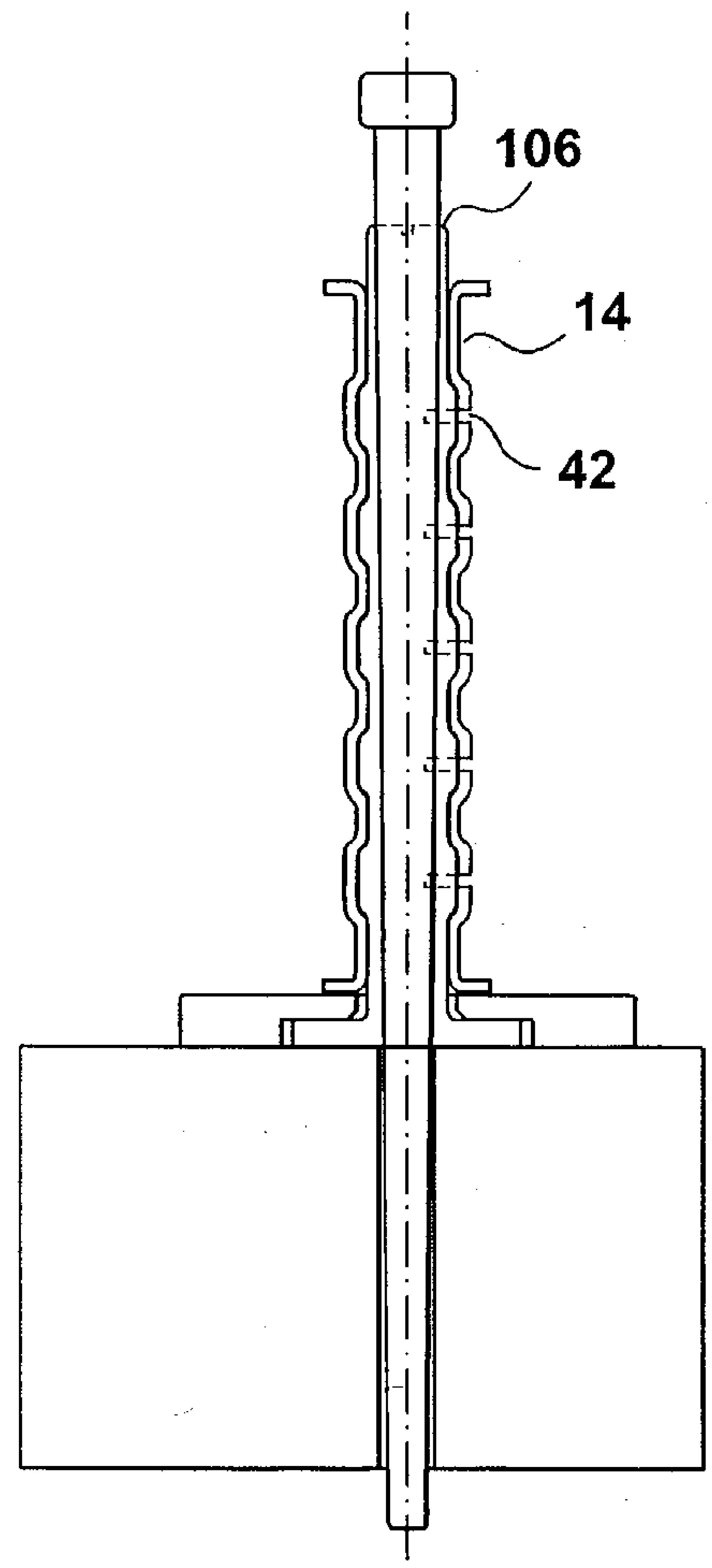

FIG. 12B

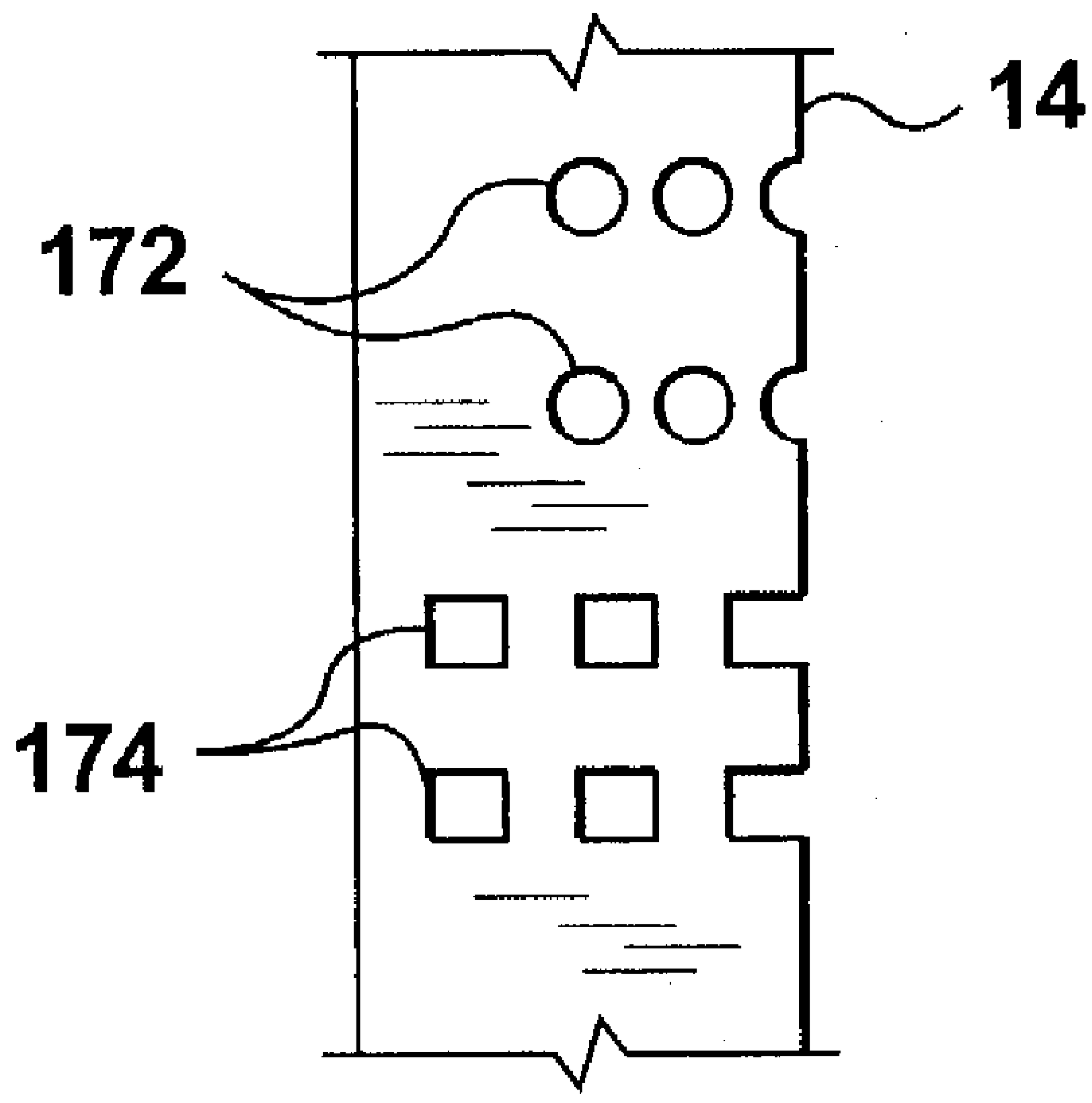

FIG. 13

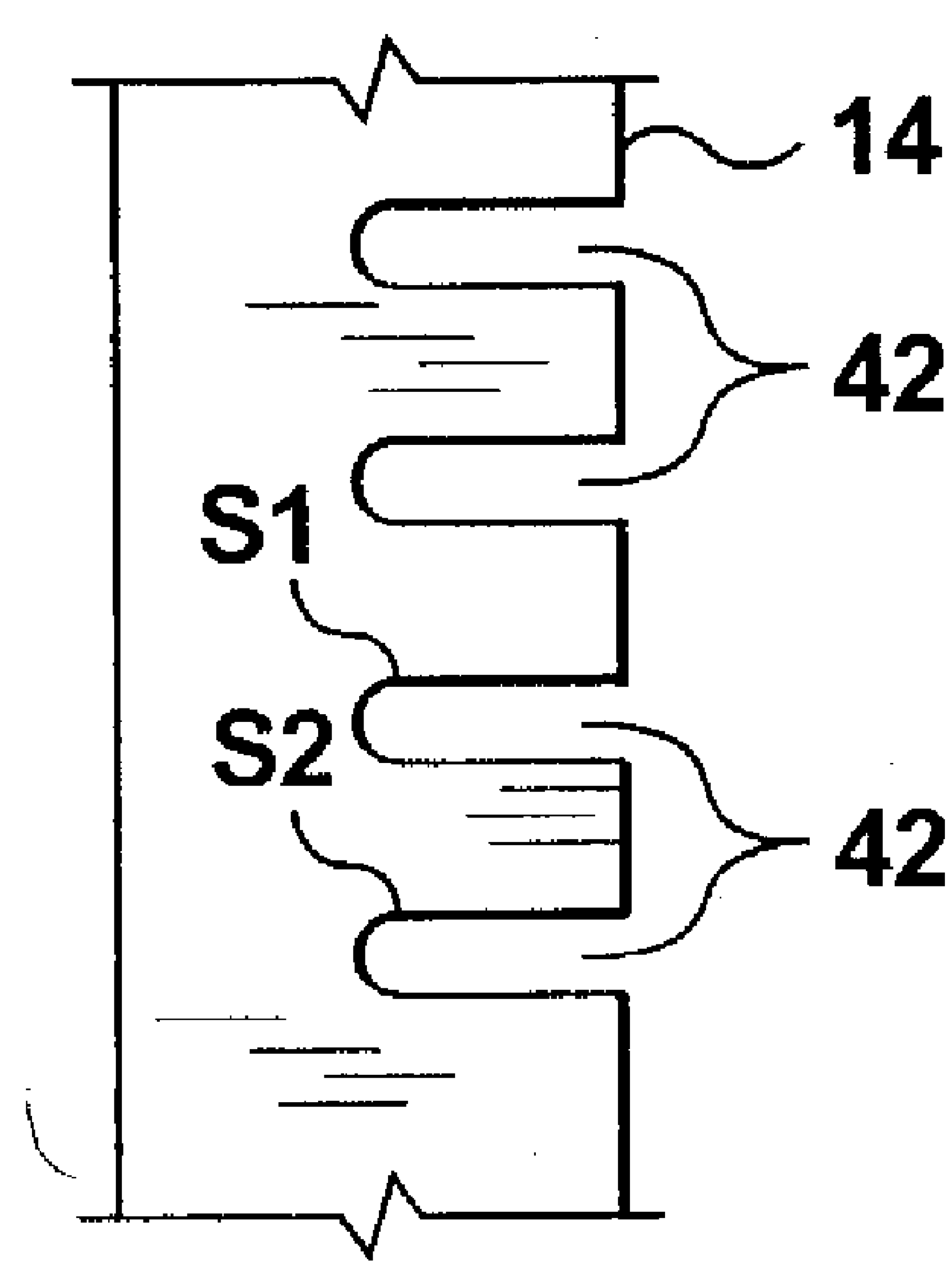

FIG. 14

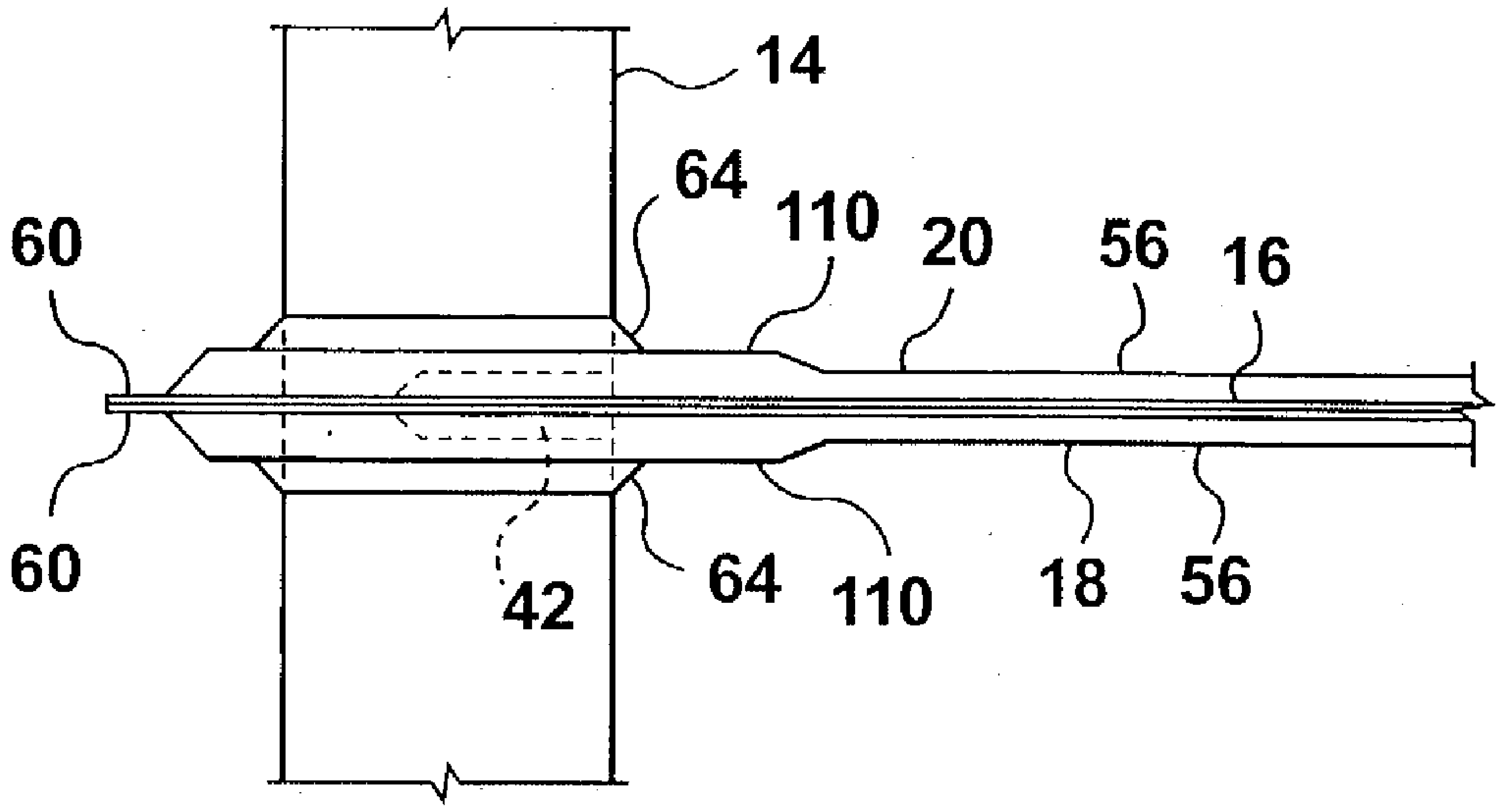

FIG. 15

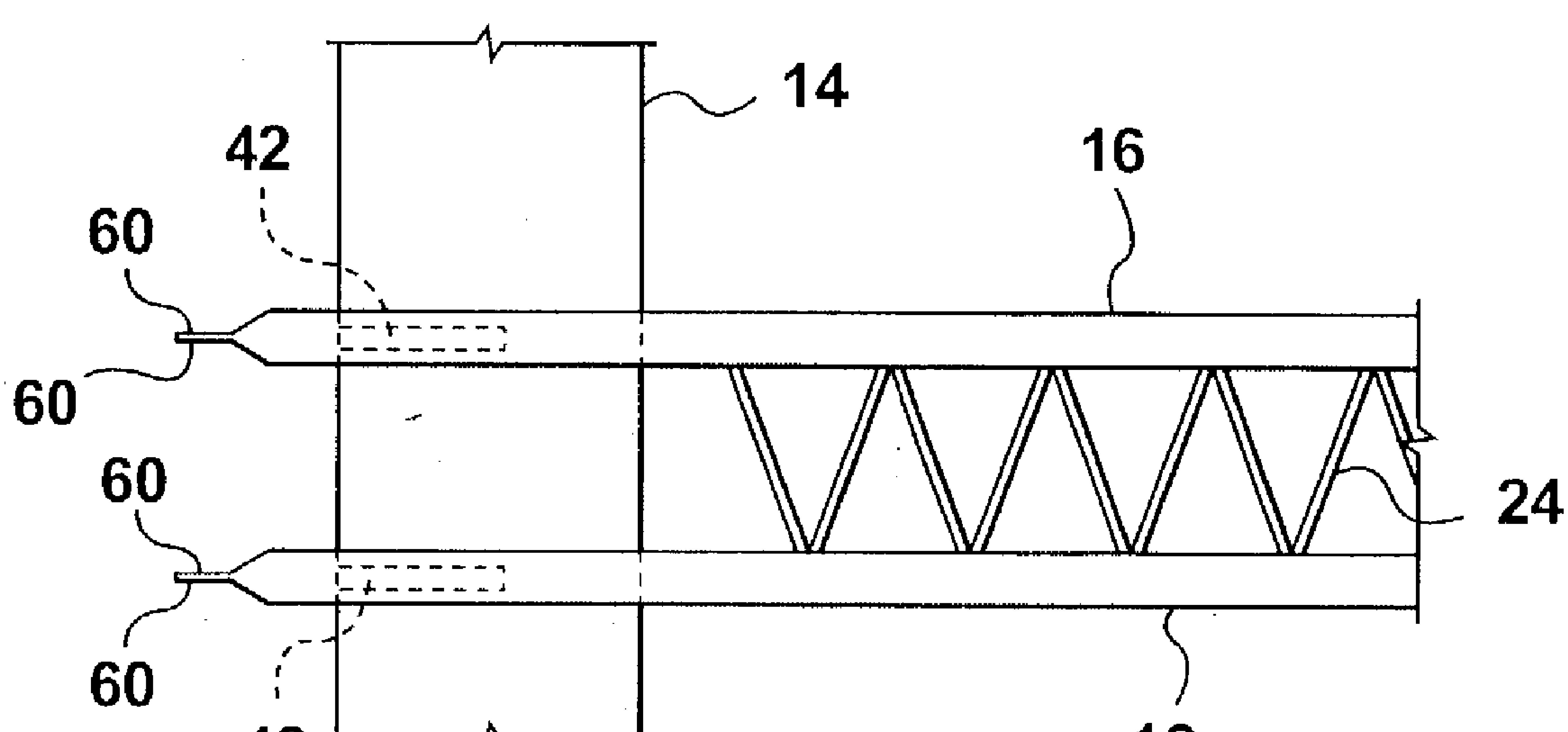

FIG. 16

