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(54) HEAT EXCHANGER WITH FLUID EXPANSION IN HEADER

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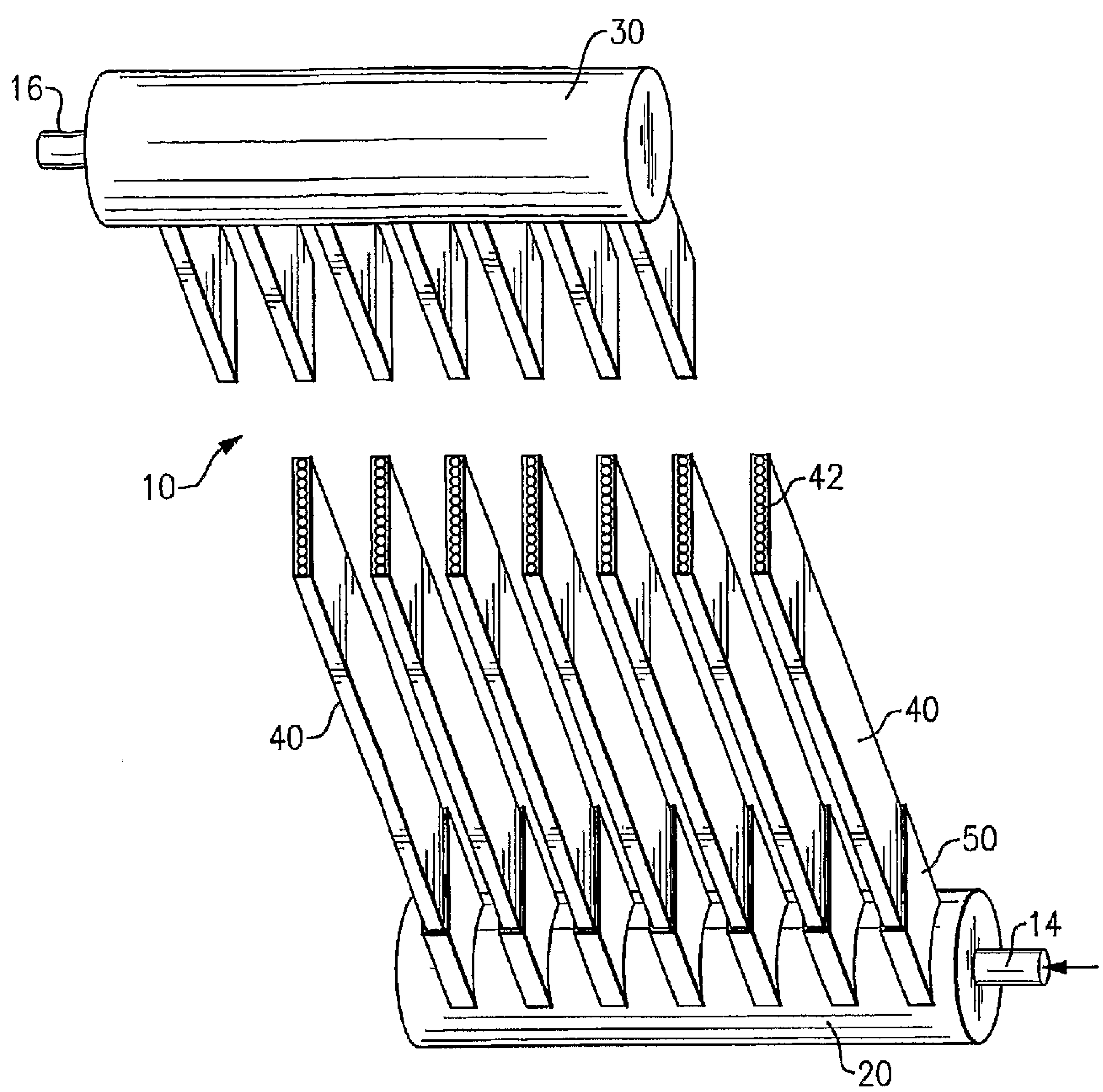
(57) **ABSTRACT**

A heat exchanger includes a plurality of flat, multi-channel heat exchange tubes extending between spaced headers. Each heat exchange tube has a plurality of flow channels extending longitudinally in parallel relationship from its inlet end to its outlet end. A plurality of connectors are positioned between the inlet header and the heat transfer tubes such that the connector inlet ends are in fluid flow communication with the header through a relatively small cross-sectional flow area openings and the connector outlet ends are adapted to receive the inlet end of a heat exchanger tube. The connector defines a fluid flow pathway from the relatively small cross-sectional flow area opening in the inlet end of the connector to an outlet opening in the outlet end of the connector that opens to the flow channels of the heat exchange tube received in the outlet end of the connector.



