(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 392 886 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.12.2011 Bulletin 2011/49

(51) Int Cl.:
F28F 9/02 *(2006.01)* *F28D 1/053* *(2006.01)*

(21) Application number: **11167680.5**

(22) Date of filing: **26.05.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **01.06.2010 US 350123 P**
24.05.2011 US 114405

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(54) **Orientation insensitive refrigerant distributor tube**

(57) A heat exchanger assembly (10) having an inlet header (12a), an outlet header (12b) spaced from the inlet header (12a), a plurality of refrigerant tubes (14) hydraulically connecting the inlet header (12a) with the outlet header (12b). A distributor tube (20) having a plurality of orifices (22) disposed in the inlet header (12a), wherein the orifices (22) are arranged along the distributor tube (20) such that at least one orifice is oriented in the liquid phase (24) of the refrigerant pressed against the internal surface of the distributor tube (20) regardless of orientation of the evaporator. The orifices(22) may be arranged in a random order about the distributor tube (20), positioned in groups of at least two at predetermined locations, or spiraled along the distributor tube (20).

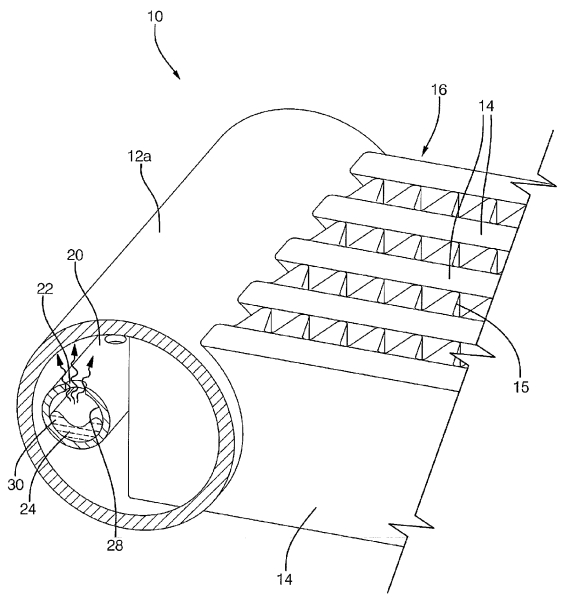

FIG. 2

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Description

TECHNICAL FIELD OF INVENTION

[0001] The present disclosure relates to an inlet distributor for an evaporator; more particularly to an inlet distributor having a plurality of orifices arranged along the length of the distributor tube.

BACKGROUND OF INVENTION

[0002] Residential and commercial air conditioning and heat pump systems are known to employ modified automotive heat exchangers, which are desirable for its proven high heat transfer efficiency, durability, and relatively ease of manufacturability. Automotive heat exchangers typically include an inlet header, an outlet header, and a plurality of refrigerant tubes hydraulically connecting the headers for refrigerant flow therebetween. Corrugated fins interconnect adjacent refrigerant tubes to increase the available heat transfer area, as well as to increase the structural integrity of the heat exchanger. The coil of the heat exchanger is defined by the refrigerant tubes and interconnecting corrugated fins. To meet the demands of residential and commercial applications, the size of the coil of the heat exchanger has to be increased accordingly, which in turn dramatically increased the lengths of the inlet and outlet headers. For a heat exchanger operating in evaporator mode, the increased length of the headers tends to result in refrigerant mal-distribution through the refrigerant tubes. Momentum and gravity effects, due to the large mass differences between the liquid and gas phases, can result in separation of the phases in the inlet header and cause poor refrigerant distribution through the refrigerant tubes. Poor refrigerant distribution degrades evaporator performance and can result in uneven temperature distribution over the coil. To assist in providing uniform refrigerant distribution though the refrigerant tubes, it is known to provide a distributor tube in the inlet header.

[0003] A typical distributor tube extends the length of the inlet header and includes a plurality of uniformly spaced orifices for distributing the two-phase refrigerant throughout the length of the header. The orifices are oriented at a designed angle relative to the center of the cross-section of the refrigerant tube to provide the maximum performance for the coil in a specific application. Typically, the angle of the orifices is selected based on testing a vertical slab coil design with the refrigerant tube aligned in the opposite direction of gravity. Indoor evaporators also have the additional challenge of packaging constraints; the evaporators have to fit within the limited volume offered by the plenums of residential HVAC systems. In a slab coil design, the refrigerant tubes lie in a plane much like that of an automotive heat exchanger, and for maximum efficiency it is preferable that the refrigerant tubes are aligned in the direction of gravity with the inlet header lower than the outlet header. To provide the cooling capacity required within a limited space, two smaller slab coils are assembled into an A-Frame design or a single larger slab coil is bent into an ARC design. The A-Frame design or ARC design may need to be installed in various orientations with respect to gravity, in which the refrigerant tubes may not be aligned in the direction of gravity and the inlet header may not be lower than the outlet header. The desired distribution of refrigerant flowing through the coil may be adversely affected due to the orientation of the evaporator. There is a long felt need for an evaporator that provides good refrigerant distribution regardless of its orientation.