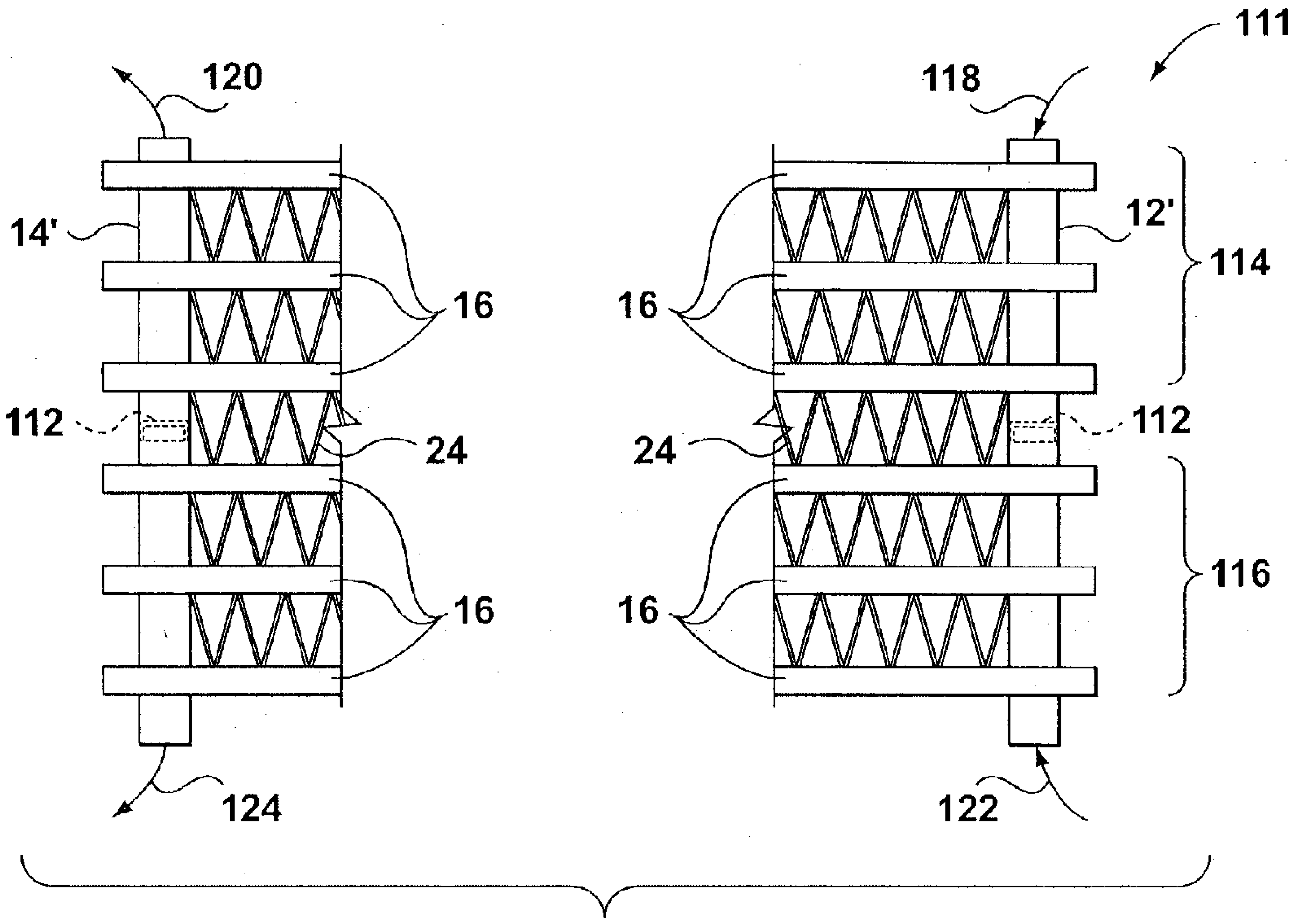

FIG. 17

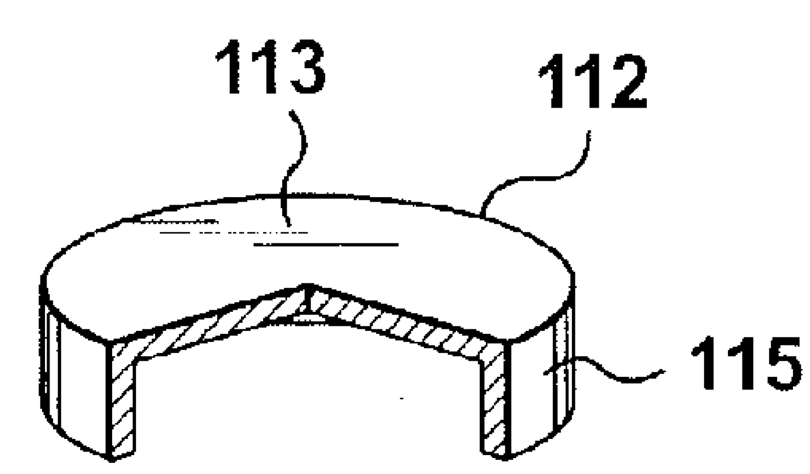

FIG. 18

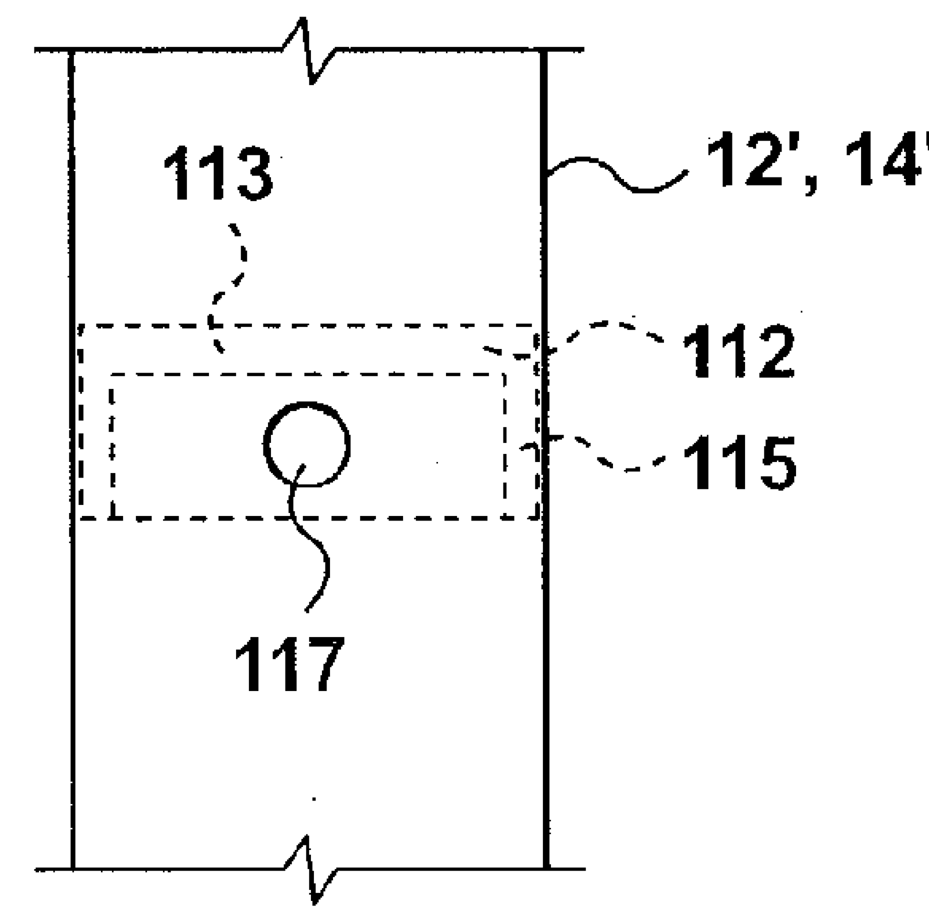

FIG. 19

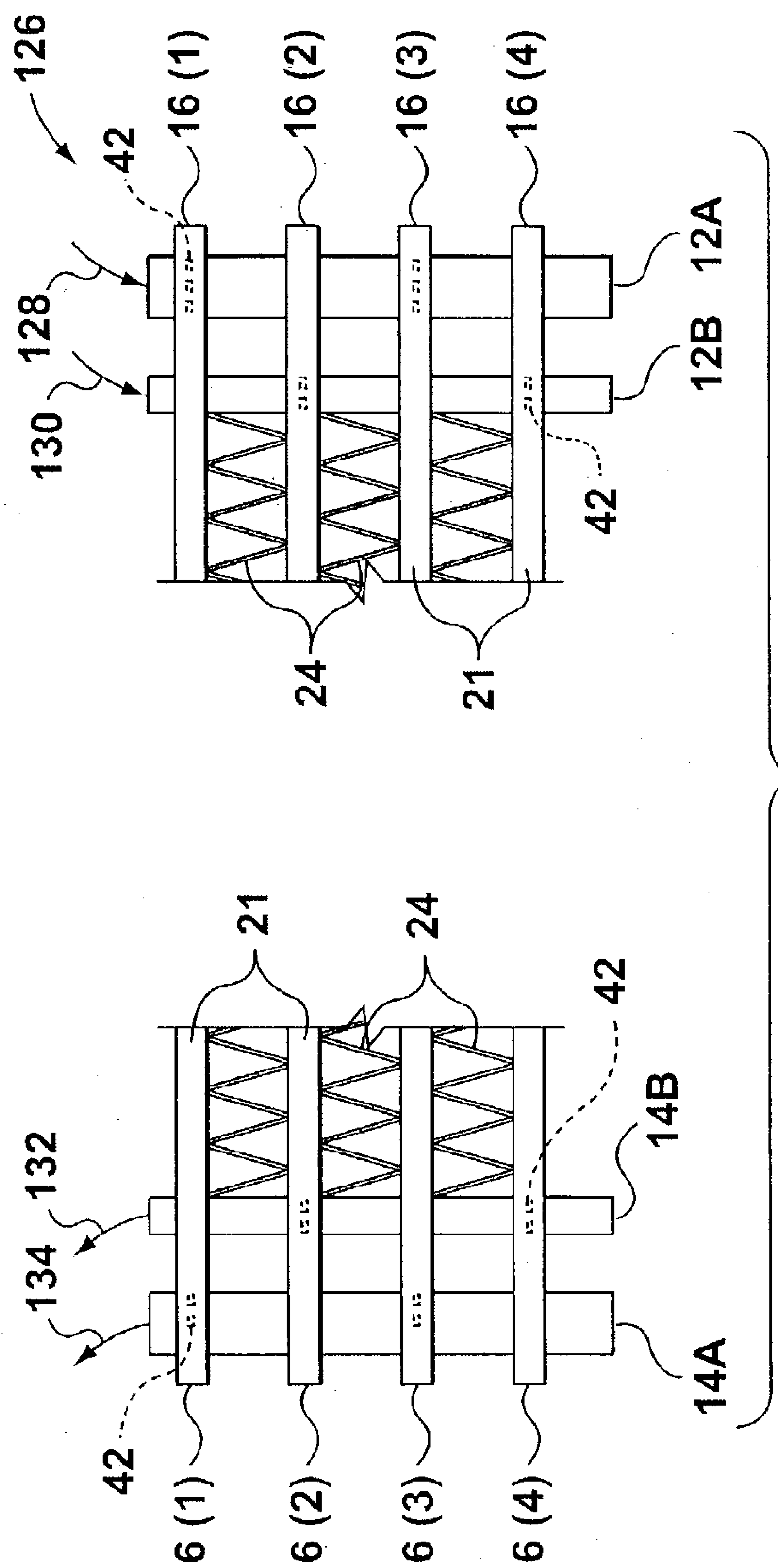
126
128
130
132
134
42
16 (1)
16 (2)
16 (3)
16 (4)
12A
12B
14A
14B
24
21