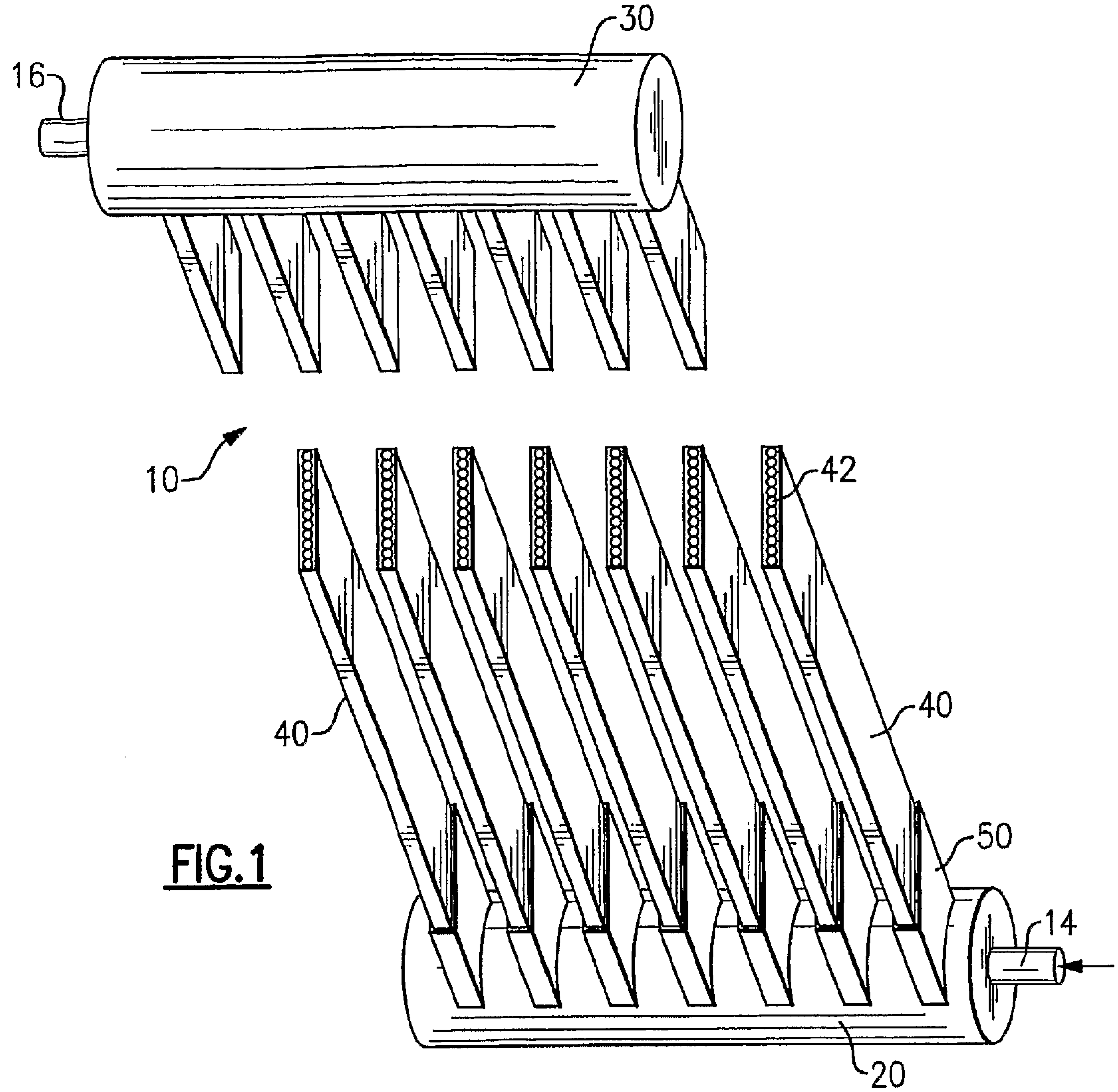


FIG.1

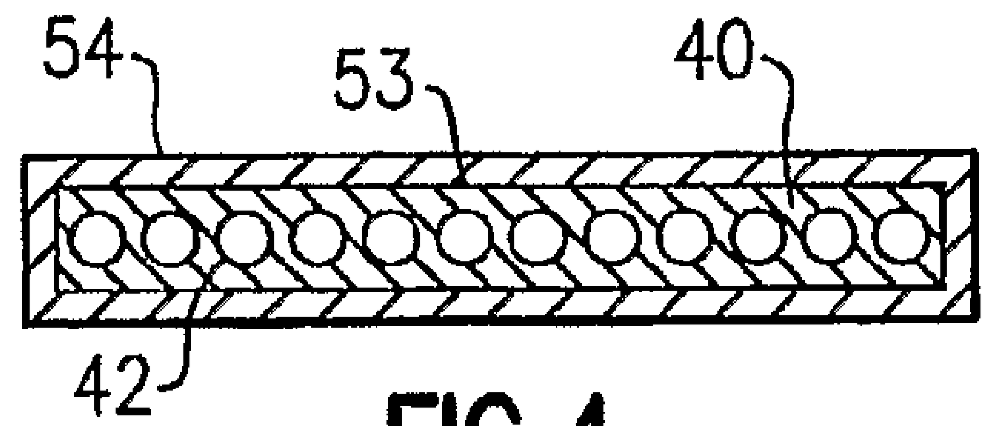


FIG.4

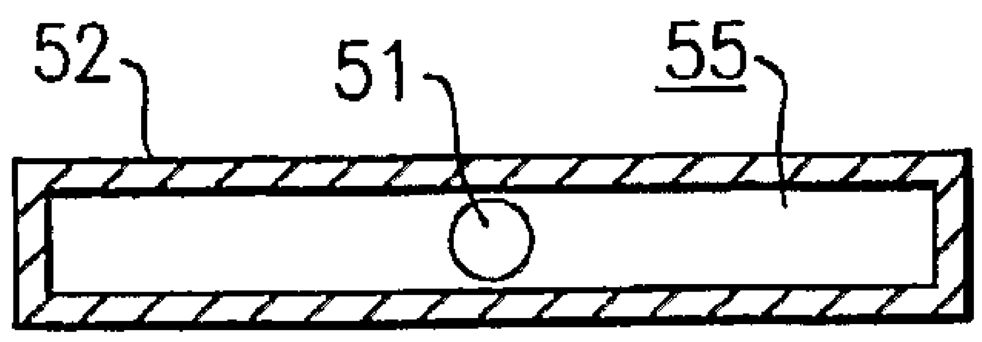


FIG.5

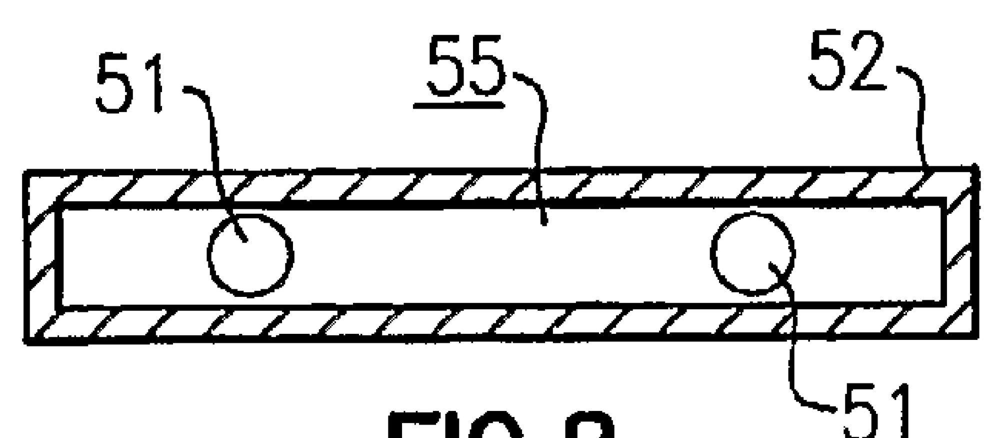


FIG.8

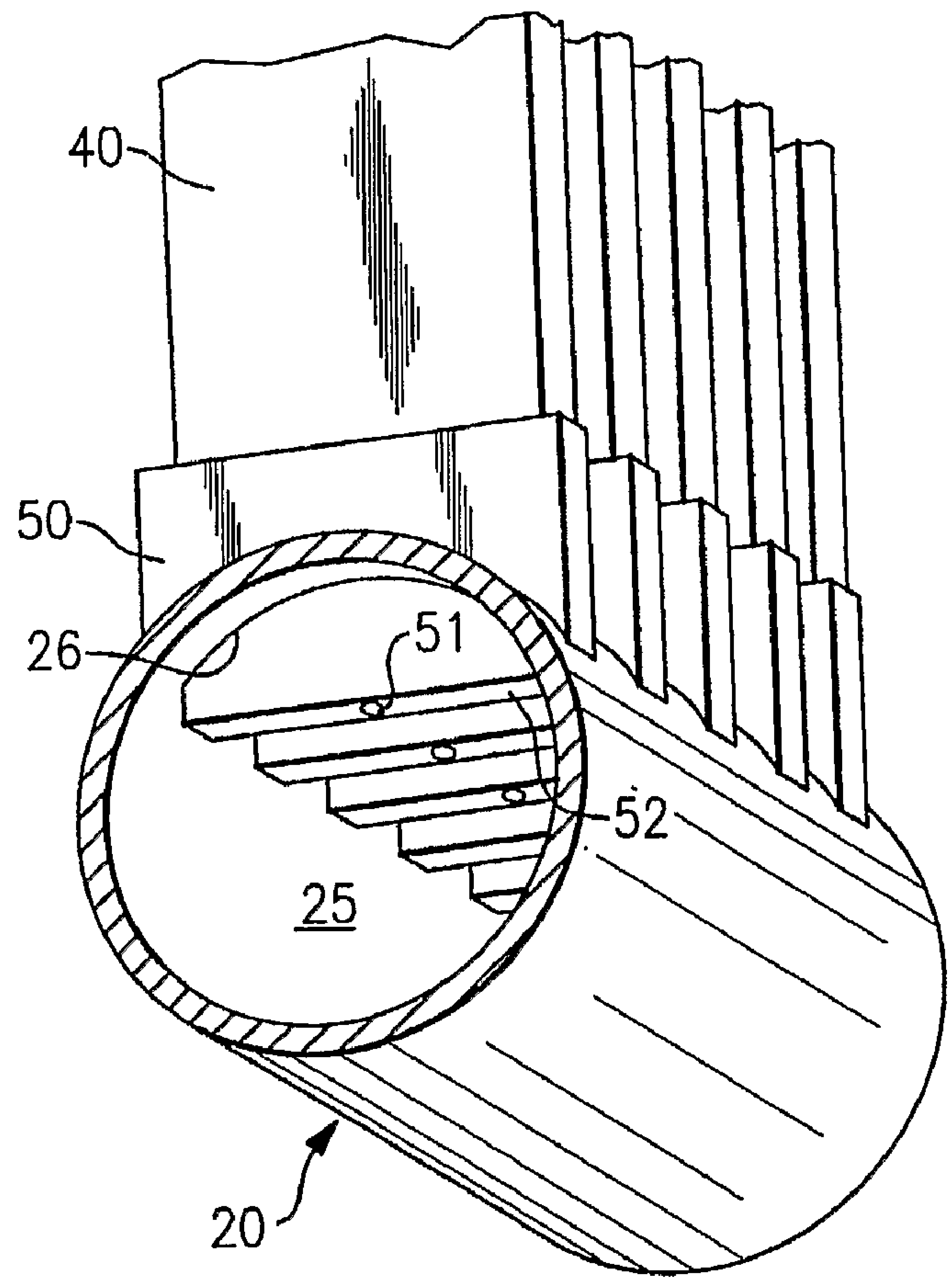


FIG.2

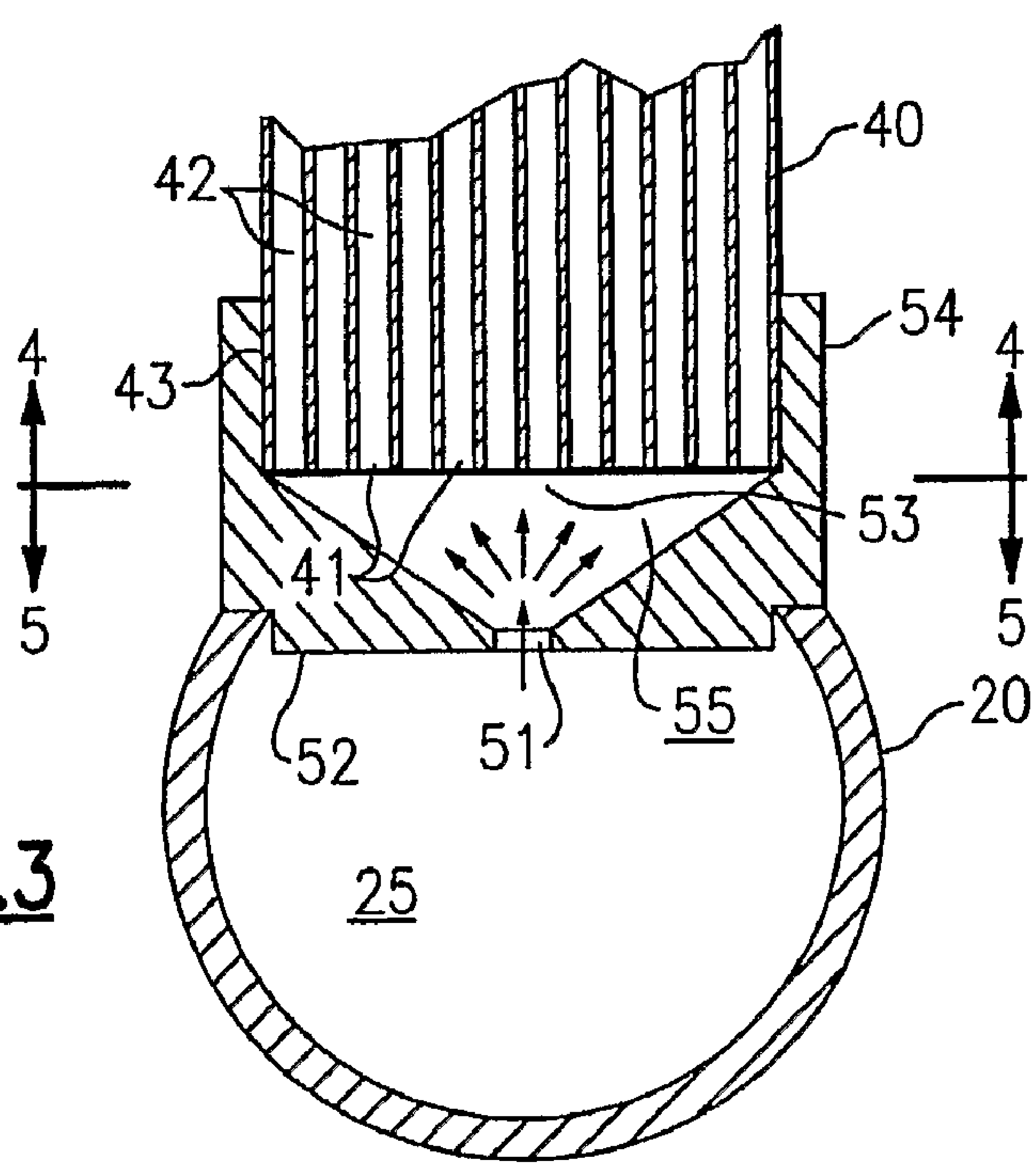


FIG.3

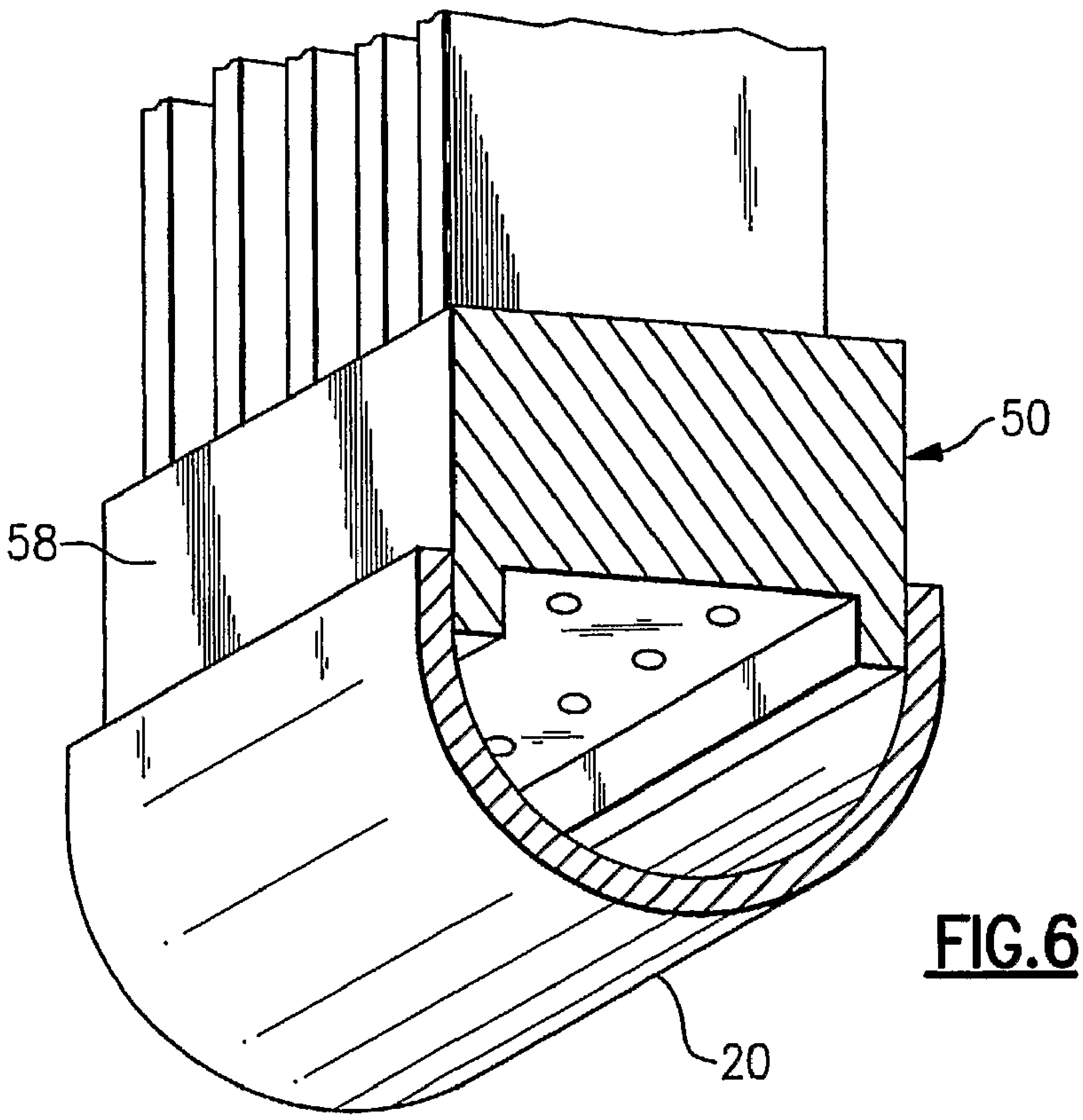


FIG.6

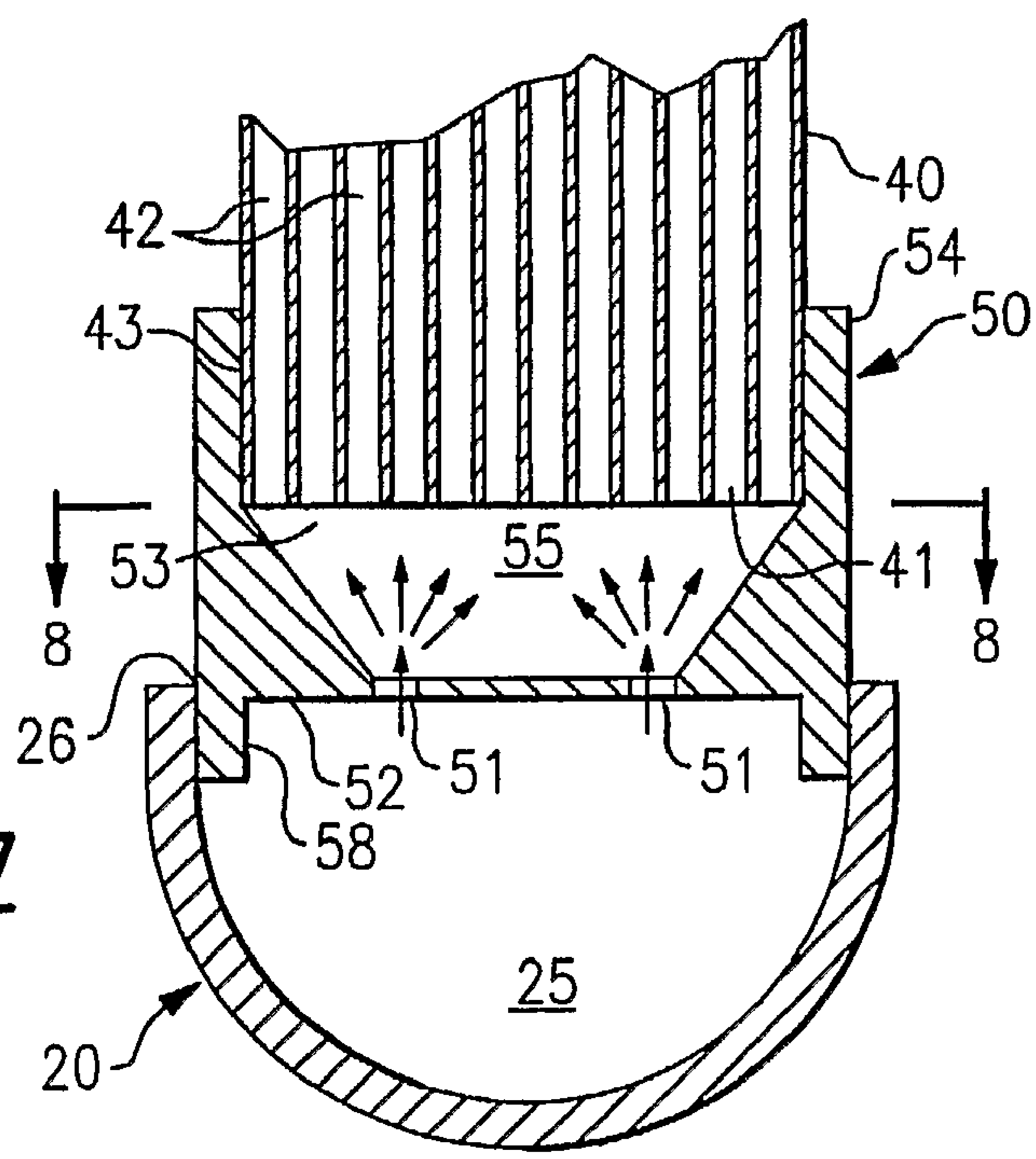


FIG.7

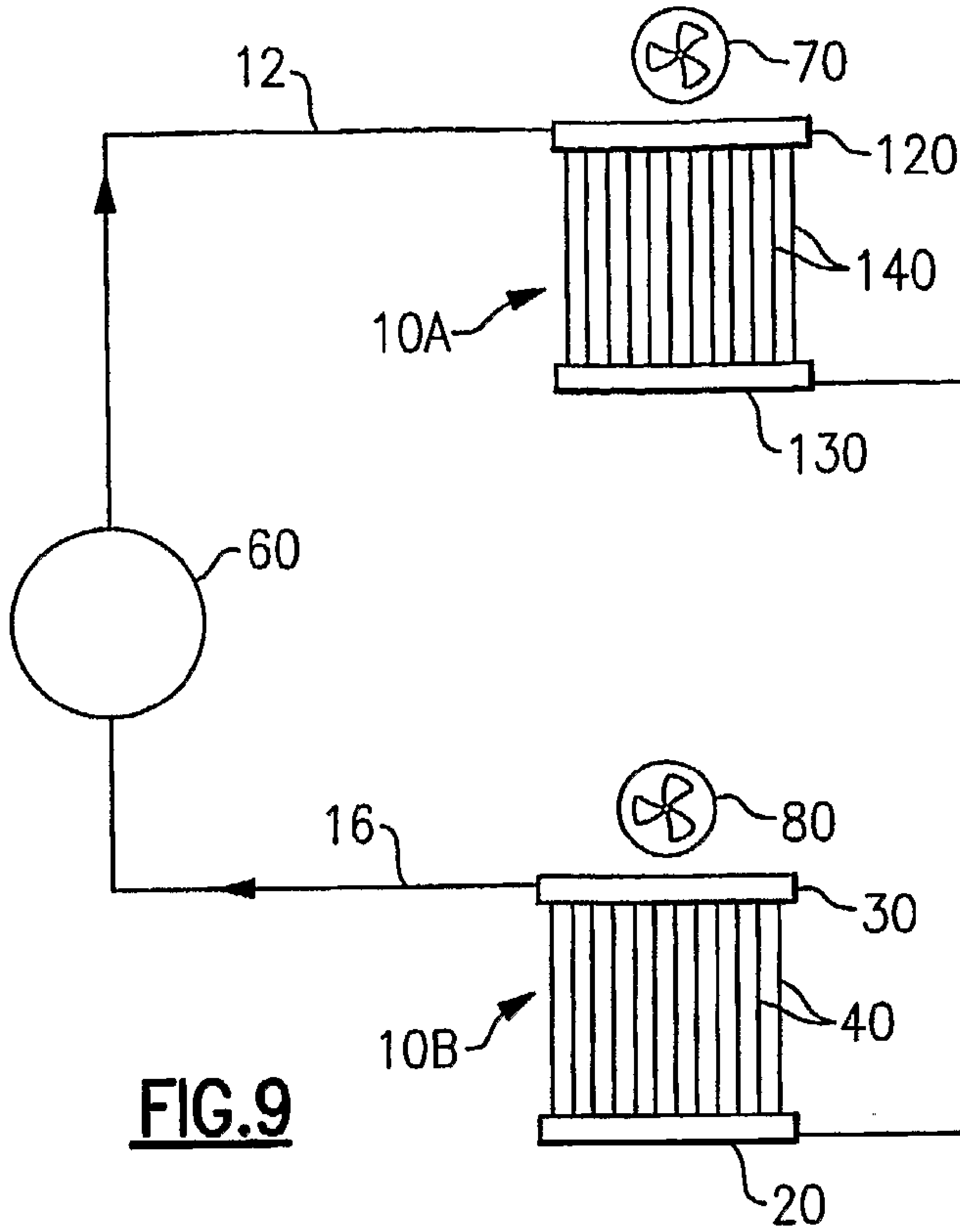

12
70
120
140
10A
130
60
14
16
80
30
40
10B
20

FIG.9

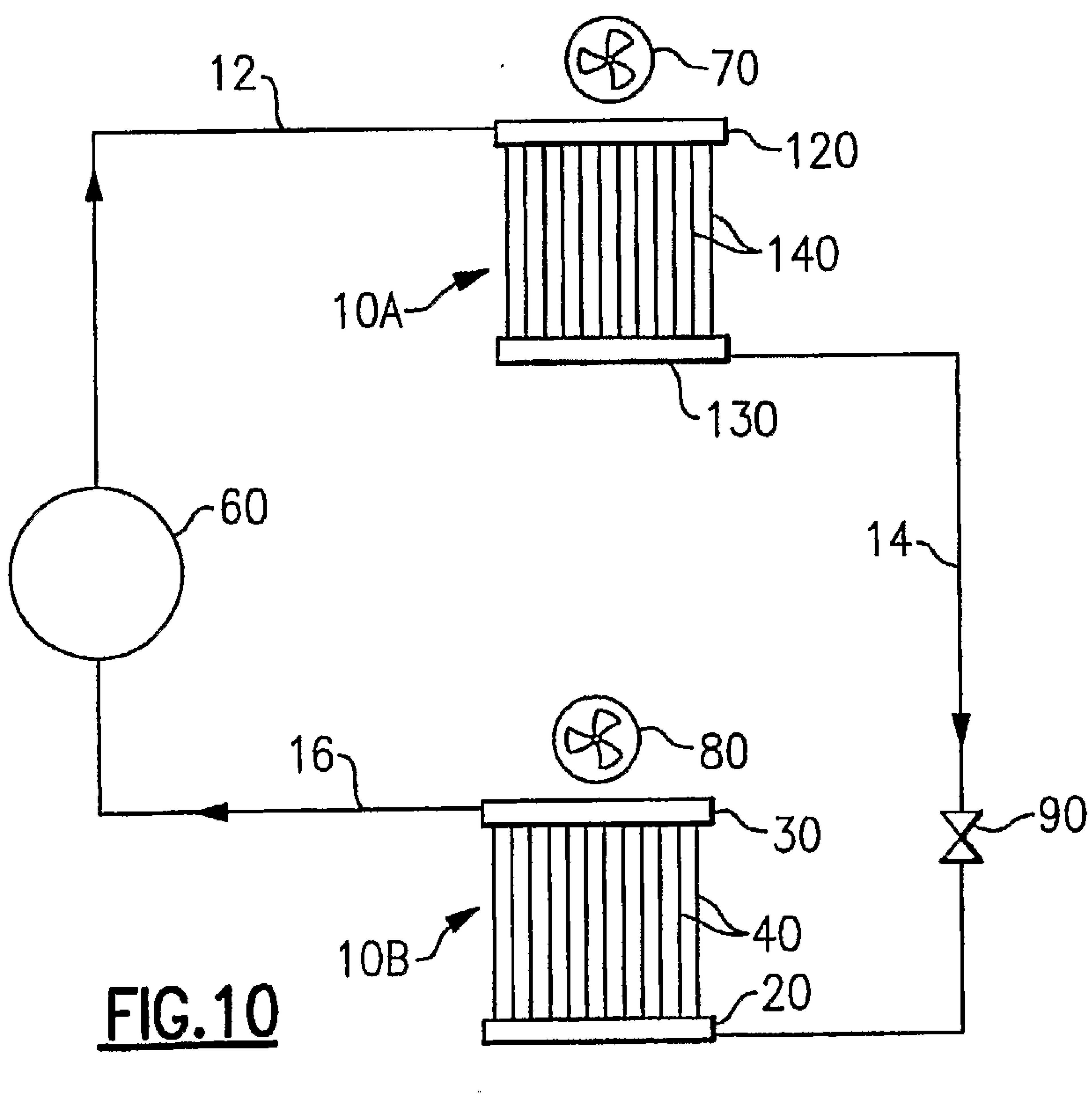

12
70
120
140
10A
130
60
14
16
80
30
90
40
10B
20

FIG.10

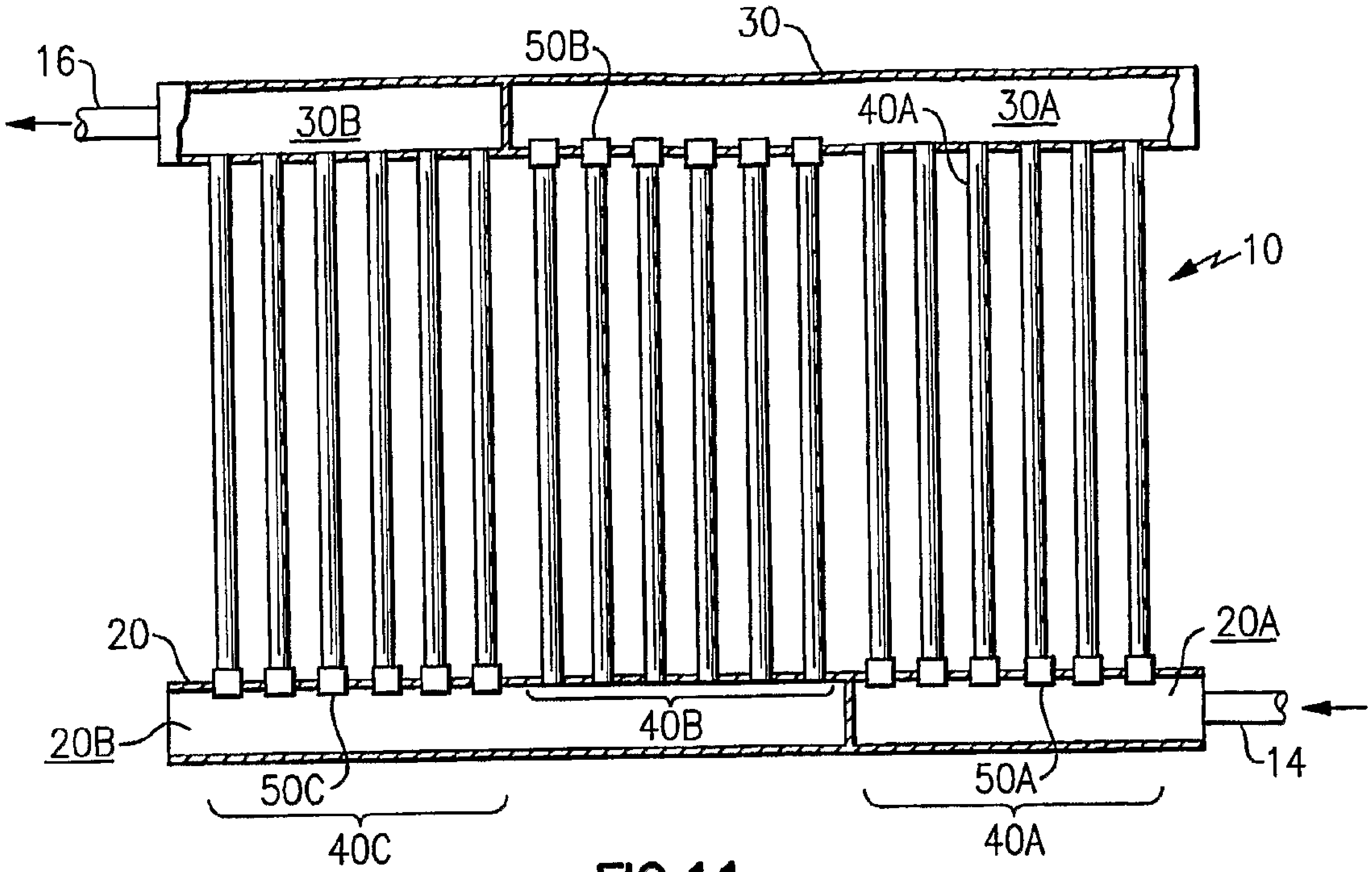

16
30
50B
30B
40A
30A
10
20
20A
20B
40B
14
50C
50A
40C
40A

FIG.11

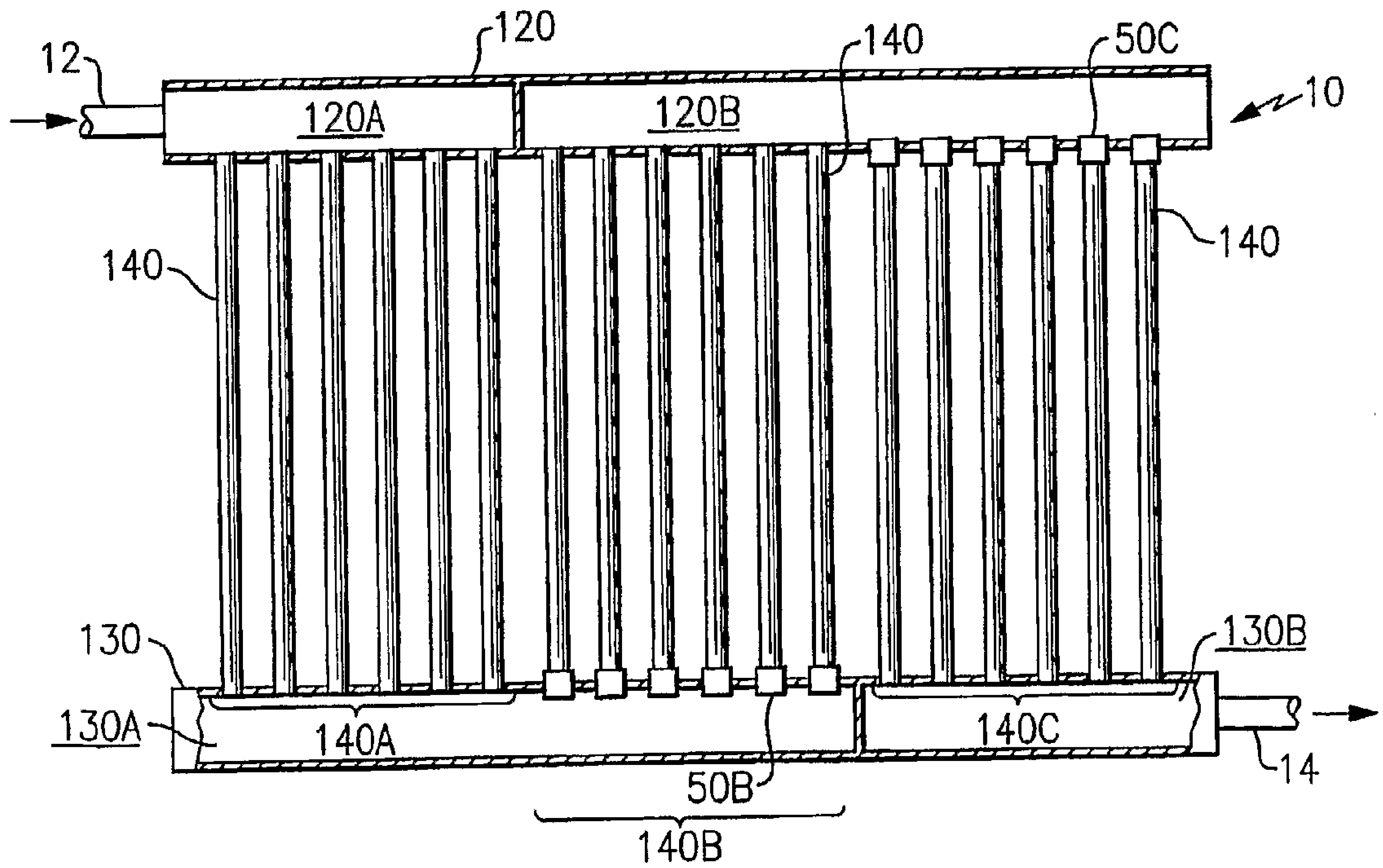

12
120
140
50C
10
120A
120B
140
140
130
130B
130A
140A
140C
14
50B
140B

FIG.12