SUMMARY OF THE INVENTION

[0004] The invention relates to a heat exchanger assembly having an inlet header, an outlet header spaced from the inlet header, a plurality of refrigerant tubes hydraulically connecting the inlet header with the outlet header. A distributor tube having a plurality of orifices disposed in the inlet header, wherein the orifices are arranged along the distributor tube such that at least one orifice is oriented in the liquid phase of a two-phased refrigerant pressed against the internal surface of the distributor tube regardless of the orientation of the evaporator.

[0005] According to one aspect of the invention, the orifices may be substantially uniformly spaced along the length of the distributor tube in pairs or groups of four (4). Within each pair of orifices, one of the orifices may be oriented 90 to 180 degrees apart from the other with respect to the pair's respective point on a central axis. Each pair of orifices may be rotated 90 to 180 degrees from the adjacent pair of orifices. For groups of four (4) orifices, each of the orifices may be oriented 90 degrees apart from the adjacent orifice with respect to the group's respective point on a central axis. Each group of four (4) orifices may be rotated 45 degrees from the adjacent group of four (4) orifices.

[0006] In another aspect of the invention, the cylindrical refrigerant distributor tube may have a plurality of orifices spiraled along the tube. With respect to an end view of the central axis, each succeeding orifice may be offset 45 to 180 degrees from the preceding orifice.

[0007] The above configurations of orifices on the distributor tube provide that at least one of the orifices will be located within the liquid phase of the two-phase refrigerant flowing through the distributor tube regardless of the final orientations of the evaporator coil. This provides at least the advantage of improved refrigerant distribution through the refrigerant tube of the heat exchanger assembly resulting in improved heat transfer efficiency.

BRIEF DESCRIPTION OF DRAWINGS

[0008] This invention will be further described with reference to the accompanying drawings in which:

Figs. 1 A-C show representative end views of an A-type coil or bent coil design evaporator.

Fig. 2 shows a distributor tube in an inlet header of an evaporator, in which the orifices of the distributor tube are oriented in a direction opposite that of the direction of gravity.

Fig. 3 shows a distributor tube in an inlet header of an evaporator, in which the orifices of the distributor tube are oriented in the direction of gravity.

Fig. 4 shows a cross-section of the inlet header having a distributor tube with the liquid phase of refrigerant pressed-up against the interior surface of the distributor tube.

Fig. 5 shows a refrigerant distributor tube having groups of two (2) orifices along the length of the distributor tube, wherein the orifices in each group are oriented 180 degrees apart from each other and the groups of two (2) orifices are rotated 90 degrees apart from each other.

Fig. 6 shows a refrigerant distributor tube having groups of four (4) orifices along the length of the distributor tube, wherein the orifices in each group are oriented 90 degrees apart from each other.

Fig. 7 shows a refrigerant distributor tube having a plurality of orifices spiraled along the tube at an exemplary 90 degrees between adjacent orifices.

DETAILED DESCRIPTION OF INVENTION

[0009] For a typical slab coil design evaporator, the desired angle of the orifices of a distributor tube is selected based on testing of a vertical slab coil in which the refrigerant tubes are aligned in the direction of gravity with the inlet header lower than the outlet header. To accommodate the packaging constraints required for residential applications, a residential indoor evaporator may be constructed by using two slab coils in an A-Frame design or a single slab coil bent into an ARC design. Shown in Figs. 1A-1C are representations of an end view of an A-Frame design or ARC design residential indoor evaporator 10 having an inlet header 12a, an outlet header 12b spaced apart from the inlet header 12a, and a plurality of refrigerant tubes 14 hydraulically connecting the headers 12a, 12b for refrigerant flow. An evaporator coil 16, partially shown in Figs. 2 and 3, is defined by the plurality of refrigerant tubes 14 together with external fins 15 interconnecting the adjacent refrigerant tubes 14. The evaporator 10 includes a distributor tube 20 in the inlet header 12a, shown in Figs. 2-7, for improved refrigerant distribution. The above mentioned components of the evaporator 10 are typically constructed of a heat conductive material such as aluminum.

[0010] Each of the A-Frame design and ARC design provides an evaporator 10 having at least one apex 18. The A-Frame or ARC design can be installed within a HVAC plenum in various orientations with respect to the direction of gravity, in which the apex 18 may be up, down, horizontal, and any other orientation therebetween. With these varieties of possible orientations, the inlet header 12a may be located above the outlet header 12b, below the outlet header 12b, or horizontal with the outlet header12b. The headers 12a, 12b are typically perpendicular to that of the direction of gravity, but the bottom header may be slightly angled toward the direction of gravity to facilitate condensate drainage.