FIG. 20

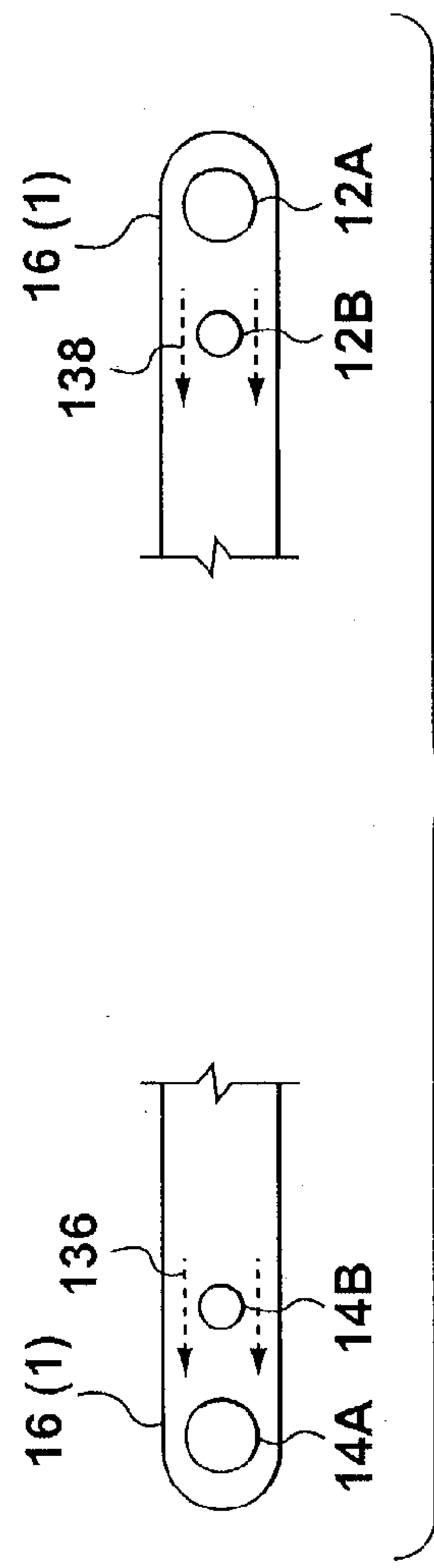
16 (1)
12A
12B
138
136
14A
14B

FIG. 21

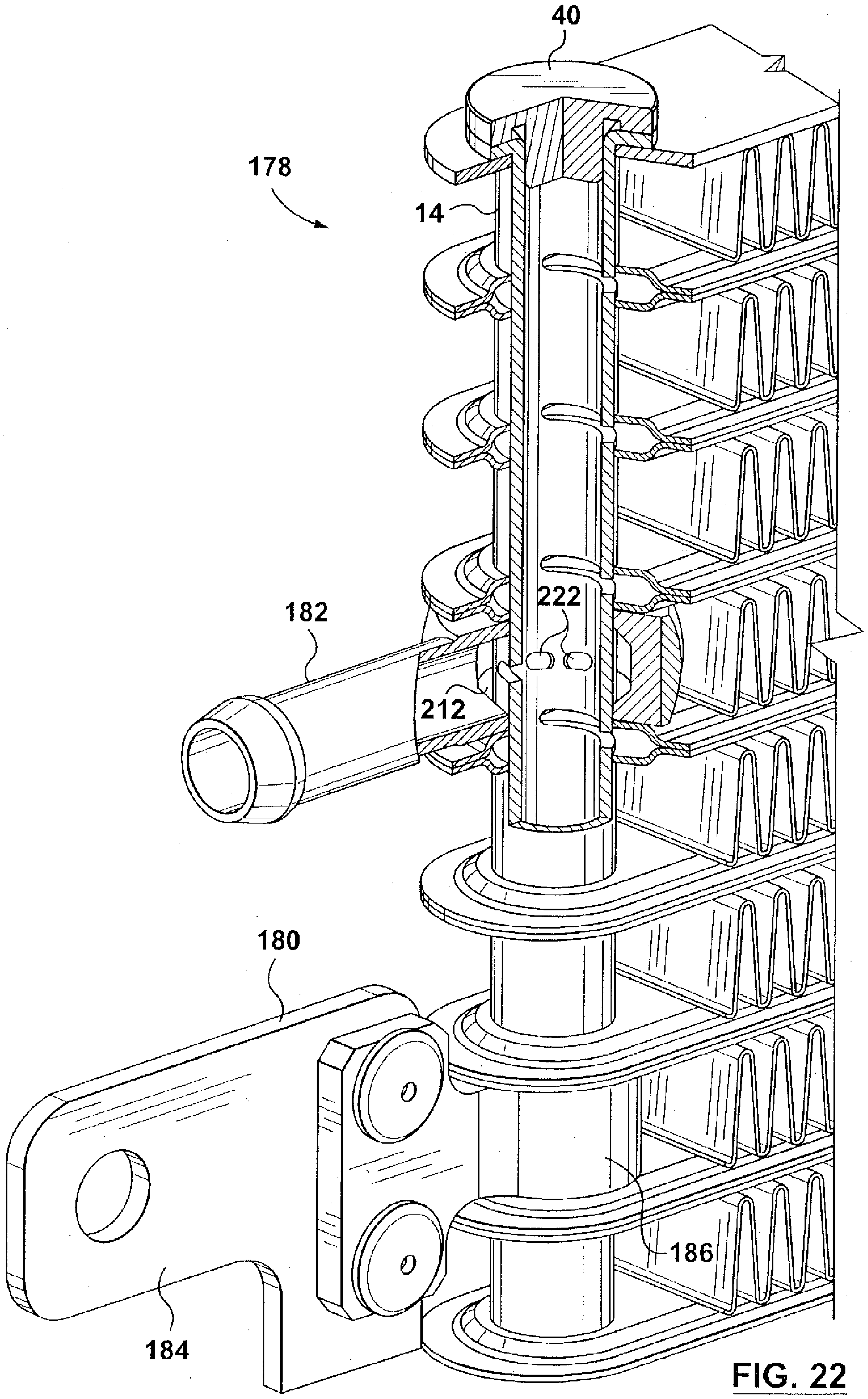

FIG. 22

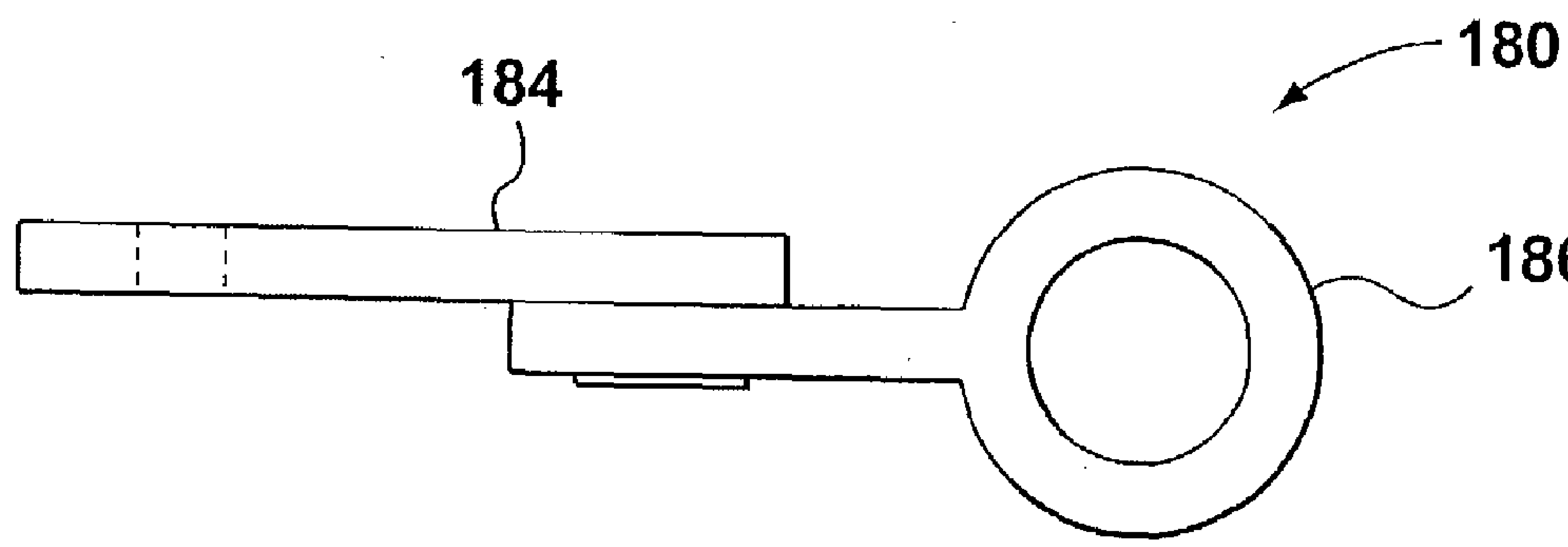

FIG. 23

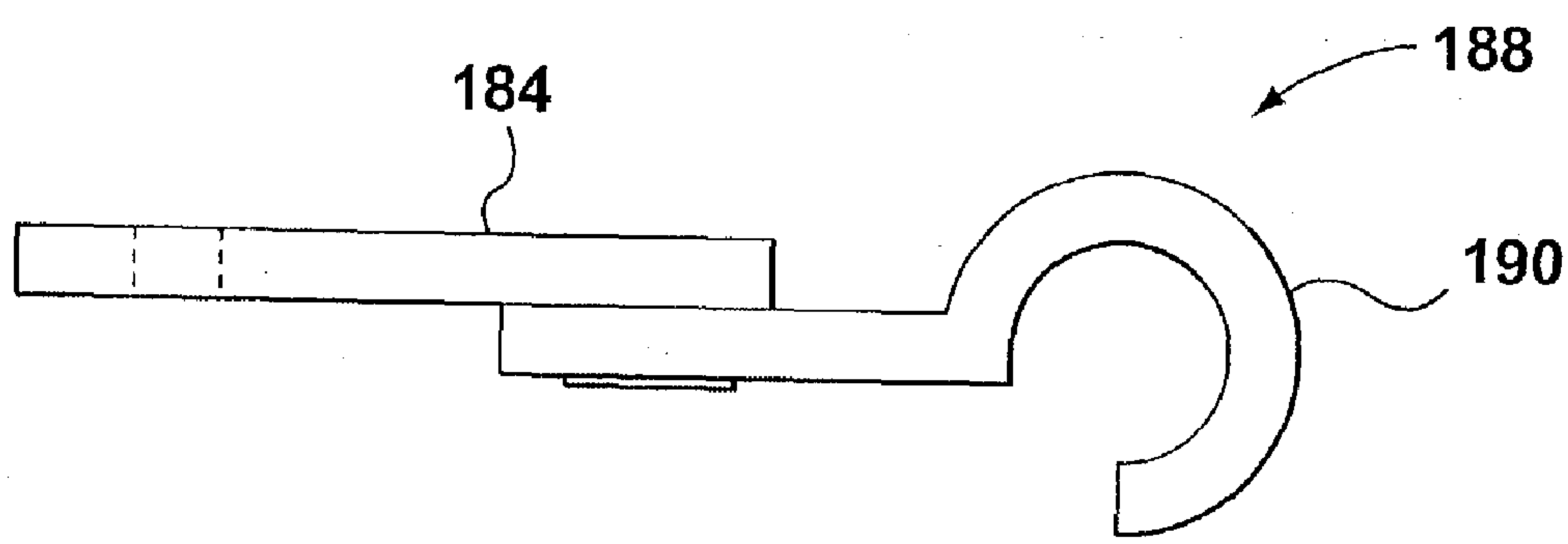

FIG. 24

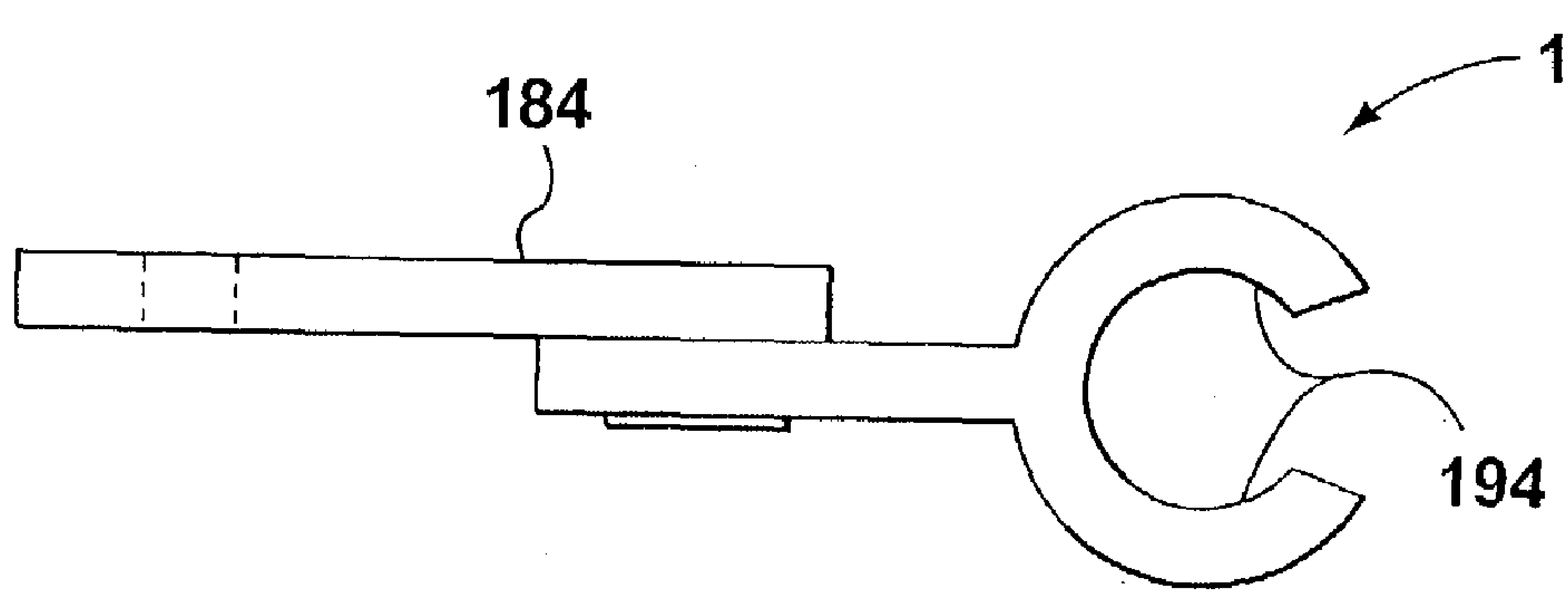

FIG. 25

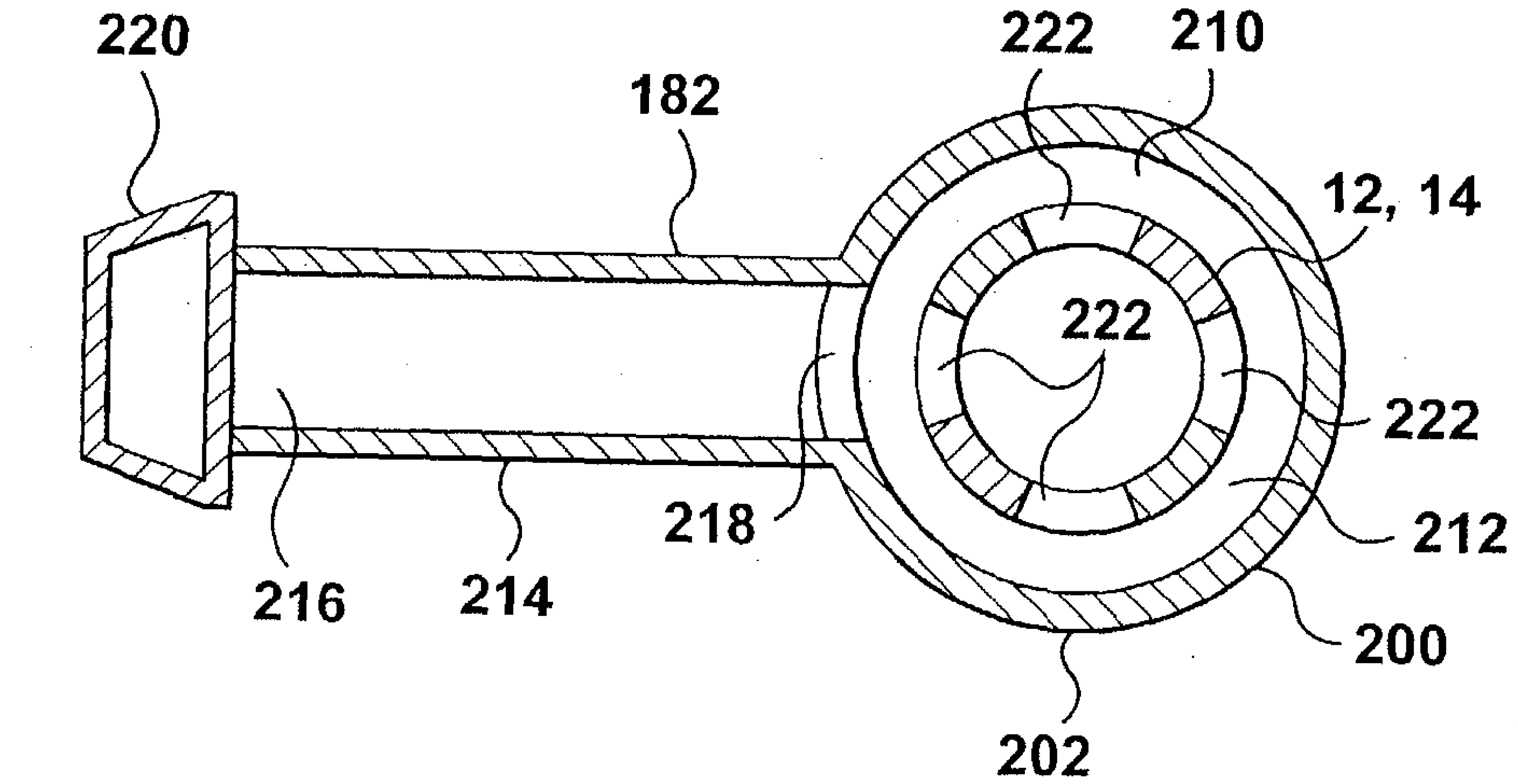

FIG. 26

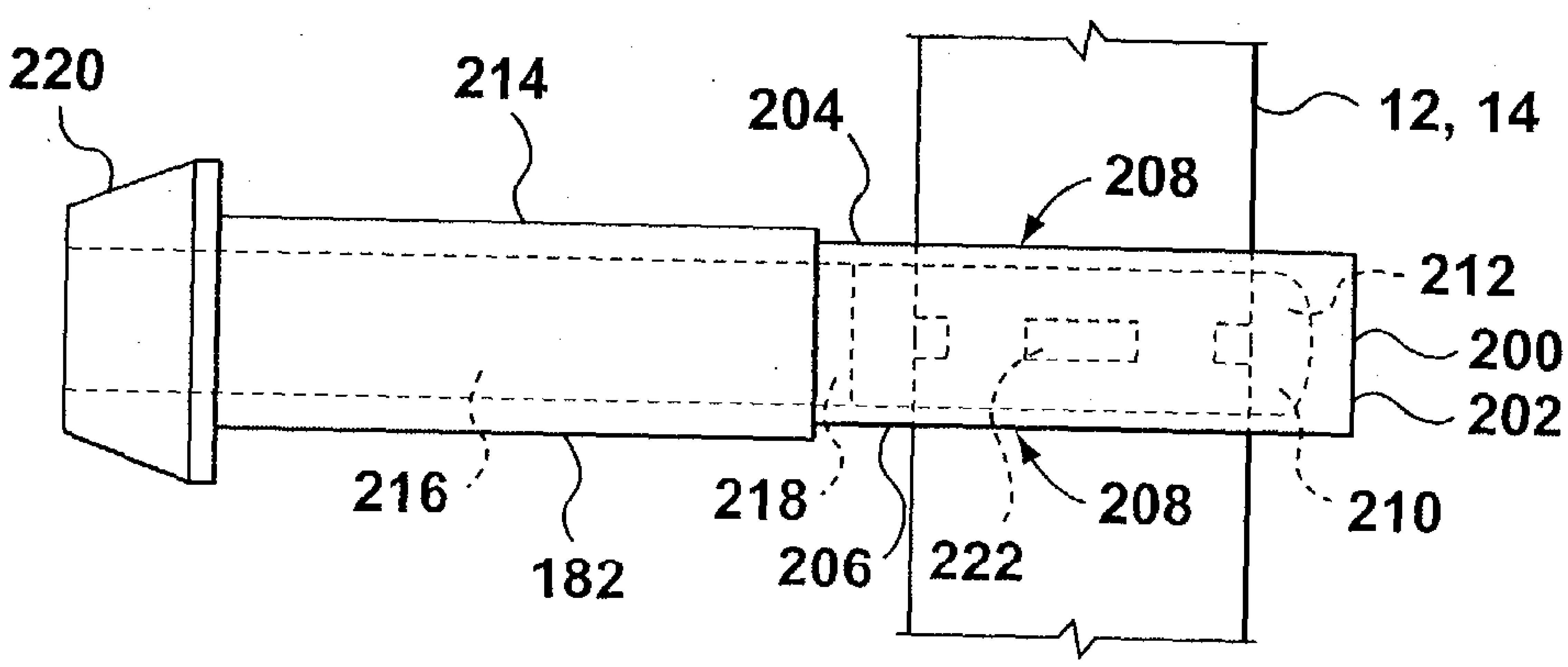

FIG. 27

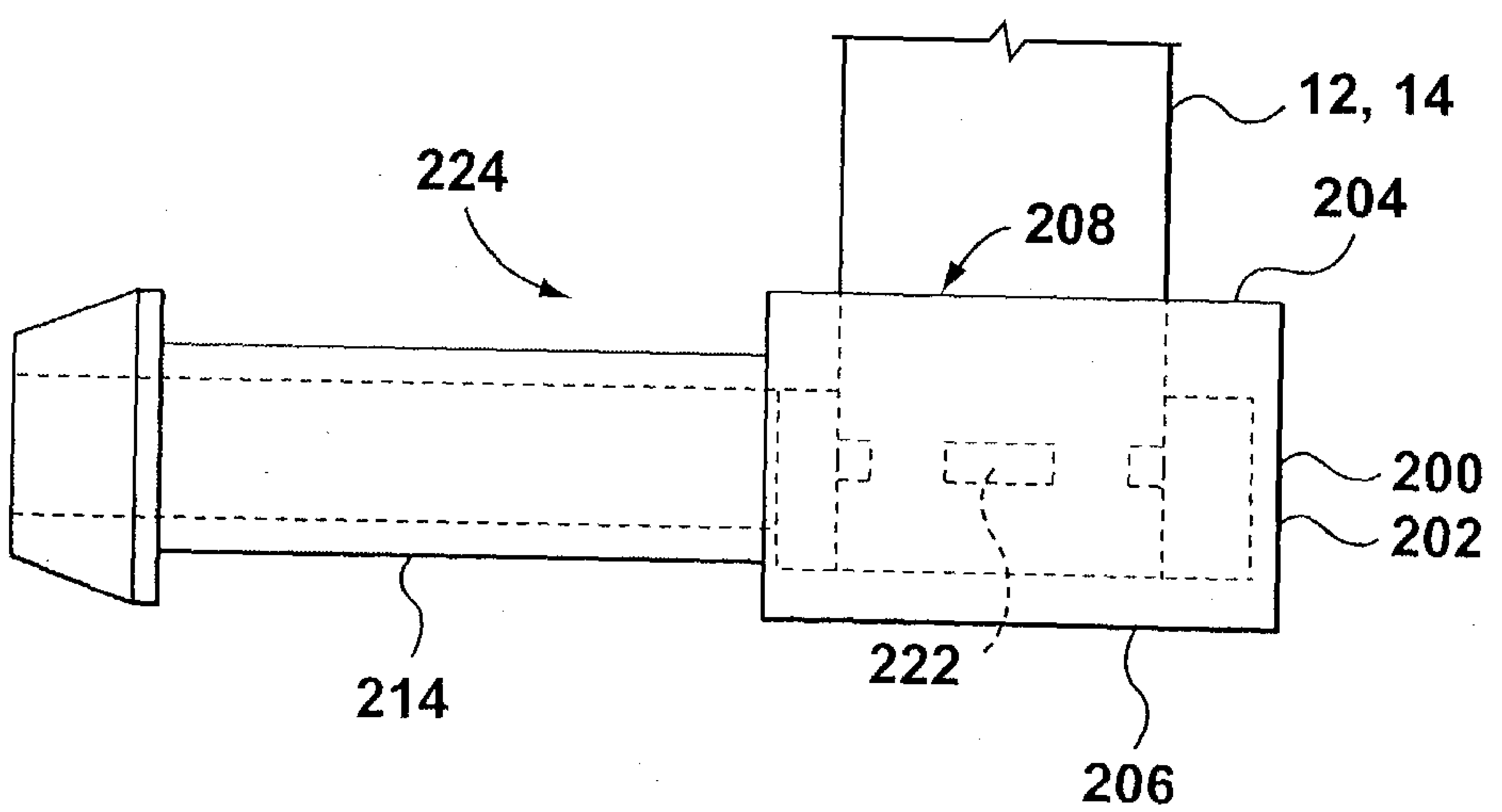

FIG. 28

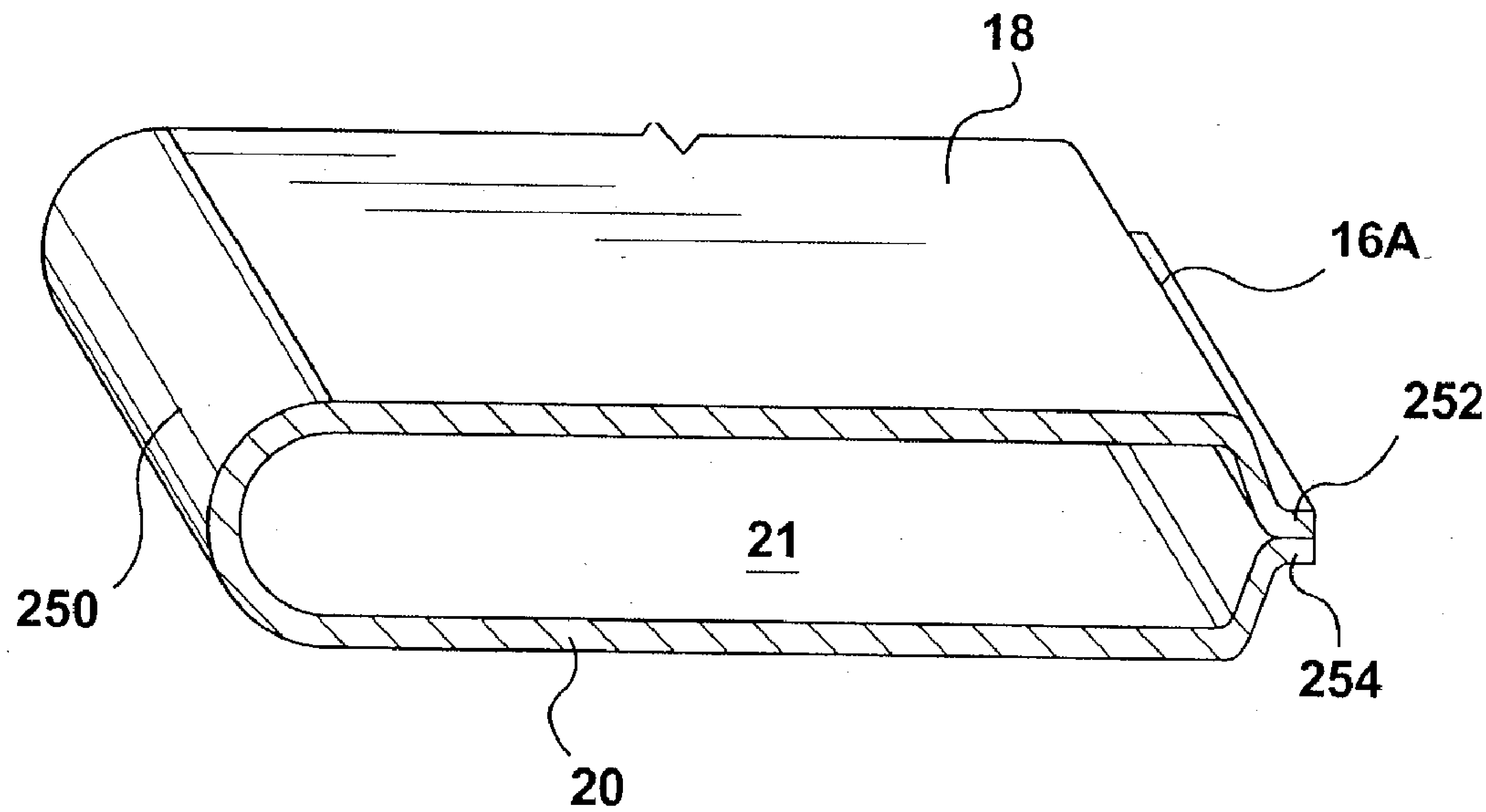

FIG. 29

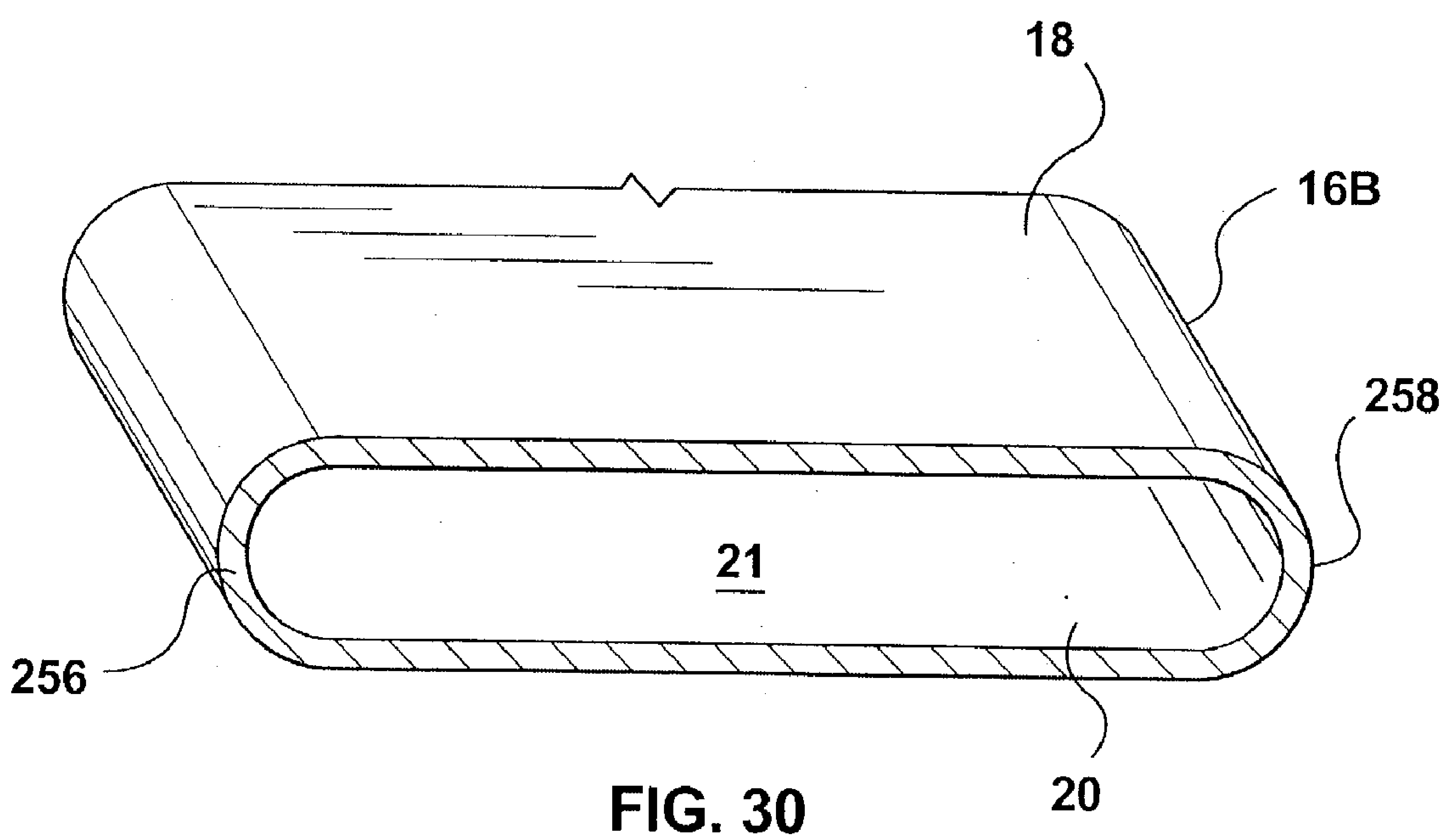

FIG. 30

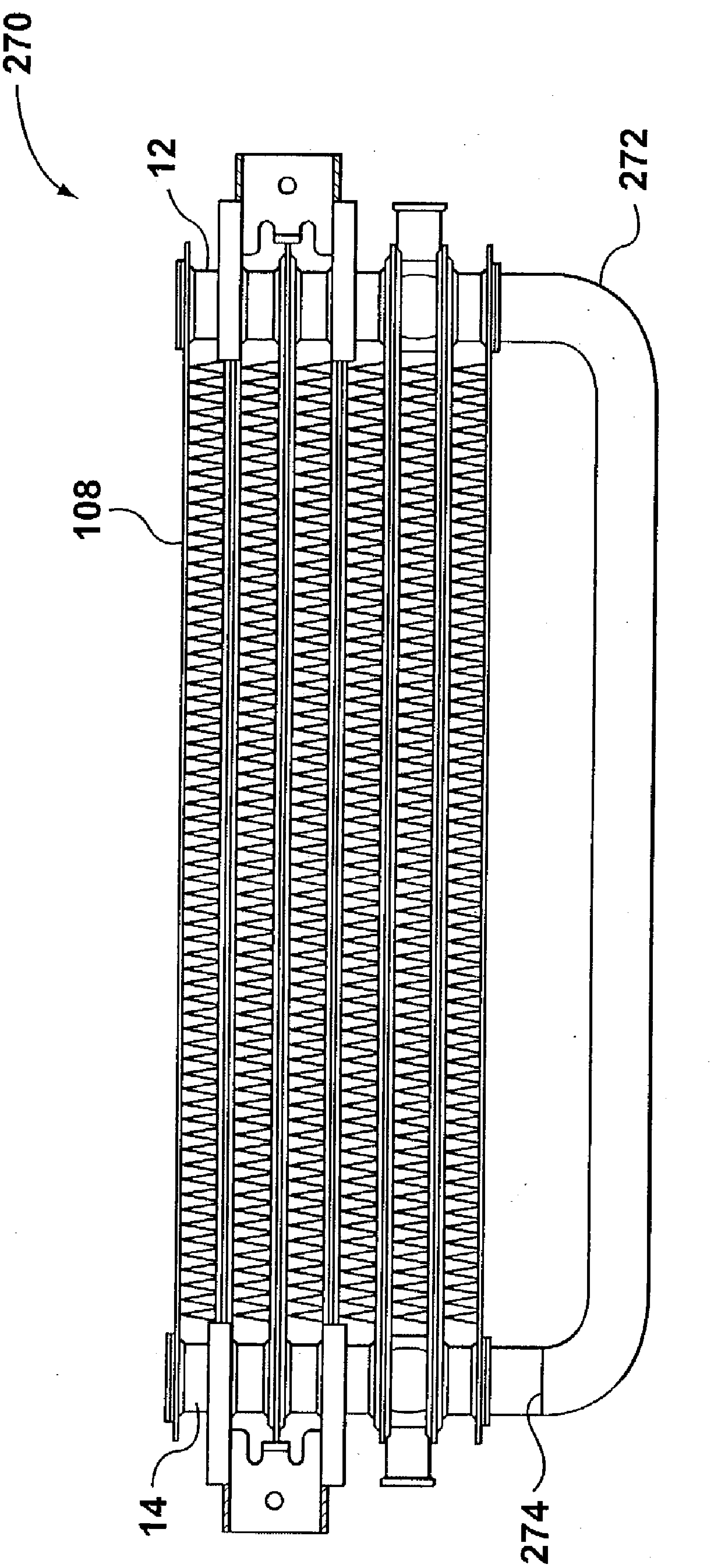

FIG. 31

HEAT EXCHANGER WITH INTERNAL SLOTTED MANIFOLD

BACKGROUND OF THE INVENTION

[0001] This invention relates to heat exchangers, and in particular to stacked plate heat exchangers using slotted manifold tubes.

[0002] Current heat exchangers for use in automobiles are well known and are generally of the flat plate type constructed with alternating and adjacent laterally extending fluid flow and air flow passages. Flat plate heat exchangers that use slotted manifold tubes are known, including for example the heat exchangers illustrated in U.S. Pat. No. 5,908,070 (Kato et al.) and U.S. Pat. No. 6,073,686 (Park et al.) in which the opposite ends of flat fluid flow tubes are inserted into slots provided in manifold tubes. Inserted plate type heat exchangers can be cumbersome to assemble, and be prone to leak or otherwise fail at higher fluid pressures.

[0003] Other types of slotted manifold heat exchangers, for example as shown in U.S. Pat. No. 5,560,425 (Sugawara et al.), have been proposed that use flat fluid flow tubes that have flanges for abutting against a portion of the manifold adjacent a corresponding slot in the manifold. Abutting plate type heat exchangers can also be cumbersome to assemble due to difficulties in maintaining manifold and plate alignment prior to brazing, and also may have failure concerns at higher fluid pressures.

[0004] Still a further type of slotted manifold heat exchange is illustrated in U.S. Pat. No. 3,605,882 (P. R. Smith et al.) in which the manifold is inserted through holes provided in the flat fluid flow tubes, with tube spacers being positioned on the manifold between adjacent flat tubes in order to secure the flat tubes in place. Such a configuration can be complex to assemble. Another slotted manifold heat exchanger can be seen in U.S. Pat. No. 2,511,084 (J. C. Shaw), in which the manifolds are also inserted through holes provided through core elements. In such a configuration, the core elements are secured together by bolts, independently of the manifolds.

[0005] Thus, there is a need for a slotted manifold heat exchanger that is easy to assemble and that is high pressure resistant. A heat exchanger and corresponding assembly method that require relatively little manufacturing adjustments or retooling to produce heat exchangers of varying length, width or height are also desirable.

SUMMARY OF THE INVENTION

[0006] According to one aspect of the invention, there is provided a heat exchanger that includes a manifold tube having a wall defining a flow passage therethrough and having a plurality of spaced apart openings formed through the wall in flow communication with the flow passageway, and a plurality of stacked flat tube elements each including a first plate and a second plate defining a flow channel therebetween, the plates each being provided with an aperture therethrough, the apertures in the first and second plates of each of the tube elements being substantially in alignment with each other. The manifold tube is received through the apertures in the first and second plates of each of the flat tube elements with each of the spaced apart openings in flow communication with the flow channel of a respective one of the flat tube elements. The wall of the manifold tube and the apertures are respectively sized that an outer surface of the manifold tube engages an inner surface surrounding the aperture in each of the first and second plates to secure the flat tube elements to the manifold tube, the flat tube elements being supported by the manifold tube. The openings formed through the manifold tube wall may vary in size along a length of the manifold tube.