HEAT EXCHANGER WITH FLUID EXPANSION IN HEADER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] Reference is made to and this application claims priority from and the benefit of U.S. Provisional Application Ser. No. 60/649,269, filed Feb. 2, 2005, and entitled MINI-CHANNEL HEAT EXCHANGER WITH EXPANSION CONNECTOR, which application is incorporated herein in its entirety by reference.

FIELD OF THE INVENTION

[0002] This invention relates generally to heat exchangers having a plurality of parallel tubes extending between a first header and a second header, also sometimes referred to as manifolds, and, more particularly, to providing fluid expansion within the header of a heat exchanger for improving distribution of two-phase flow through the parallel tubes of the heat exchanger, for example a heat exchanger in a refrigerant compression system.

BACKGROUND OF THE INVENTION

[0003] Refrigerant vapor compression systems are well known in the art. Air conditioners and heat pumps employing refrigerant vapor compression cycles are commonly used for cooling or cooling/heating air supplied to a climate controlled comfort zone within a residence, office building, hospital, school, restaurant or other facility. Refrigeration vapor compression systems are also commonly used for cooling air or other secondary fluid to provide a refrigerated environment for food items and beverage products within, for instance, display cases in supermarkets, convenience stores, groceries, cafeterias, restaurants and other food service establishments.

[0004] Conventionally, these refrigerant vapor compression systems include a compressor, a condenser, an expansion device, and an evaporator connected in refrigerant flow communication. The aforementioned basic refrigerant system components are interconnected by refrigerant lines in a closed refrigerant circuit and arranged in accord with the vapor compression cycle employed. An expansion device, commonly an expansion valve or a fixed-bore metering device, such as an orifice or a capillary tube, is disposed in the refrigerant line at a location in the refrigerant circuit upstream, with respect to refrigerant flow, of the evaporator and downstream of the condenser. The expansion device operates to expand the liquid refrigerant passing through the refrigerant line running from the condenser to the evaporator to a lower pressure and temperature. In doing so, a portion of the liquid refrigerant traversing the expansion device expands to vapor. As a result, in conventional refrigerant vapor compression systems of this type, the refrigerant flow entering the evaporator constitutes a two-phase mixture. The particular percentages of liquid refrigerant and vapor refrigerant depend upon the particular expansion device employed and the refrigerant in use, for example R12, R22, R134a, R404A, R410A, R407C, R717, R744 or other compressible fluid.

[0005] In some refrigerant vapor compression systems, the evaporator is a parallel tube heat exchanger. Such heat exchangers have a plurality of parallel refrigerant flow paths therethrough provided by a plurality of tubes extending in parallel relationship between an inlet header and an outlet header. The inlet header receives the refrigerant flow from the refrigerant circuit and distributes it amongst the plurality of flow paths through the heat exchanger. The outlet header serves to collect the refrigerant flow as it leaves the respective flow paths and to direct the collected flow back to the refrigerant line for a return to the compressor in a single pass heat exchanger or through an additional bank of heat exchange tubes in a multi-pass heat exchanger.

[0006] Historically, parallel tube heat exchangers used in such refrigerant compression systems have used round tubes, typically having a diameter of ½ inch, ⅜ inch or 7 millimeters. More recently, flat, rectangular or oval shape, multi-channel tubes are being used in heat exchangers for refrigerant vapor compression systems. Each multi-channel tube has a plurality of flow channels extending longitudinally in parallel relationship the length of the tube, each channel providing a small cross-sectional flow area refrigerant path. Thus, a heat exchanger with multi-channel tubes extending in parallel relationship between the inlet and outlet headers of the heat exchanger will have a relatively large number of small cross-sectional flow area refrigerant paths extending between the two headers. In contrast, a parallel tube heat exchanger with conventional round tubes will have a relatively small number of large flow area flow paths extending between the inlet and outlet headers.

[0007] Non-uniform distribution, also referred to as maldistribution, of two-phase refrigerant flow is a common problem in parallel tube heat exchangers which adversely impacts heat exchanger efficiency. Two-phase maldistribution problems are caused by the difference in density of the vapor phase refrigerant and the liquid phase refrigerant present in the inlet header due to the expansion of the refrigerant as it traversed the upstream expansion device.

[0008] One solution to control refrigeration flow distribution through parallel tubes in an evaporative heat exchanger is disclosed in U.S. Pat. No. 6,502,413, Repice et al. In the refrigerant vapor compression system disclosed therein, the high pressure liquid refrigerant from the condenser is partially expanded in a conventional in-line expansion device upstream of the heat exchanger inlet header to a lower pressure refrigerant. Additionally, a restriction, such as a simple narrowing in the tube or an internal orifice plate disposed within the tube, is provided in each tube connected to the inlet header downstream of the tube inlet to complete the expansion to a low pressure, liquid/vapor refrigerant mixture after entering the tube.

[0009] Another solution to control refrigeration flow distribution through parallel tubes in an evaporative heat exchanger is disclosed in Japanese Patent No. JP4080575, Kanzaki et al. In the refrigerant vapor compression system disclosed therein, the high pressure liquid refrigerant from the condenser is also partially expanded in a conventional in-line expansion device to a lower pressure refrigerant upstream of a distribution chamber of the heat exchanger. A plate having a plurality of orifices therein extends across the chamber. The lower pressure refrigerant expands as it passes through the orifices to a low pressure liquid/vapor mixture downstream of the plate and upstream of the inlets to the respective tubes opening to the chamber.

[0010] Japanese Patent No. 6241682, Massaki et al., discloses a parallel flow tube heat exchanger for a heat pump wherein the inlet end of each multichannel tube connecting to the inlet header is crushed to form a partial throttle restriction in each tube just downstream of the tube inlet. Japanese Patent No. JP8233409, Hiroaki et al., discloses a parallel flow tube heat exchanger wherein a plurality of flat, multi-channel tubes connect between a pair of headers, each of which has an interior which decreases in flow area in the direction of refrigerant flow as a means to uniformly distribute refrigerant to the respective tubes. Japanese Patent No. JP2002022313, Yasushi, discloses a parallel tube heat exchanger wherein refrigerant is supplied to the header through an inlet tube that extends along the axis of the header to terminate short of the end the header whereby the two phase refrigerant flow does not separate as it passes from the inlet tube into an annular channel between the outer surface of the inlet tube and the inside surface of the header. The two phase refrigerant flow thence passes into each of the tubes opening to the annular channel.

[0011] Obtaining uniform refrigerant flow distribution amongst the relatively large number of small cross-sectional flow area refrigerant flow paths is even more difficult than it is in conventional round tube heat exchangers and can significantly reduce heat exchanger efficiency.

SUMMARY OF THE INVENTION

[0012] It is a general object of the invention to reduce maldistribution of fluid flow in a heat exchanger having a plurality of multi-channel tubes extending between a first header and a second header.

[0013] It is an object of one aspect of the invention to reduce maldistribution of refrigerant flow in a refrigerant vapor compression system heat exchanger having a plurality of multi-channel tubes extending between a first header and a second header.

[0014] It is an object of one aspect of the invention to distribute refrigerant to the individual channels of an array of multi-channel tubes in a relatively uniform manner.

[0015] It is an object of another aspect of the invention to provide for distribution and expansion of the refrigerant in a refrigerant vapor compression system heat exchanger having a plurality of multi-channel tubes as the refrigerant flow passes from a header to the individual channels of an array of multi-channel tubes.

[0016] In one aspect of the invention, a heat exchanger is provided having a header defining a chamber for receiving a fluid and at least one heat exchange tube having a plurality of fluid flow paths therethrough from an inlet end to an outlet end of the tube and having an inlet opening to the plurality of fluid flow paths. A connector has an inlet end in fluid flow communication with the chamber of the header through a first opening and an outlet end in fluid communication with the inlet opening of said at least one heat exchange tube through a second opening. The connector defines a fluid flow path extending from its inlet end to its outlet end. In an embodiment, the flow path through the connector may be divergent in the direction of fluid flow therethrough. The first opening has a relatively small flow area so as to provide a flow restriction through which fluid passes in flowing from the chamber of the header to the flow paths of the heat exchange tube.

[0017] In another aspect of the invention, a refrigerant vapor compression system includes a compressor, a condenser and an evaporative heat exchanger connected in refrigerant flow communication whereby high pressure refrigerant vapor passes from the compressor to the condenser, high pressure refrigerant liquid passes from the condenser to the evaporative heat exchanger, and low pressure refrigerant vapor passes from the evaporative heat exchanger to the compressor. The evaporative heat exchanger includes an inlet header and an outlet header, and a plurality of heat exchange tubes extending between the headers. The inlet header defines a chamber for receiving liquid refrigerant from a refrigerant circuit. Each heat exchange tube has an inlet end, an outlet end, and a plurality of fluid flow paths extending from an inlet opening at the inlet end to an outlet opening at the outlet end of the tube. A connector has an inlet end in fluid flow communication with the chamber of the inlet header through a first opening and has an outlet end in fluid flow communication through a second opening with the inlet opening of a heat exchange tube. The connector defines a fluid flow path extending from its inlet end to its outlet end. In an embodiment, the flow path through the connector may be divergent in the direction of fluid flow therethrough. The first opening has a relatively small cross-sectional flow area so as to provide a flow restriction through which fluid passes in flowing from the chamber of the header to the flow paths of the heat exchange tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] For a further understanding of these and objects of the invention, reference will be made to the following detailed description of the invention which is to be read in connection with the accompanying drawing, where:

[0019] FIG. **1** is a perspective view of an embodiment of a heat exchanger in accordance with the invention;

[0020] FIG. **2** is a perspective view, partly sectioned, taken along line **2-2** of FIG. **1**;

[0021] FIG. **3** is a sectioned elevation view taken along line **3-3** of FIG. **2**;

[0022] FIG. **4** is a sectioned view taken along line **4-4** of FIG. **3**;

[0023] FIG. **5** is a sectioned view taken along line **5-5** of FIG. **3**;

[0024] FIG. **6** is a perspective view, partly sectioned, of an another embodiment of a heat exchanger in accordance with the invention;

[0025] FIG. **7** is a sectioned view taken along line **7-7** of FIG. **6**;

[0026] FIG. **8** is a sectioned view taken along line **8-8** of FIG. **7**;

[0027] FIG. **9** is a schematic illustration of a refrigerant vapor compression system incorporating the heat exchanger of the invention;

[0028] FIG. **10** is a schematic illustration of another refrigerant vapor compression system incorporating the heat exchanger of the invention;

[0029] FIG. **11** is an elevation view, partly in section, of an embodiment of a multi-pass evaporator in accordance with the invention; and

[0030] FIG. **12** is an elevation view, partly in section, of an embodiment of a multi-pass condenser in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0031] The heat exchanger **10** of the invention will be described in general herein with reference to the illustrative single pass, parallel-tube embodiment of a multi-channel tube heat exchanger as depicted in FIG. **1**. In the illustrative embodiment of the heat exchanger **10** depicted in FIG. **1**, the heat exchange tubes are shown arranged in parallel relationship extending generally vertically between a generally horizontally extending inlet header **20** and a generally horizontally extending outlet header **30**. However, the depicted embodiment is illustrative and not limiting of the invention. It is to be understood that the invention described herein may be practiced on various other configurations of the heat exchanger **10**. For example, the heat exchange tubes may be arranged in parallel relationship extending generally horizontally between a generally vertically extending inlet header and a generally vertically extending outlet header. As a further example, the heat exchanger could have a toroidal inlet header and a toroidal outlet header of a different diameter with the heat exchange tubes extend either somewhat radially inwardly or somewhat radially outwardly between the toroidal headers. The heat exchange tubes may also be arranged in parallel tube, multi-pass embodiments, as will be discussed in further detail later herein with reference to FIGS. **11** and **12**.