[0007] According to another aspect of the invention, there is provided a method of assembling a stacked plate heat exchanger, including steps of (a) providing a manifold tube having a wall defining a flow passage therethrough and having a plurality of spaced apart openings formed through the wall in flow communication with the flow passageway; (b) providing a plurality of flat tube elements each including a first plate and a second plate defining a flow channel therebetween, the plates each being provided with an aperture therethrough, the apertures in the first and second plates of each of the flat tube elements being substantially in alignment with each other; (c) positioning the manifold tube through the apertures in the first and second plates of each of the flat tube elements with each of the spaced apart openings in flow communication with the flow channel of a respective one of the flat tube elements; and (d) radially expanding at least portions of the manifold tube such that manifold tube engages each of the first and second plates about the apertures thereof to secure the flat tube elements to the manifold tube. The heat exchanger may be brazed after expansion of the manifold tube.

[0008] According to another aspect of the invention there is provided is a heat exchanger comprising a manifold tube having a wall defining a fluid flow passage therethrough and a stack of flat tube elements connected to the manifold tube and each having a flow channel therethrough in fluid communication with the fluid flow passage. A baffle cup having a wall engages an inner surface of the manifold tube wall, the manifold tube wall having an error proofing hole formed therethrough at a location where the baffle cup wall is positioned, the hole being sized such that a visual check can be performed to ensure that the baffle cup is in place. The error proofing hole is sealably covered by the wall of the baffle cup.

[0009] According to still another aspect of the invention, there is provided a heat exchanger comprising a manifold tube having a wall defining a fluid flow passage therethrough, a stack of flat tube elements connected to the manifold tube and each having a flow channel therethrough in flow communication with the fluid flow passage, and a port fixture having a collar providing an annular flow way surrounding an annular area of the manifold tube wall having a plurality of radially spaced openings formed therethrough. The annular flow way is in flow communication with the fluid flow passage through the radially spaced openings, the port fixture having a connecting member extending from the collar and defining a fluid passageway in flow communication with the annular flow way.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

[0011] **FIG. 1** is an elevational view of a preferred embodiment of a flat plate heat exchanger according to the present invention;

[0012] **FIG. 2** is a perspective view of the heat exchanger of **FIG. 1**;

[0013] **FIG. 3** is a partial sectional perspective view of the heat exchanger of **FIG. 1**;

[0014] **FIG. 3A** is a partial sectional elevational view showing an inlet port mounted to a manifold tube of the heat exchanger;

[0015] **FIG. 4** is a plan view of a plate pair tube element of the heat exchanger of **FIG. 1**;

[0016] **FIG. 5** is an exploded elevational view of a plate pair tube element;

[0017] **FIG. 6** is a perspective view of a turbulizer of the plate pair tube element;

[0018] **FIG. 7** is an elevational view of a manifold tube of the heat exchanger;

[0019] **FIG. 8** is a plan view of the manifold tube;

[0020] **FIG. 9** is a perspective view of a bracket for the heat exchanger according to one embodiment of the invention;

[0021] **FIG. 10** is a schematic illustration of an assembly process for the heat exchanger;

[0022] **FIG. 11** is a partial sectional perspective view of the heat exchanger of **FIG. 1**, showing a hydraulic bladder being used to expand a manifold tube;

[0023] **FIGS. 12A and 12B** illustrate, in elevational view, the use of a tapered pin mandrel to expand a manifold tube;

[0024] **FIG. 13** is a partial elevational view showing a manifold tube having slot openings in accordance with a further embodiment of the invention;

[0025] **FIG. 14** is a partial elevational view showing a manifold tube having slot openings in accordance with still a further embodiment of the invention;

[0026] **FIG. 15** is a partial elevational view showing a flat tube element mounted on a manifold tube in accordance with a further embodiment of the invention;

[0027] **FIG. 16** is a partial elevational view showing a manifold tube having slot openings in accordance with a further embodiment of the invention;

[0028] **FIG. 17** is a simplified elevational view showing a further embodiment of a heat exchanger in which a baffle cup is used to separate the manifold tubes;

[0029] **FIG. 18** is a sectional perspective view of a baffle cup;

[0030] **FIG. 19** is a partial elevational view showing an error proofing hole for the baffle cup;

[0031] **FIG. 20** is a simplified elevational view of yet a further embodiment of a heat exchanger according to the present invention;

[0032] **FIG. 21** is a plan view of the heat exchanger of **FIG. 20**;

[0033] **FIG. 22** is a partial sectional perspective view of a heat exchanger according to another embodiment of the invention;

[0034] **FIG. 23** is a plan view of a bracket of the heat exchanger of **FIG. 22**;

[0035] **FIG. 24** is a plan view of a further bracket configuration;

[0036] **FIG. 25** is a plan view of yet a further bracket configuration;

[0037] **FIG. 26** is a sectional plan view of a further port fitting mounted on a tube manifold;

[0038] **FIG. 27** is an elevational view of the further port fitting;

[0039] **FIG. 28** is an elevational view of yet another port fitting;

[0040] **FIGS. 29 and 30** are partial sectional perspective views of further flat tube element embodiments; and

[0041] **FIG. 31** is a elevational view of still a further embodiment of a heat exchanger according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0042] The structure, operation, and method of assembly of the heat exchanger of the subject invention will now be described, with like reference numerals used throughout to refer to similar parts of different embodiments of the heat exchanger.

[0043] Referring to **FIGS. 1, 2** and **3**, a flat plate heat exchanger according to one preferred embodiment of the present is shown generally by reference numeral **10**. The heat exchanger **10** is a single pass heat exchanger which may be used in an automotive application such as a transmission oil cooler or power steering fluid cooler, however the features of the present invention can be applied to a wide range of heat exchangers for different applications and the heat exchanger **10** of **FIG. 1** is provided as just one example of a heat exchanger according to the present invention. The heat exchanger **10** includes a first manifold tube **12** and second manifold tube **14**, which in the single pass configuration illustrated function as an intake manifold tube and an out take manifold tube respectively. A plurality of elongate flat tube elements **16** are arranged in parallel fashion on the manifold tubes **12**,**14**. The flat tube elements **16** each include a first plate **18** and a second plate **20** sealed together to form a flow passage way **21** there between. Air passages **22** are located between adjacent flat tube elements **16**, and corrugated fins **24** are located in air passages **22**, fins **24** being in thermal contact with adjacent flat tube elements **16** for providing a high surface area for heat exchange between the fins **24** and air flowing through the air passages **22**.

[0044] As best seen in **FIG. 3**, the manifold tube **12** includes a series of slots **42** that are longitudinally spaced along and extend through the cylindrical wall of the manifold tube **12**. The slots **42** are arranged so that their length runs transverse to the longitudinal axis of the manifold tube **12**. The flat tube elements **16** are each arranged along the manifold **12** so that each of the tube elements **16** is aligned with a respective one of the tube slots **42**, and more particularly, so that the fluid passage **21** provided through each of the tube elements **16** is in flow communication with the passage **30** provided through the manifold tube **12** through the respective openings provided by manifold tube slots **42**.

[**0045**] Similar slots are provided along the cylindrical wall of the out take manifold tube **14**, and the out take ends of the flat tube elements **16** are arranged on the out take manifold **14** such that an out take end of each of the fluid passages **21** provided through the flat plate tube elements **16** communicates with the flow passage **34** provided through the out take manifold tube **14** by way of the slots provided along the out take manifold tube **14**.

[**0046**] A fluid inlet port **26** is provided on the intake manifold tube **12** and a fluid outlet port **28** is provided on the out take manifold tube **14**. The inlet and outlet ports **26**, **28** are shown in arbitrary locations along their respective manifold tubes in FIGS. **1** to **3**. The inlet port **26** defines a passage that is in flow communication with a fluid flow passage **30** provided through the interior of intake manifold tube **12** such that a fluid can flow through the inlet port **26** into the interior of the manifold tube **12** as illustrated by arrow **32** in **FIG. 3**. Similarly, the outlet port **28** defines a flow passage in communication with a flow passage **34** defined by an interior surface of the out take manifold tube **14**. In the illustrated embodiment, end plates **36** and **38** without flow passages there through are provided as the first and last plate on the heat exchanger **10**.