[0032] Referring now to FIGS. **1-5** in particular, the heat exchanger **10** includes an inlet header **20**, an outlet header **30**, and a plurality of longitudinally extending multi-channel heat exchanger tubes **40** thereby providing a plurality of fluid flow paths between the inlet header **20** and the outlet header **30**. Each heat exchange tube **40** has an inlet **43** at one end in fluid flow communication to the inlet header **20** through a connector **50** and an outlet at its other end in fluid flow communication to the outlet header **30**. Each heat exchange tube **40** has a plurality of parallel flow channels **42** extending longitudinally, i.e. along the axis of the tube, the length of the tube thereby providing multiple, independent, parallel flow paths between the inlet of the tube and the outlet of the tube. Each multi-channel heat exchange tube **40** is a "flat" tube of, for instance, rectangular or oval cross-section, defining an interior which is subdivided to form a side-by-side array of independent flow channels **42**. The flat, multi-channel tubes **40** may, for example, have a width of fifty millimeters or less, typically twelve to twenty-five millimeters, and a height of about two millimeters or less, as compared to conventional prior art round tubes having a diameter of ½ inch, ⅜ inch or 7 mm. The tubes **40** are shown in drawings hereof, for ease and clarity of illustration, as having twelve channels **42** defining flow paths having a circular cross-section. However, it is to be understood that in commercial applications, such as for example refrigerant vapor compression systems, each multi-channel tube **40** will typically have about ten to twenty flow channels **42**, but may have a greater or a lesser multiplicity of channels, as desired. Generally, each flow channel **42** will have a hydraulic diameter, defined as four times the flow area divided by the perimeter, in the range from about 200 microns to about 3 millimeters. Although depicted as having a circular cross-section in the drawings, the channels **42** may have a rectangular, triangular, trapezoidal cross-section or any other desired non-circular cross-section.

[0033] Each of the plurality of heat exchange tubes **40** of the heat exchanger **10** has its inlet end **43** inserted into a connector **50**, rather than directly into the chamber **25** defined within the inlet header **20**. Each connector **50** has an inlet end **52** and an outlet end **54** and defines a fluid flow path **55** extending from the inlet end **52** to the outlet end **54**. The inlet end **52** is in fluid flow communication with the chamber **25** of the inlet header **20** through a first opening **51**. The outlet end **54** is in fluid communication through a second opening **53** with the inlet openings **41** of the channels **42** at the inlet end of the associated heat transfer tube **40** received therein. The first opening **51** at the inlet end **52** of each connector **50** has a relatively small cross-sectional flow area. Therefore, the connectors **50** provide a plurality of flow restrictions, at least one associated with each heat transfer tube **40**, that provide uniformity in pressure drop in the fluid flowing from the chamber **25** of the header **20** into the fluid flow path **55** within the connector **50**, thereby ensuring a relatively uniform distribution of fluid amongst the individual tubes **40** operatively associated with the header **20**.

[0034] In the embodiment depicted in FIGS. **1**, **2** and **3**, the inlet header **20** comprises a longitudinally elongated, hollow, closed end cylinder having a circular cross-section. The inlet end **52** of each connector **50** is mated with a corresponding slot **26** provided in and extending through the wall of the inlet header **20** with the inlet end **52** of the connector **50** inserted into its corresponding slot. Each connector may be brazed, welded, soldered, adhesively bonded, diffusion bonded or otherwise secured in a corresponding mating slot in the wall of the header **20**. However, the inlet header **20** is not limited to the depicted configuration. For example, the header **20** might comprise a longitudinally elongated, hollow, closed end cylinder having an elliptical cross-section or a longitudinally elongated, hollow, closed end pipe having a square, rectangular, hexagonal, octagonal, or other cross-section.

[0035] In the embodiment depicted in FIGS. **6**, **7** and **8**, the inlet header **20** comprises a longitudinally elongated, hollow, closed end, half cylinder shell having a generally semi-circular cross-section and a block-like insert **58** that is brazed, welded, adhesively bonded or otherwise secured to the open face of the half cylinder shell. In this embodiment, instead of a plurality of connectors **50**, the longitudinally, extending block-like insert **58** forms a single connector **50**. A plurality of longitudinally spaced, parallel flow paths **55** is formed within the block-like structure of the connector **50**. Each flow path **55** has an inlet end **52** having at least one relatively small flow area inlet opening **51** in fluid communication with a fluid chamber **25** defined within the header **20** and an outlet end **54** having an opening **53** adapted to receive the inlet end **42** of a heat exchange tube **40**. Therefore, in this embodiment, a plurality of heat exchange tubes **40** are connected to the header by means of a single block-like connector **50**. The block-like insert **58** provides a connector **50** having a plurality of flow restrictions, with at least one relatively small flow area opening **51** in operative association with each heat transfer tube **40**, that provide uniformity in pressure drop in the fluid flowing from the chamber **25** of the header **20** into the fluid flow path **55** within the connector **50**, thereby ensuring a relatively uniform distribution of fluid amongst the individual tubes **40** operatively associated with the header **20**.

[**0036**] In the embodiment depicted in FIGS. **2**, **3** and **5**, only one first opening **51** of relatively small flow area is provided in the inlet end **52** of each connector **50**. However, it is to be understood that, if desired, more than one first opening **51** of relatively small flow area may be provided at the inlet end **52** of the connector **50**. For example, when the heat exchange tubes are relatively wide and/or have a relatively large number of channels, it may be desirable to have two, three or even more relatively small flow area first openings **51** disposed at spaced intervals in the inlet end **52** of the connector **50**, such as illustrated in FIGS. **6**, **7** and **8**, to ensure uniform distribution of fluid flow to the multiplicity of flow channels **42** of the tube **40** inserted in the outlet end **54** of the connector **50**.

[**0037**] The fluid flow path **55** extending from the inlet opening **51** at the inlet end **52** of the connector **50** to the outlet opening **53** at the outlet end **54** of the connector **50** may, as best depicted in FIG. **3** and in FIG. **7**, diverge in the direction of fluid flow from the inlet opening **51** to the outlet opening **53**. A divergent flow path assists in distributing the fluid flowing through the flow path **55** uniformly amongst the various flow channels **42** of the heat exchange tube **40** inserted into the outlet end **54** of the connector **50**, particularly in refrigerant flow applications wherein the fluid is a liquid refrigerant and vapor refrigerant mixture or expands to a liquid refrigerant/vapor refrigerant mixture as the fluid passes through the relatively small flow area opening or openings **51**.

[**0038**] Referring now to FIGS. **9** and **10**, there is depicted schematically a refrigerant vapor compression system **100** having a compressor **60**, the heat exchanger **10**A, functioning as a condenser, and the heat exchanger **10**B, functioning as an evaporator, connected in a closed loop refrigerant circuit by refrigerant lines **12**, **14** and **16**. As in conventional refrigerant vapor compression systems, the compressor **60** circulates hot, high pressure refrigerant vapor through refrigerant line **12** into the inlet header **120** of the condenser **10**A, and thence through the heat exchanger tubes **140** of the condenser **10**A wherein the hot refrigerant vapor condenses to a liquid as it passes in heat exchange relationship with a cooling fluid, such as ambient air which is passed over the heat exchange tubes **140** by a condenser fan **70**. The high pressure, liquid refrigerant collects in the outlet header **130** of the condenser **10**A and thence passes through refrigerant line **14** to the inlet header **20** of the evaporator **10**B. The refrigerant thence passes through the heat exchanger tubes **40** of the evaporator **10**B wherein the refrigerant is heated as it passes in heat exchange relationship with air to be cooled which is passed over the heat exchange tubes **40** by an evaporator fan **80**. The refrigerant vapor collects in the outlet header **30** of the evaporator **10**B and passes therefrom through refrigerant line **16** to return to the compressor **60** through the suction inlet thereto. Although the exemplary refrigerant vapor compression cycles illustrated in FIGS. **9** and **10** are simplified air conditioning cycles, it is to be understood that the heat exchanger of the invention may be employed in refrigerant vapor compression systems of various designs, including, without limitation, heat pump cycles, economized cycles and refrigeration cycles.

[**0039**] In the embodiment depicted in FIG. **9**, the condensed refrigerant liquid passes from the condenser **10**A directly to the evaporator **10**B without traversing an expansion device. Thus, in this embodiment the refrigerant typically enters the inlet header **20** of the evaporative heat exchanger **10**B as a high pressure, liquid refrigerant, not as a fully expanded, low pressure, refrigerant liquid/vapor mixture, as in conventional refrigerant compression systems. Thus, in this embodiment, expansion of the refrigerant occurs within the evaporator **10**B of the invention as the refrigerant passes through the relatively small area opening or openings **51** at the inlet end **52** into the flow path **55** of the connector **50**, thereby ensuring that expansion occurs only after the distribution has been achieved in a substantially uniform manner.