[**0047**] End caps **40**, which are shown in exploded view in **FIGS. 1 and 2**, can conveniently be used to seal the ends of the intake and out take manifold tubes **12**, **14**. Brackets **43** may be positioned along the manifold tubes **12**, **14** to permit the heat exchanger **10** to be secured in position.

[**0048**] Thus, during operation of the heat exchanger **10**, the fluid to be cooled enters the heat exchanger **10** through the inlet port **26** and flows into the passage **30** in the intake manifold tube **12**. From the intake manifold tube **12**, the fluid is dispersed through slots **42** into the plurality of fluid passages **21** that are provided through the flat tube elements **16**. The fluid exits the fluid passages **21** through corresponding slots provided on the out take manifold tube **14** to enter the fluid passage **34** provided by the out take manifold tube **14**. As the fluid travels across the heat exchanger **10** through the fluid passages **21**, its heat energy is drawn off by corrugated fins **24**, which in turn are cooled by air flowing through the air passages **22**. The cooled fluid leaves the out take manifold tube **14** through the outlet port **28**.

[**0049**] An overview of the heat exchanger **10** having been provided, the details of the structure and fabrication of the elements of the heat exchanger **10** will now be discussed in greater detail with reference to the Figures.

[**0050**] As can be seen in FIGS. **1-3**, the flat tube elements **16** each include openings at their opposite ends through which the manifold tubes **12** and **14** are internally received. With reference to **FIGS. 4 and 5**, which show a top plan view and an exploded elevational view, respectively, of a preferred embodiment of one of the flat tube elements **16**, each of the first and second plates **18**,**20** includes a elongate substantially planar central portion **56**. Inwardly offset flanges **58** are located along the longitudinal edges of the plates **18** and **20**, forming longitudinal peripheral edges. End flanges **60** extend between the ends of longitudinal flanges **58**, thus forming end edges on the plates **18**, **20**. Thus, flanges **58** and **60** collectively form a continuous inwardly offset edge portion that surrounds the planar central portion **56**. When the plate pairs **18** and **20** are joined together, the offset longitudinal flanges **56** of one plate abut against the longitudinal flanges of the other plate, and similarly the end flanges **60** of plate abut against the end flanges **60** of the other plate. As will be explained in greater detail below, in one preferred embodiment the first and second plates **18**, **20** are sealably connected along the longitudinal edges and end edges thereof through a brazing process. In some embodiments, soldering or adhesive bonding could be used.

[**0051**] The longitudinal flow passage **21** is defined between the central planar portions **58** of the first and second plates **18**, **20**. A turbulizer or turbulator **62** is, in a preferred embodiment, located within the fluid channel **21** that is formed between the planar portions **56**. Greater detail of one possible turbulizer **62** configuration is shown in **FIG. 6**. The turbulizer **62** includes a series of undulations or convolutions formed therein to create turbulence in the fluid flow and in this way increase heat transfer in the heat exchanger. In some embodiments, turbulizers may not be used, or could be replaced by dimples, ribs or ripples formed on the plates **18**,**20**.

[**0052**] With reference to **FIG. 4**, an opening **44** is provided through one end of the flat tube element **16** for receiving the intake manifold tube **12**, and a second spaced-apart opening **46** is located at the other end of the flat tube element **16** for receiving the out take manifold tube **14**. With reference to **FIG. 5**, the opening **44** is provided by aligned apertures **48** that are pierced through the first and second plates **18**, **20**, and similarly, opening **46** is provided by aligned apertures **50** that are pierced through opposite ends of the plates **18**, **20**. The apertures **48** and **50** are pierced through end portions of the outwardly offset planar portions **56** such that when the flat tube elements are assembled, the openings **44** and **46** are both in flow communication with the fluid passage **21** that is defined between the plates **18**, **20**. As best seen in **FIG. 3A and 4**, the apertures **44**,**46** are, in a preferred embodiment, arranged such that an annular portion **23** of the flow channel **21** extends around the circumferences of the manifold tubes.

[**0053**] A peripheral flange **64** defines an inner circumference of each of the apertures **48**. The flange **64** extends outward (i.e. away from the flow channel) from the outer surface of the central planer portion **56**. The peripheral flanges **64** are integrally formed on their respective plates, and provide an overlap joint between the flat tube elements **16** and the respective manifold tubes **12**,**14**, as can best be seen in **FIG. 3A**.

[**0054**] In a preferred embodiment, the plates **18**, **20**, are roll formed to form the central planar portion **56** and longitudinal flanges **58**, after which the roll formed raw plate is lanced at a desired length and peripheral end flanges **60** are end formed. The apertures **48** and **50** are formed by piercing and subsequently extruding the peripheral flange **64**. As shown in **FIG. 4**, the longitudinal flanges **58** can extend further into the centre of the plates **18**, **20** near the apertures **48**, **50** to form shoulders **59** to abut against each other to support the plates **18**,**20** near the openings **44**,**46**, but still provide the annular flow path **23** around the outer facing portions of the manifold tubes. Shoulders **59** provide increased strength around the apertures **48**,**50**.

[**0055**] The use of roll formed plates conveniently allows plates of varying lengths to be made with minimal assembly line changes required. Plates **18**,**20** could also be formed using other techniques, including for example, stamping, however such alternatives may not be as flexible as roll forming for permitting changes in plate length.

[**0056**] **FIG. 7** shows an elevational view of a preferred embodiment of the intake manifold tube **12**, which is basically a cylindrical wall having manifold tube slots **42** spaced along a length thereof. In one preferred embodiment, an inlet opening **68** is provided for the inlet port **26**. An outwardly extending flange **70**, which in the illustrated embodiment is annular, is optionally provided at one end of the manifold tube **12** in order to provide a stop for the end plate **36** or **38** during assembly of the heat exchanger. The slots **42** are preferably formed by using a die punch with internal die support, or a saw, however it would be appreciated that other slot forming methods could be used, for example, saw cutting, milling, piercing, laser cutting, or lancing.

[**0057**] With reference to **FIG. 8**, an outer diameter of the manifold tube **12** is illustrated as having a dimension D1. Prior to assembly of the heat exchanger **10**, the outer diameter D1 is less than an inner diameter D2 (see **FIG. 4**) of the opening **44** through the plate pair **16**, in order to allow the plate pair **16** to be slidably mounted on the manifold **12**. The out take manifold tube **14** is basically identical to the intake manifold tube **12**, and has an outer diameter D1 that, prior to assembly, is less than an inner diameter D2 of the opening **46** through each of the flat tube element **16** so that the plate pair elements can be mounted thereon.

[**0058**] With reference to **FIG. 3**A, in a preferred embodiment, the inlet port **26** includes a cylindrical collar **98** through which the intake manifold tube **12** can pass. A cylindrical connecting wall **100** defining an inlet passage extends transversely from the collar **98**. Conveniently, the collar **98** can be supported by the peripheral flanges **64** of opposing flat tube elements as illustrated in **FIG. 3A** in such a manner that it can be pivoted to a desired position during heat exchanger assembly prior to manifold tube expansion. In the illustrated embodiment of FIGS. **1** to **3**, the outlet port **28** is identical to and mounted in the same manner as the inlet port **26**.

[**0059**] **FIG. 9** shows in greater detail a mounting bracket **43** according to one embodiment of the invention for use on the intake or out take manifold tube **12**,**14** side of the heat exchanger **10**. Each mounting bracket **43** has first clip part **146** including spaced-apart C-shaped clips **148**, **149**, each of which defines respective contacting surfaces **150**, and a central portion or spacer member **152** extends between and connects the clips **148**,**149**. A second clip part **154**, has spaced apart C-shaped clips **156**,**157**. Each clip **156**,**157** defines a respective contacting surface **158**. A central portion or spacer member **160** extends between and connects the clips **156**,**157**. The C-shaped clips **148**, **149** are dimensioned to receive one flat tube element **16**, and the C-shaped clips **156**, **157** a second flat tube element **16**. Preferably, the C-shaped clips are dimensioned to frictionally engage their respective flat tube element with sufficient force to hold the bracket in place until brazing occurs.

[**0060**] The inlet and outlet ports **26**, **28** and brackets **43** as described above are only one example of several different inlet and outlet port and bracket configurations that can be used with the present invention, and examples of further alternatives will be provided further below. Alternative manifold tube and flat tube element configurations to those described above can be used as well, and examples of further alternatives will also be provided below. But first, a description of the elements of a preferred embodiment of the heat exchanger **10** having been provided, assembly of the elements to form the heat exchanger **10** will now be described.

[**0061**] With reference to the schematic flowchart of **FIG. 10**, as indicated by brace **92**, in one preferred assembly method a core heat exchanger stack (indicated by reference numeral **108** in **FIG. 11**) is assembled from end plates **36**,**38**, first and second plates **16**, **18**, turbulizers **62** and fins **24**. In particular, the end plate **38** is positioned (step **90-1**) and a fin **24** placed along it (step **90-2**), after which a first plate **16** is added (step **90-3**), followed by a turbulizer **62** (step **90-4**), followed by a second plate **18** (step **90-5**) such that the first and second plates **16**,**18** define fluid flow channel **21** therebetween in which the turbulizer **62** is positioned. As indicated in **FIG. 10** by line **94**, building up the core stack through the method sequence of adding a fin **24**, a first plate **16**, a turbulizer, and a second plate **18** continues until the core stack reaches a predetermined height (which, in the example shown in FIGS. **1-3**, includes five plate pairs), after which a final fin **24** is added and the core stack topped off with end plate **36** (step **90-6**). As the core stack **108** is being assembled, all the core stack components are aligned as illustrated in FIGS. **1** to **3**, with plate apertures **48** substantially aligned and plate apertures **50** substantially aligned. End plates **38** and **36** also have corresponding apertures provided there through.

[**0062**] Preferably, fittings, namely the inlet and outlet ports **26**,**28** and brackets **43** are then positioned on the core stack **108** as required (step **90-7**). Once the fittings and brackets are added to the core stack, the manifold tubes **12** and **14** are slidably inserted through the corresponding aligned apertures in the assembled core stack (step **90-8**). The annular flanges **70** on the ends of the manifold tubes **12** and **14** act as stop members to assist in positioning the manifold tubes. Preferably, the core stack **108** is then compressed (step **90-9**) until the slots **42** in the manifold tubes **12** and **14** are each aligned with a respective flow channel **21** through a corresponding flat tube element **16**.

[**0063**] The manifold tubes **12** and **14** are each then internally expanded to increase their respective outer circumferences so that they each securely engage an inner circumference of the apertures **48** and **50**, respectively, of each of the plates **18** and **20** thereby effectively locking the plate pairs **16** in place (step **90-10**). As mentioned above, prior to expansion, the manifold tubes **12** and **14** each have a respective outer diameter D1 (**FIG. 8**) that is less that an inner diameter D2 (**FIG. 4**) of the corresponding plate apertures **48** and **50**, in order to facilitate assembly of the heat exchanger. During expansion, at least the portions of the manifold tube walls adjacent the plate apertures **48** and **50** are enlarged such that the enlarged diameter exceeds the inner diameter D2 of the apertures. Thus after expansion, the enlarged manifold tubes **12** and **14** each engage substantially the entire circumference of the plate apertures **48** and **50**, respectively (in the preferred embodiment that is shown in the drawings, an overlap joint is formed between each of annular flange **64** and the manifold tubes that it surrounds), preventing any further movement of the plates **16**,**18** relative to the enlarged manifold tubes **12** and **14**.

[**0064**] With reference to **FIG. 11**, in one preferred embodiment a hydraulic bladder **102** is placed inside each of the manifold tubes **12** and **14**, and expanded by pumping hydraulic fluid through an inlet **106** to radially enlarge the manifold tubes in a substantially uniform manner along their entire lengths through radial pressure applied uniformly throughout the manifold tubes in the direction indicated by arrows **104**. The use of a uniform radial pressure along the length of the manifold tubes decreases any axial loading during the expansion process. Axial loading is generally not desired, especially in longer manifold tubes, as it can result in deformation that is exacerbated by the slotted nature of the manifold tubes.

[**0065**] It will be appreciated that alternative expansion methods can also be used. For example, in shorter manifold tubes where axial loading is not as great a concern, a tapered pin mandrel can be used to expand the manifold tubes. **FIGS. 12A and 12B** show pre-expansion and post-expansion, respectively, views illustrating the use of a stepped tapered pin mandrel **106** to radially expand the manifold tube **14** in the vicinity of each of the slots **42** to achieve locally pronounced expansion at the points along the manifold tube **14** where the flat tube elements (not shown in **FIGS. 12A and 12B**) are engaged by the manifold tube. If desired, in embodiments in which a hydraulic bladder is used to effect expansion, bands could be provided around the bladder to localize expansion at the points along the manifold tubes in the manner shown in **FIG. 12B**.

[**0066**] With reference again to **FIG. 10**, subsequent to manifold tube expansion, end caps **40** are placed on the manifold tubes **12** and **14**, for example by a swage or press-fit operation (step **90-11**), after which the entire heat exchanger **10** assembly is sent to a brazing oven (step **90-12**). At least the first and second plates **18**, **20** of the heat exchanger are preferably braze clad such that in the brazing oven, the flat tube elements are sealaby brazed along their respective edges, the peripheral flanges **64** about the plate apertures **48**, **50** are sealably brazed about their entire circumferences to the manifold tubes **12**,**14**, respectively, the end caps **40** are sealably brazed in place, and the fins **24** and end plates **36**,**38** are all secured by brazing.

[**0067**] Compression of the core stack **108** (step **90-9**) prior to radial expansion of the manifold tubes is performed in the preferred assembly method to compensate for shrinkage of the core stack that occurs during brazing. In some heat exchanger configurations, if the flat tube elements are locked in place by expansion of the manifold tubes without pre-compression of the core stack, then the centre area of the core stack may bow inwards due to shrinkage in the brazing oven. Preferably, compression of the core stack is applied preferentially to the core plate stack **108** in the areas closer to the manifold tubes **12**,**14**, where the greatest resistance to compression will generally be experienced.

[**0068**] The core plate stack **108** could be assembled using methods differing from that shown in **FIG. 10**. For example, in an alternative preferred embodiment, the manifold tubes **12**,**14** are loaded into a fixture, and the core plate stack **108** built up by sliding the plates onto the manifold tubes one at a time, or in groups, along with alternating fins and turbulizers, rather than assembling the entire core plate stack **108** and then inserting the manifold tubes as described above in respect of **FIG. 10**.

[**0069**] The configuration of the present invention provides a heat exchanger with a relatively high burst strength as the slotted manifold tubes **12**,**14** are supported internally within the apertures of each of the plates **18**,**20**. Such configuration also provides a relatively strong joint between each of the flat tube elements and each of the manifold tubes. Assembly is uncomplicated as the use of expanded manifold tubes to secure the plates **18**,**20** in place prior to brazing reduces the need for any additional spacers or collars to be mounted on the manifold tubes to hold the plates in position.

[**0070**] With relatively few assembly line changes, the heat exchanger configuration and assembly method of the present invention can be used to produce a number of variations of the heat exchanger. For example, heat exchangers of different heights can be produced by using longer or shorter manifold tubes (for taller and shorter heat exchangers, respectively) and a corresponding increased or decreased number of flat tube elements and fins. Heat exchangers of different lengths (as measured from manifold tube to manifold tube in the illustrated embodiment) can be produced by roll forming longer or shorter first and second plates **18**, **20**, and longer or shorter end plates **36**,**38**, and using longer or length-wise shorter fins **24**. Heat exchangers of different widths can be produced by roll forming wider or narrower first and second plates **18**, **20**, and wider and narrower end plates **36**,**38**, and using wider or narrower fins. If desired, larger or smaller diameter tube manifolds can be used with corresponding changes being made to the apertures pierced through the plates **18**,**20**. The spacing between flat tube elements **16** can be changed by changing the spacing of the manifold slots **42** along the tube manifolds **12**,**14**, and using higher or lower fins **24**. It will thus be appreciated that features of the present invention can be used in the production of heat exchangers having varied length, width and height, without significant assembly line tooling changes.

[**0071**] The present invention also provides flexibility in fitting and bracket placement. The location of inlet and outlet ports **26**, **28**, can be varied relatively easily by using manifold tubes with inlet and outlet openings **68** in a different location, and then adding the inlet and/or outlet ports **26**, **28** to the core stack **108** at a location corresponding to the different inlet and/or outlet openings. In practice the positions of the fittings in this invention can easily be adjusted to suit heat exchanger flow distribution constraints or to correspond to preferred fluid supply connector locations. One or both of the manifold tubes **12**,**14** could also be configured without side inlets or outlets, and instead have an inlet or outlet, respectively, at a manifold tube end rather than an end cap **40**.

[**0072**] Some examples of alternative preferred embodiments of the present invention will now be described.

[**0073**] It will be appreciated that in some embodiments, the slots **42** may be replaced by openings of a different configuration, for example circular or oval, or each individual slot **42** could be replaced with a plurality of openings. By way of example, **FIG. 13** shows a manifold tube **14** having radial rows of circular openings **172** and radial rows of square openings **174** in place of slots **42**. Such openings may be radially located about part of or the entire circumference of the manifold tube.

[0074] In a further preferred embodiment of the invention, the sizes of the slots 42 along one or both of the manifold tubes 12, 14 are varied along the length thereof. For example, with reference to FIG. 14, in such further preferred embodiment, the opening defined by the slot 42 designated by S2 is larger than the opening defined by the slot 42 designated by S1. The larger size of slot 42-S2 may be the result of slot 42-S2 having a greater height than slot 42-S1 (slot height being parallel to the longitudinal axis of the manifold tube 14), or may be the result of slot 42-S2 having a greater length than slot 42-S1 (slot length being transverse to the longitudinal axis of the manifold tube), or may be a result of both of these factors. In embodiments where a plurality of openings are used in the place of a single slot, the same effect can be achieved by using more openings to communicate with the flow channels of flat tube elements where a larger opening area is desired. Varying the size of the slot openings along the manifold tubes may be used to improve flow distribution through the heat exchanger 10. In the embodiment of FIG. 14, the slot openings become progressively larger from the bottom to the top of the manifold tube 14. In some embodiments, the slots may be grouped with slot size increasing progressively for groups of slots, with for example a group of three longitudinally adjacent slots having the same size, and then the next three slots having a different size and so on. The size of the respective slot openings through the intake and out take manifold tubes 12, 14 in flow communication with the inside channel through a given flat tube element 16 need not be identical in all applications, however slot to slot centre spacing on the two manifold tubes should be substantially identical to maintain proper plate pair spacing throughout the core stack 108.

[0075] The height of slots 42 is limited to less that the distance between the plates 18 and 20. Larger slot heights can be used if the spacing between the plates 18 and 20 is increased in the area around the manifold tubes. By way of example, FIG. 15 shows an embodiment of the invention in which the spacing between first and second plates 18 and 20 of tube element 16 is increased in an annular area 110 surrounding the manifold tube 14 to accommodate a slot 42 having a height greater than the flow channel defined by planar portions 56.

[0076] The slots 42 along the manifold tubes 12,14 may, in some embodiments of the present invention, be directed in some other manner than inward towards the centre of the heat exchanger. For example, FIG. 16 shows an out take tube manifold 14 in which the slots 42 face the ends 60 of the plates making up flat tube elements 16, rather than facing towards the centre of the heat exchanger. Such a configuration forces the fluid flowing through the flat tube elements 16 into the ends of such elements.

[0077] In some embodiments of the invention, spacing of the slots 42, and the corresponding spacing of the flat tube elements 16 may be varied along the length of the manifold. For example, with reference to FIG. 7, spacing H1 could be different than spacing H2.

[0078] Another embodiment of a heat exchanger according to the present invention is shown in a simplified view indicated by reference number 111 in FIG. 17. The heat exchanger 111 is similar in construction and operation to the heat exchanger 10 as described above except for the differences noted below. As with heat exchanger 10, the heat exchanger 111 includes a stack of alternating fins 24 and flat tube elements 16 that extend between a first manifold tube 12' and a second manifold tube 14'. The manifold tubes 12' and 14' each have spaced apart slots along their respective lengths that connect flow passages inside the manifold tubes 12' and 14' with flow channels in the flat tube elements 16. However, cup baffles 112 are sealably secured inside each of the manifold tubes 12' and 14', effectively turning the heat exchanger into two separate heat exchangers, as identified by reference numbers 114 and 116, for two different fluids. In the illustrated embodiment of the heat exchanger 111, as indicated by arrow 118, a first fluid flows into the portion of the manifold tube 12' above the cup baffle 112. The first fluid then flows through slots in the upper portion of manifold tube 12', through corresponding plate pair flow tubes 16, and subsequently into the out take manifold tube 14', and then out of the manifold tube 14' as indicated by arrow 120. As indicated by arrow 122, a second fluid flows into the portion of the manifold tube 12' below the cup baffle 112. The second fluid then flows through slots in the lower portion of manifold tube 12', through corresponding plate pair flow tubes 16, and subsequently into the out take manifold tube 14', and then out of the manifold tube 14' as indicated by arrow 124. In such embodiment, the first and second fluids are kept separated in the heat exchanger 111. Various features could be varied between the two sub-heat exchangers 114, 116 depending on the desired treatment for the first and second fluids. For example, higher flat tube element 16 spacing could be used for one sub-heat exchanger than the other and/or larger manifold slots could be used in one sub-heat exchanger than in the other.

[0079] In some configurations a baffle cup 112 having a calibrated opening therethrough may be located in either one or both of the intake or out take manifold tubes 12' and 14' to control fluid flow therein. In some embodiments, baffle cups may divide only one of the manifold tubes 12', 14', and only a single fluid be used in the heart exchanger, which then assumes a double pass configuration. For example, a baffle cup 112 could be used only in the first manifold tube 12' to divide it in two chambers as indicated in FIG. 17, the baffle cup 112 in second manifold tube 14' omitted, and the second manifold tube 14' capped with no outlet or inlet ports provided therein. In such configuration, fluid would flow into the portion of first manifold tube 12' above the baffle cup 112 as indicated by arrow 118, through the upper three flat tube elements 16 shown in FIG. 17 and into the second manifold tube 14', then into the three lower flat tube elements 16, and back into the first manifold tube 12' below the baffle cup 112, and out of the manifold tube 12' in the opposite direction of arrow 122. From this example, it will be appreciated that further baffle cups could be used to configure the heat exchanger as a multi-pass exchanger.

[0080] The baffle cups 112 can each be stamped from a brazing sheet, and will typically be installed after manifold tube expansion has been carried out. An example of one possible configuration of a baffle cup 112 is shown in greater detail in FIG. 18, in which the baffle cup 112 includes a circular disc like member 113 having an cylindrical wall 115 formed about its outer peripheral edge. Wall 115 provides an overlap joint with the wall of the manifold tube 12' or 14' in which the baffle cup 112 is inserted. Preferably the baffle cup is sized so that the circumference of the outer surface of wall 115 is small enough to slidably fit into the expanded manifold tube **12'** or **14'**, but large enough to frictionally engage the inner surface of the wall of the manifold tube **12'** or **14'** so that the baffle cup **112** does not move unintentionally prior to brazing once positioned in place. In one embodiment, the baffle cup **113** is inserted into its respective manifold tube using a rod fixture of calibrated length to correctly position the baffle cup. In a preferred embodiment of the invention, an error proofing hole **117** is provided through the wall of the manifold tubes **12'**, **14'** in alignment with the location where the baffle cup **12** should be positioned once installed. As seen in **FIG. 19**, the error proofing hole **117** is positioned to align with and be covered by the baffle cup wall **115** when the baffle cup is mounted in the manifold tube **12'**, **14'**. The error proofing hole **117** provides for a visual check to ensure the baffle cup is in place as an operator can look into the hole to ensure that it is blocked by wall **115**. The error proofing hole **117** also provides a functional check as a test fluid fed into the manifold tube will leak out of the hole if the baffle cup **112** is not sealably in place. It will be appreciated that the baffle **112** and error proofing hole **117** combination could be used for flat plate tube heat exchanger configurations other than the expanded manifold tube configuration of the present invention.

[**0081**] The heat exchanger of the present invention could be divided into separate sub-heat exchangers using configurations other than the baffle cup divided configuration shown in **FIG. 17**. In this regard, **FIGS. 20 and 21** illustrate yet another embodiment of a heat exchanger **126** of the present invention. The heat exchanger **126** is similar to the heat exchanger **10** described above, except for the differences noted below. Like the heat exchanger **10**, the heat exchanger **126** includes a stack of alternating flat tube elements **16(1)**-**16(4)** and fins **24**. However, the heat exchanger includes a pair of intake manifold tubes **12A** and **12B**, and a pair of out take manifold tubes **14A** and **14B**. As illustrated in **FIG. 21**, the manifold tubes **12A**, **12B**, **14A** and **14B** are each internally received through openings provided through each of the flat tube elements **16(1)-16(4)**. The intake manifold tubes **12A** and **12B** are slotted so that neither intake manifold tube is in flow communication with the same flow channel **21** through the same flat tube element, and similarly the out take manifold tubes **14A** and **14B** are slotted so that neither out take manifold tube is in flow communication with the same flow channel **21** through the same flat tube element. For example, in the illustrated embodiment, the first intake manifold **12A** receives a first fluid through an inlet port as indicated by arrow **128**. The first intake manifold **12A** has slots in communication with the flow channels through flat tube elements **16(1)** and **16(3)**, but does not include slots along the portions of its length that pass through flat tube elements **16(2)** or **16(4)**. Similarly the first out take manifold tube **14A** has slots in communication with the flow channels through flat tube elements **16(1)** and **16(3)**, but does not include slots along the portions of its length that pass through flat tube elements **16(2)** or **16(4)**, such that the first fluid passes from the first intake tube manifold **12A** through flat tube elements **16(1)** and **16(3)** to the first out take manifold **14A**, and out of the heat exchanger through an outlet port as indicated by arrow **134**.

[**0082**] Each of the second intake manifold tube **12B** and the second out take manifold tube **14B** have manifold slots **42** in communication with the flow channels through flat tube elements **16(2)** and **16(4)**, but not with alternating flat tube elements **16(1)** and **16(3)**. Thus, a second fluid can flow into the second intake manifold tube **12B** as indicated by arrow **130**, through the flat tube elements **16(2)** and **16(4)** into second out take tube manifold **14B**, and then out of the heat exchanger as indicated by arrow **132**. As best seen in **FIG. 21**, the inner manifold tubes **12B** and **14B** preferably have smaller diameters than the outer manifold tubes **12A** and **14A** in order to facilitate flow of the first fluid by the inner manifolds as indicated by arrows **136** and **138**. Conveniently, the manifold slots **42** on the inner manifold tubes **12B** and **14B** can be outwardly directed (i.e. towards the outer manifold tubes **12A** and **14A**) in order to force the second fluid to travel closer to the outer ends of the heat exchanger.

[**0083**] As noted above, the heat exchanger configuration of the present invention permits different fittings and brackets to be used. In this regard, **FIG. 22** illustrates yet another embodiment of a heat exchanger **178** of the present invention. The heat exchanger **178** is similar to the heat exchanger **10** described above, except that inlet and outlet ports **26** and **28** are replaced by differently configured inlet and outlet ports **182** (inlet port not shown in **FIG. 22**), and brackets **43** have been replaced by differently configured mounting brackets **180**.

[**0084**] The bracket **180** includes an L-shaped mounting plate **184** that is connected to a cylindrical wall forming a closed collar **186** that is sized to receive wall of a manifold tube **12** or **14** therein. **FIG. 23** shows a plan view of the bracket **180** having closed collar **186**. Other bracket configurations can be used in which an open snap-on style collar is used. For example **FIG. 24** shows a further bracket **188** having a hook shaped open collar **190** for engaging the manifold tube between two flat tube elements, and **FIG. 25** shows a bracket **192** having a Y-shaped open collar having opposed semi-circular portions **194** for engaging the manifold tube. The hook shaped collar **190** and collar portions **194** are preferably braze clad and appropriately dimensioned and sufficiently resilient so that the brackets **188**, **192** can be snapped on the manifold tube at a desired location and will stay in place until brazing. Alternatively, the collar **190** and collar portions **194** could be crimped to secure them in place.

[**0085**] Turning again to **FIG. 22**, as indicated above, an alternative port fitting **182** is shown mounted to the manifold tube **14**. The port fitting **182**, which can function as either an inlet or outlet port, is shown in sectional plan view and elevational view, respectively, in **FIGS. 26 and 27**. Fitting **182** includes an annular collar **200** for receiving the manifold tube **12** or **14**. The collar **200** includes a cylindrical wall **202** that is capped on opposite ends thereof by disk-like end plates **204** and **206**, each of which has a circular opening **208** therethrough for receiving the manifold tube **12** or **14**. The inner surfaces of the cylindrical wall **202** and end plates **204**,**206** collectively define an internal cavity **210** through which the manifold **12** or **14** passes. The internal cavity **210** has diameter, transverse to the longitudinal axis of tube manifold **12**,**14**, that, is greater than the diameter of the tube manifold **12**, **14** such that an annular flow passage **212** is defined between the tube manifold **12**,**14** and the inner surface of wall **202**. A cylindrical connecting member **214** extends radially from the outer surface of the collar wall **202**, and the connecting member **214** defines an fluid flow passage **216** that is in flow communication, through an opening **218** provided in the wall **202**, with the annular flow passage **212**. A frustal-conical flange is provided at an extending end of the connecting member **216** for internally engaging a connector hose or like flow passage connected to the connecting member **216**.

[**0086**] The port fitting **182** is intended to be used in conjunction with a manifold tube **12**,**14** having a plurality of radially spaced flow openings **222** provided therethrough which are each in flow communication with the annular passage **212**. The port fitting and manifold tube combination of **FIGS. 22, 26** and **27** permits fluid to be forced into or drawn from multiple locations about the radius of the manifold tube, providing improved flow management in some heat exchanger applications. The annular collar **200** preferably has a height that corresponds to the spacing between two flat tube elements **16** so that it can fit between adjacent tube elements as shown in **FIG. 22**.

[**0087**] **FIG. 28** shows a further embodiment of a port fitting, indicated generally by reference **224**, that is similar to port fitting **182** except that it is a banjo-type fitting adapted for use at the end of a manifold tube **12**,**14**. In such configuration, an opening **208** for receiving the tube manifold **12** or **14** is only provided at an one end plate (plate **204** in the **FIG. 28**), and the other end plate (end plate **206** in **FIG. 28**) is sealed and acts as a stop for engaging an end of the manifold tube **12**,**14**. In banjo-type fitting, openings **22** could be spaced apart from the end of the manifold tube as shown in **FIG. 28**, or could be notches formed about the radius of the bottom of the tube.

[**0088**] In some embodiments where the fitting **182** is to be used between two adjacent flat tube elements **16** that each encircle the manifold tubes, integral top plates **204** and **206** may be omitted from the collar **200**, and functionally replaced by the facing surfaces of the two adjacent flat tube elements **16**.

[**0089**] In some embodiments, the collar **200** and passage **212** may extend only partially around the manifold tube. In some embodiments, the collar **200** could be secured in place prior to brazing by radial expansion of the manifold tube. In some embodiments, the collar could be formed from a non-metal such as a polymer material and secured by epoxy or other adhesive. It will be appreciated that the collar fitting and manifold tube combination of **FIGS. 26 and 27** could be used in heat exchangers having a variety of different configurations, including for example conventional stacked plate exchangers in which the plate ends are received within the manifold tubes.