[**0040**] In the embodiment depicted in FIG. **10**, the condensed refrigerant liquid passes through an expansion valve **50** operatively associated with the refrigerant line **14** as it passes from the condenser **10**A to the evaporator **10**B. In the expansion valve **50**, the high pressure, liquid refrigerant is partially expanded to lower pressure and lower temperature, liquid refrigerant or a liquid/vapor refrigerant mixture. In this embodiment, the final expansion of the refrigerant is completed within the evaporator **10**B as the refrigerant passes through the relatively small flow area opening or openings **51** at the inlet end **52** into the flow path **55** of the connector **50**. Partial expansion of the refrigerant in an expansion valve upstream of the inlet header **20** to the evaporator **10**B may be advantageous when the cross-sectional flow area of the openings **51**, can not be made small enough to ensure complete expansion as the liquid passes through the openings **51** or when an expansion valve is used as a flow control device.

[**0041**] Referring now to FIG. **11**, the heat exchanger **10** of the invention is depicted in a multi-pass, evaporator embodiment. In the illustrated multi-pass embodiment, the inlet header **20** is partitioned into a first chamber **20**A and a second chamber **20**B, the outlet header is also partitioned into a first chamber **30**A and a second chamber **30**B, and the heat exchange tubes **40** are divided into three banks **40**A, **40**B and **40**C. The tubes of the first tube bank **40**A have inlet ends inserted into respective connectors **50**A that are open into the first chamber **20**A of the inlet header **20** and outlet ends are open to the first chamber **30**A of the outlet header **30**. The tubes of the second tube bank **40**B have inlet ends inserted into respective connectors **50**B that are open into the first chamber **30**A of the outlet header **30** and outlet ends are open to the second chamber **20**B of the inlet header **20**. The tubes of the third tube bank **40**C have inlet ends inserted into respective connectors **50**C that open into the second chamber **20**B of the inlet header **20** and outlet ends are open to the second chamber **30**B of the outlet header **30**. In this manner, refrigerant entering the heat exchanger from refrigerant line **14** passes in heat exchange relationship with air passing over the exterior of the heat exchange tubes **40** three times, rather than once as in a single pass heat exchanger. In accord with the invention, the inlet end **43** of each of the tubes of the first, second and third tube banks **40**A, **40**B and **40**C is inserted into the outlet end **54** of its associated connector **50** whereby the channels **42** of each of the tubes **40** will receive a relatively uniform distribution of expanded refrigerant liquid/vapor mixture. Distribution and expansion of the refrigerant occurs as the refrigerant passes from the header into the connector through the relatively small cross-sectional flow area opening **51**, not only as the refrigerant passes into the first tube bank **40**A, but also as the refrigerant passes into the second tube bank **40**B and into the third tube bank **40**C, thereby ensuring more uniform distribution of the refrigerant liquid/vapor upon entering the flow channels of the tubes of each tube bank.

[**0042**] Referring now to FIG. **12**, the heat exchanger **10** of the invention is depicted in a multi-pass, condenser embodiment. In the illustrated multi-pass embodiment, the inlet header **120** is partitioned into a first chamber **120**A and a second chamber **120**B, the outlet header **130** is also partitioned into a first chamber **130**A and a second chamber **130**B, and the heat exchange tubes **140** are divided into three banks **140**A, **140**B and **140**C. The tubes of the first tube bank **140**A have inlet end openings into the first chamber **120**A of the inlet header **120** and outlet end openings to the first chamber **130**A of the outlet header **130**. The tubes of the second tube bank **140**B have inlet ends inserted into respective connectors **50**B that are open into the first chamber **130**A of the outlet header **130** and outlet ends that are open to the second chamber **120**B of the inlet header **120**. The tubes of the third tube bank **140**C have inlet ends inserted into respective connectors **50**C that are open into the second chamber **120**B of the inlet header **120** and outlet ends are open to the second chamber **130**B of the outlet header **130**. In this manner, refrigerant entering the condenser from refrigerant line **12** passes in the heat exchange relationship with air passing over the exterior of the heat exchange tubes **140** three times, rather than once as in a single pass heat exchanger. The refrigerant entering the first chamber **120**A of the inlet header **120** is entirely high pressure, refrigerant vapor directed from the compressor outlet via refrigerant line **14**. However, the refrigerant entering the second tube bank and the third tube bank typically will be a liquid/vapor mixture as refrigerant partially condenses in passing through the first and second tube banks. In accord with the invention, the inlet end of each of the tubes of the second and third tube banks **140**B, **140**C is inserted into the outlet ends of their associated connectors **50**B, **50**C whereby the channels **42** of each of the tubes will receive a relatively uniform distribution of expanded refrigerant liquid/vapor mixture. Obviously, it has to be noted that pressure drop through the openings **51** has to be limited to not exceed a predetermined threshold for the condenser applications, in order not to compromise the heat exchanger efficiency. Further, a person ordinarily skilled in the art would understand that other multi-pass arrangements for condensers and evaporators are also within the scope of the invention.

[**0043**] While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawing, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the invention as defined by the claims.

We claim:

1. A heat exchanger comprising:

a header defining a chamber for collecting a fluid; and

at least one heat exchange tube defining a plurality of discrete fluid flow paths therethrough and having an inlet opening to said plurality of fluid flow paths; and

a connector having an inlet end and an outlet end and defining a fluid flow path extending from said inlet end to said outlet end, said inlet end in fluid flow communication with the chamber of said header through a first opening and said outlet end in fluid communication with the inlet opening of said at least one heat exchange tube through a second opening, said first opening having a relatively small cross-sectional flow area.

2. A heat exchanger as recited in claim 1 wherein said first opening of said connector comprises an expansion orifice.

3. A heat exchanger as recited in claim 1 wherein the fluid flow path of said connector comprises a divergent fluid flow path expanding in cross-section in the direction of fluid flow therethrough from said first opening to said second opening.

4. A heat exchanger as recited in claim 3 wherein said first opening of said connector comprises an expansion orifice.

5. A heat exchanger as recited in claim 1 wherein said at least one heat exchange tube has a flattened, non-round cross-section.

6. A heat exchanger as recited in claim 5 wherein said at least one heat exchange tube has a flattened, rectangular cross-section.

7. A heat exchanger as recited in claim 5 wherein said at least one heat exchange tube has a flattened, generally oval cross-section.

8. A heat exchanger as recited in claim 1 wherein each of said plurality of channels defines a flow path having a non-circular cross-section.

9. A heat exchanger as recited in claim 8 wherein each of said plurality of channels defines a flow path is selected from a group of a rectangular, triangular or trapezoidal cross-section.

10. A heat exchanger as recited in claim 1 wherein each of said plurality of channels defines a flow path having a circular cross-section.

11. A heat exchanger as recited in claim 1 wherein said first opening comprises a plurality of openings.

12. A refrigerant vapor compression system comprising:

a compressor, a condenser and an evaporative heat exchanger connected in fluid flow communication in a refrigerant circuit whereby high pressure refrigerant vapor passes from said compressor to said condenser, high pressure refrigerant passes from said condenser to said evaporative heat exchanger, and low pressure refrigerant vapor passes from said evaporative heat exchanger to said compressor; characterized in that said evaporative heat exchanger includes:

an inlet header and an outlet header, each in fluid flow communication with the refrigerant circuit, said inlet header defining a chamber for receiving refrigerant from the refrigerant circuit;

at least one heat exchange tube having an inlet opening and an outlet opening and having a plurality of discrete fluid flow paths extending from the inlet opening to the outlet opening, the outlet opening in fluid flow communication with said outlet header; and

a connector having an inlet end and an outlet end and defining a fluid flow path extending from said inlet end to said outlet end, said inlet end in fluid flow communication with the chamber of said header through a first opening and said outlet end in fluid communication with the inlet opening of said at least one heat exchange tube through a second opening, said first opening having a relatively small flow area.

13. A refrigerant vapor compression system as recited in claim 12 wherein said first opening of said connector comprises an expansion orifice.

14. A refrigerant vapor compression system as recited in claim 12 wherein the fluid flow path of said connector comprises a divergent fluid flow path expanding in cross-section in the direction of fluid flow therethrough from said first opening to said second opening.

15. A refrigerant vapor compression system as recited in claim 14 wherein said first opening of said connector comprises an expansion orifice.

16. A refrigerant vapor compression system as recited in claim 12 wherein said at least one heat exchange tube has a flattened, non-round cross-section.

17. A refrigerant vapor compression system as recited in claim 16 wherein said at least one heat exchange tube has a flattened, rectangular cross-section.

18. A refrigerant vapor compression system as recited in claim 16 wherein said at least one heat exchange tube has a flattened, generally oval cross-section.

19. A refrigerant vapor compression system as recited in claim 12 wherein each of said plurality of channels defines a flow path having a non-circular cross-section.

20. A refrigerant vapor compression system as recited in claim 12 wherein each of said plurality of channels defines a flow path is selected from a group of a rectangular, triangular or trapezoidal cross-section.

21. A refrigerant vapor compression system as recited in claim 12 wherein each of said plurality of channels defines a flow path having a circular cross-section.

22. A refrigerant vapor compression system as recited in claim 12 wherein said heat exchanger comprises a single-pass heat exchanger.

23. A refrigerant vapor compression system as recited in claim 12 wherein said heat exchanger comprises a multi-pass heat exchanger.

24. A refrigerant vapor compression system as recited in claim 12 wherein said heat exchanger comprises a condenser.

25. A refrigerant vapor compression system as recited in claim 12 wherein said heat exchanger comprises an evaporator.

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