[**0090**] The flat tube elements **16** have been described as comprising two separate opposing plates **18**, **20** that are joined together by brazing along their respective edges. It will be appreciated that flat tube elements in which the opposing plates are formed in another manner can be used in the present invention. By way of example, **FIGS. 29 and 30** illustrate partial sectional perspective views of two further flat tube elements **16**A and **16**B, respectively, each of which defines a flow channel **21**. The first and second plates **18** and **20** of flat tube element **16**A are preferably roll formed longitudinally together as a single sheet with longitudinal flanges **252** and **254** provided along opposite side edges thereof. Apertures **48**, **50** for the manifold tubes (not shown in **FIG. 21**) are then pierced through each of the plates **18**, **20**, and the flange about the apertures extruded, after which the plates **18**, **20** are folded together about a common longitudinal edge **250** until the flanges **252** and **254** contact each other. With respect to the flat tube element **16**B, in such configuration the edges **256**, **258** joining the first and second plates **18**, **20** are seamless.

[**0091**] Although the heat exchanger **10** has been shown in its preferred embodiment as including a flange **64** about the apertures **48**, **50** in first and second plates **18**, **20**, in some applications a flangeless aperture may suffice, in which case a somewhat weaker butt joint rather than an overlap joint would be formed between the plates **18**, **20** and each of the manifold tubes **12**, **14**. Furthermore, in some embodiments, the annular flow path **23** may not be present about the entire circumference of the manifold tubes.

[**0092**] The heat exchangers of the present invention as described above have each included corrugated fins **24** located between adjacent flat tube elements **16**. In some embodiments, such fins may be omitted, or replaced with ribs or other protrusions formed on the flat tube elements **16**. In embodiments where the fins are omitted, spacing between the adjacent flat tube elements **16** may be provided by enlarged bosses around the apertures, such as the enlarged annular area **110** as shown in **FIG. 15**. In some fin-less embodiments, removable spacers may be positioned between adjacent tube elements **16** to support them during assembly.

[**0093**] Another embodiment of a heat exchanger according to the present invention is shown in a simplified view indicated by reference number **270** in **FIG. 31**. The heat exchanger **270** is similar in construction and operation to the heat exchanger **10** as described above except for the differences noted below. In heat exchanger **10**, the manifold tubes **21** and **14** are connected by a bypass tube **272** through which fluid can flow directly from one manifold tube to the other, bypassing the core stack **108**. A calibrated baffle **274** or other flow control means such as a thermostatically actuated valve can be located in the bypass tube **272** to control flow therethrough. The tubes **12**, **14**, and **272** may be integrally formed as a single U-shaped unit.

[**0094**] In some embodiments, only a single expanded manifold tube may be used, with the second manifold having a different configuration, such as, for example, the cup configuration shown in U.S. Pat. No. 5,634,518 issued Jun. 3, 1997.

[**0095**] The above description has anticipated that the heat exchanger components are made out of metal. However, other materials such as plastics or other polymers could be used in some applications for all or some of the heat exchanger components. In a polymer embodiment, manifold tubes may be thermally expanded rather than or in addition to being pressure expanded. Alternatively, the manifold tube may not be expanded, but a friction fit between the flat plate tube element and the manifold tubes used in combination with bonding effected, for example, thermally, ultrasonically, or through the use a bonding agent or adhesive.

[**0096**] The heat exchanger of the present invention can be adapted for a number of different applications for use, among other things, in automobiles, recreational vehicles, and fuel cell thermal management systems. In addition to the transmission oil and power steering fluid cooling applications mentioned above in respect of heat exchanger **10**, the present invention can be adapted for use in, among other things, engine oil cooling, hydraulic fluid cooling (which requires high pressure strength) and air conditioning applications (for both evaporator and condenser applications). Selective variable manifold tube slot size and positioning can be particularly helpful in evaporator applications where flow distribution sensitivity is high.

[0097] It will also be apparent to those skilled in the art that in light of the foregoing disclosure, many other alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. Accordingly, the scope of the invention is to be construed in accordance with the substance defined in the following claims.

What is claimed is:

1. A heat exchanger comprising:

a manifold tube having a wall defining a flow passage therethrough and having a plurality of longitudinally spaced apart openings formed through the wall in flow communication with the flow passageway; and

a plurality of flat tube elements located along a longitudinal axis of the manifold tube, each including a first plate and a second plate defining a flow channel therebetween, the plates each being provided with an aperture therethrough, the apertures in the first and second plates of each of the tube elements being substantially in alignment with each other, the manifold tube being received through the apertures in the first and second plates of each of the flat tube elements with each of the spaced apart openings in flow communication with the flow channel of a respective one of the flat tube elements;

the wall of the manifold tube and the apertures being respectively sized that an outer surface of the manifold tube engages an inner surface surrounding the aperture in each of the first and second plates to secure the flat tube elements to the manifold tube, the flat tube elements being supported by the manifold tube.

2. The heat exchanger of claim 1 wherein the manifold tube is radially expanded at least along portions thereof where the outer surface engages the first and second plates of the flat tube elements.

3. The heat exchanger according to claim 1 wherein the inner surface of the aperture in the first and second plates that is engaged by the wall of the manifold tube is defined by an integral peripheral flange extending outward from the plate such that an overlap joint is formed between the wall and the peripheral flange, and the wall is brazed to the peripheral flange of each of the plates to seal a juncture therebetween.

4. The heat exchanger according to claim 1 wherein the first and second plates each have a substantially planar elongate central portion surrounded by a planar edge portion inwardly offset from and parallel to the planar central portion, the first and second plates of each flat tube element being joined together with the planar central portions spaced apart from each other to define the flow channel and the offset edge portion of the first plate abutting against the offset edge portion of the second plate.

5. The heat exchanger or claim 1 wherein, in at least some of the flat tube elements, the first plates and second plates are identical to each other.

6. The heat exchanger according to claim 1 wherein the flat tube elements are spaced apart from each other defining lateral passageways therebetween, and including fins located in the lateral passageways and in thermal contact with the flat tube elements.

7. The heat exchanger of claim 1 wherein the spaced apart openings include openings of more than one size.

8. The heat exchanger of claim 1 wherein the spaced apart openings are progressively larger along a length of the manifold tube.

9. The heat exchanger of claim 1 including at least one flat tube element having a flow channel that is in flow communication with the flow passage of the manifold tube through a plurality of radially spaced openings formed through the manifold tube wall.

10. The heat exchanger of claim 1 wherein the flat tube elements are spaced apart from each other and the spacing distance between the flat tube elements varies along the manifold tube.

11. The heat exchanger of claim 1 wherein the flow passage through the manifold tube is divided into first and second flow chambers with some of the flat tube elements being in flow communication with the first chamber and others of the flat tube elements being in flow communication with the second flow chamber.

12. The heat exchanger of claim 11 wherein a baffle cup located within the manifold tube divides the manifold tube into the first and second flow chambers, the baffle cup having a cylindrical wall having an outer surface in engagement with an inner surface of the manifold tube wall.

13. The heat exchanger of claim 12 wherein an error proofing opening is provided through the manifold tube wall at a location where the wall of the baffle cup overlaps the manifold tube wall, the error proofing opening being sized to permit visual confirmation of the presence of the wall of the baffle cup.

14. The heat exchanger of claim 1 including a mounting bracket having a collar engaging the manifold tube between two adjacent flat tube elements.

15. The heat exchanger of claim 1 wherein at least some of the flat tube elements include first and second plates having portions that are spaced further apart from each other closer to the manifold tube than further from the manifold tube to define a higher flow channel, relative to the longitudinal axis of the manifold tube, nearer the manifold tube than further from the manifold tube.

16. The heat exchanger of claim 1 including a port fixture mounted to the manifold tube, the port fixture defining a flow passageway that is in flow communication, through a port opening in the manifold, with the flow passage through the manifold tube, the port fixture including a collar surrounding an annular area of the manifold tube.

17. The heat exchanger of claim 16 wherein the collar of the port fixture defines an annular fluid flow way about the annular area of the manifold tube, the annular area having a plurality of radially spaced openings through which the annular fluid flow way is in flow communication with the flow passage through the manifold tube.

18. The heat exchanger of claim 17 wherein the collar is located between two adjacent flat tube elements.

19. The heat exchanger of claim 17 wherein the port fixture is a banjo-type fitting and the collar engages an end of the manifold tube.

20. The heat exchanger of claim 1 wherein the outer surface of the manifold tube engages substantially an entire

circumference of the inner surface of the aperture in each of the plates in a butt-joint fashion.

21. The heat exchanger of claim 1 including a further manifold tube having a wall defining a flow passage therethrough and having a plurality of spaced apart openings formed through the wall in flow communication with the flow passageway, each of the plurality of first and second plates being provided with a further aperture therethrough, the manifold tube being received through the further apertures in the first and second plates of each of the flat tube elements with each of the spaced apart openings through the further manifold tube in flow communication with the flow channel of a respective one of the flat tube elements, the wall of the further manifold tube and the further apertures being respectively sized that an outer surface of the further manifold tube engages an inner surface surrounding the further aperture in each of the first and second plates to secure the flat tube elements to the further manifold tube, the flat tube elements being supported by the manifold tube and the further manifold tube;

the heat exchanger further including a inlet port in flow communication with the flow passage through the manifold tube, and an outlet port in flow communication with the flow passage through the further manifold tube.

22. The heat exchanger of claim 21 wherein the manifold openings though the manifold tube and the further manifold tube are inwardly oriented towards each other.

23. The heat exchanger of claim 21 wherein the manifold openings through the manifold tube and the further manifold tube are outwardly oriented away from each other.

24. The heat exchanger of claim 21 wherein the manifold tubes are joined together by a bypass manifold tube.

25. The heat exchanger of claim 24 wherein the bypass manifold tube includes fluid flow control means for controlling the flow of fluid therethrough.

26. The heat exchanger of claim 21 further including:

third and fourth elongate spaced-apart manifold tubes each having a wall defining a flow passage therethrough and having a plurality of longitudinally spaced apart manifold openings formed through the wall in flow communication with the flow passageway;

the first and second plates of the flat tube elements each having aligned third and fourth apertures therethrough receiving the third and fourth manifold tubes respectively,

a plurality of further flat tube elements including a first plate and a second plate defining a flow channel therebetween, the plates of the further flat tube elements each being provided with respectively aligned first, second third and fourth apertures therethrough receiving the manifold tube, the further manifold tube and the third and fourth manifold tubes respectively, the flow channel of each of the further flat tube elements being in communication at a first portion thereof with the flow passage of the third manifold tube through a respective one of the manifold openings in the third manifold tube and at a second portion thereof with the flow passage of the fourth manifold tube through a respective one of the manifold openings in the fourth manifold tube;

the wall of the third manifold tube being enlarged at least along portions thereof such that an outer surface of the third manifold tube engages an inner surface surrounding the third aperture in each of the first and second plates of the further flat tube element to secure the further flat tube elements to the third manifold tube, the wall of the fourth manifold tube being enlarged at least along portions thereof such that an outer surface of the fourth manifold tube engages an inner surface surrounding the fourth aperture in each of the first and second plates of the further flat tube element to secure the further flat tube elements to the fourth manifold tube,

the flat tube elements and further flat tube elements being interspersed adjacent each other.

27. The heat exchanger of claim 1 wherein the manifold tubes and flat tube elements are formed from polymers.

28. A method of assembling a stacked plate heat exchanger, comprising:

(a) providing a manifold tube having a wall defining a flow passage therethrough and having a plurality of longitudinally spaced apart openings formed through the wall along a length thereof in flow communication with the flow passageway;

(b) providing a plurality of flat tube elements each including a first plate and a second plate defining a flow channel therebetween, the plates each being provided with an aperture therethrough, the apertures in the first and second plates of each of the flat tube elements being substantially in alignment with each other;

(c) positioning the-manifold tube-through the apertures in the first and second plates of each of the flat tube elements with each of the spaced apart openings in flow communication with the flow channel of a respective one of the flat tube elements; and

(d) radially expanding at least portions of the manifold tube such that manifold tube engages each of the first and second plates about the apertures thereof to secure the flat tube elements to the manifold tube.

29. The method of claim 28 wherein the flat tube elements are braze clad, and further including, subsequent to expansion step (d), applying heat to the manifold tube and flat tube elements to seal a joint between each of the first and second plates and the manifold tube.

30. The method of claim 28 wherein step (b) includes providing an integral peripheral flange around the apertures of the first and second plates, the peripheral flange of each aperture defining a circumference that is engaged by the radially expanded manifold tube.

31. The method of claim 28 wherein the manifold tube is radially expanded substantially uniformly along substantially an entire length thereof.

32. The method of claim 28 wherein the manifold tube is selectively radially expanded in a vicinity of each of the flat tube elements.

33. The method of claim 28 wherein the manifold tube is radially expanded using a hydraulic bladder.

34. The method of claim 28 including providing fins between and in thermal contact with adjacent flat tube elements.

35. The method of claim 34 including assembling a core stack by aligning stacked alternating flat tube elements and fins to a desired height with the apertures in alignment and subsequently inserting the manifold tube through the aligned apertures.

36. The method of claim 34 including assembling a core stack by building up flat tube elements on the manifold tube.

37. The method of claim 34 including compressing a core stack comprising the flat tube elements and the fins prior to radially expanding the manifold tube.

38. The method of claim 28 wherein said step (b) of providing a plurality of flat tube elements includes roll forming substantially identical first and second plates each with a central planer portion having longitudinal edge flanges provided along both longitudinal side edges thereof for joining the first and second plates together; cutting the roll formed first and second plates at a desired length and forming ends thereon, and piercing the apertures through the first and second plates.

39. A heat exchanger comprising a manifold tube having a wall defining a fluid flow passage therethrough; a stack of flat tube elements connected to the manifold tube and each having a flow channel therethrough in fluid communication with the fluid flow passage; and a baffle cup having a wall engaging an inner surface of the manifold tube wall, the manifold tube wall having an error proofing hole formed therethrough at a location where the baffle cup wall is positioned, the hole being sized such that a visual check can be performed to ensure that the baffle cup is in place, the error proofing hole being sealably covered by the wall of the baffle cup.

40. A heat exchanger comprising a manifold tube having a wall defining a fluid flow passage therethrough; a stack of flat tube elements connected to the manifold tube and each having a flow channel therethrough in flow communication with the fluid flow passage; and a port fixture having a collar providing a flow way surrounding at least a portion of the manifold tube wall having a plurality of spaced openings formed therethrough, the flow way being in flow communication with the fluid flow passage through the spaced openings, the port fixture having a connecting member extending from the collar and defining a fluid passageway in flow communication with the flow way.

41. The heat exchanger according to claim 40 wherein the collar includes an annular wall having a first end wall formed at one end thereof and a second end wall formed at an opposite end thereof, the first and second end walls each having an opening therethrough through which the manifold tube passes, the annular wall and first and second end walls defining the flow way.

42. The heat exchanger according to claim 40 wherein the port fixture is a banjo-type fitting, and the collar includes an annular wall having a first end wall formed at one end thereof and a second end wall formed at an opposite end thereof, the first end wall having an opening therethrough through which the manifold tube passes, an end of the manifold tube being positioned within the collar, the annular wall and first and second end walls defining the flow way.

43. The heat exchanger according to claim 40 wherein the manifold tube passes internally through openings provided through the flat tube elements and the collar of the port fixture includes an annular wall having a first end that is sealably engaged by an annular portion of one of the flat tube elements surrounding the manifold tube, and a second end that is sealably engaged by an annular portion of a further one of the flat tube elements surrounding the manifold tube, the annular wall and said annular portions defining the flow way.

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