[0011] A standard angle designed for the orifices 22 of the distribution tube 20 relative to the refrigerant tube 14 may not necessarily work efficiently when used in all the various potential orientations of the evaporator 10. It was found that only certain range of angles of the orifices 22 of the distribution tube 20 relative to the refrigerant tube 14 are acceptable for each of the various evaporator coil 16 orientations. In other words, orifice angles are application specific; therefore, the desired orifice range of angles has to be calculated for each specific orientation of the evaporator 10.

[0012] With reference to Figs. 2-4, it is believed that the liquid phase 24 of a two-phase refrigerant flowing through the distributor tube 20 tends to migrate to the bottom of the interior surface 28 of the distributor tube 20 due to gravity. It is suspected that the liquid phase 24 does not necessary puddle on the bottom or low spot of the distribution tube 20, but instead it is pressed against and rides up a portion of the interior surface 28 of the distributor tube 20 by the flow of refrigerant through the distributor tube 20, thereby forming a liquid refrigerant cross-sectional profile 30 much like a crescent moon with its apex on the bottom. The limit would be annular flow where the liquid distributes around the entire peripheral internal surface 28 of the distribution tube 20, but more typically a thicker layer would exist on the bottom.

[0013] It was found that if the orifices 22 were facing in a direction other than between 45 to 315 degrees with respect to the opposite direction of gravity being 0 degree, mostly vapor phase refrigerant tend to exits the orifices 22 migrating toward the refrigerant tubes 14. This is undesirable because optimal heat transfer efficiency is obtained when the refrigerant entering the refrigerant tubes is in a substantially liquid phase.

[0014] With reference to Fig. 3, it was surprisingly found that when the orifices 22 are oriented substantially in the direction of gravity, the pressure and momentum of the refrigerant flowing through the distributor tube 20 pushes the liquid phase refrigerant out of the distributor tube 20 through the orifices 22 toward the refrigerant tubes. The refrigerant remains substantially in liquid phase until it reaches the refrigerant tubes 14, at which point the liquid phase refrigerant starts to absorb heat and vaporizes, thereby providing optimum heat transfer and even temperature distribution across the evaporator coil 16. With reference to Fig. 4, during periods of high refrigerant flow, the liquid refrigerant cross-sectional profile 30 occupies the interior surface 28 of the distributor tube 20 from 45 to 315 degrees with respect to the opposite direction of gravity being 0 degree. During normal operating conditions, the liquid refrigerant cross-sectional profile 30 occupies the interior surface 28 of the distributor tube 20 from 90 to 270 degrees.

[0015] An aspect of the invention provides a means to transport the liquid phase refrigerant from the distributor tube 20 to the refrigerant tubes 14 for efficient boiling and thus improved heat transfer performance regardless of the orientation of the A-Frame or ARC evaporator coil evaporator. This can be achieved by having orifices 22 at angles from 45 to 315 degrees, preferably between 90 to 270 degrees, with respect to the opposite direction of gravity being 0 degree, along the distributor tube 20 to ensure that at least one, but preferably a group, of orifices 22 is substantially oriented within the liquid refrigerant cross-sectional profile 30. By having one or more orifices within the liquid profile 30, the refrigerant flowing through the distributor tube 20 will push the liquid phase refrigerant through the orifices 22 and toward the refrigerant tubes.

[0016] Fig. 5 shows a cylindrical refrigerant distributor tube 20 extending along a substantially central axis (A-axis). Pairs of orifices 22 are substantially uniformly spaced along the length of the distributor tube 20, in which each pair of orifices 22 is located about its respective point on the A-axis. Within each pair of orifices 22, one of the orifices 22 may be oriented 90 to 180 degrees apart from the other with respect to the pair's respective point on the A-axis. Furthermore, each pair of orifices 22 may be rotated 90 to 180 degrees from the adjacent pair of orifices 22.

[0017] Fig. 6 shows a cylindrical refrigerant distributor tube 20 extending along the A-axis. Groups of four (4) orifices 22 are substantially uniformly spaced along the length of the distributor tube 20, in which each group of orifices 22 is located about its respective point on the A-axis. Within each group of four (4) orifices 22, each of the orifices 22 may be oriented 90 degrees apart from the adjacent orifice 22 with respect to the group's respective point on the A-axis. Furthermore, each group of (4) orifices 22 may be rotated 45 degrees from the adjacent group of (4) orifices 22.

[0018] Fig. 7 shows a cylindrical refrigerant distributor tube 20 having a plurality of orifices 22 spiraled along the tube. With respect to an end view of the A-axis, each succeeding orifice 22 may be offset 45 to 180 degrees from the preceding orifice 22.

[0019] With the above configurations of orifices 22 on the distributor tube 20 or any configuration that provides at least one orifice 22 in the desired direction regardless of the orientation of the evaporator 10 would improve the distribution of refrigerant though the refrigerant tubes 14. Therefore, if the evaporator coil 16 is positioned in any one of the various possible orientations, at least one of the orifices 22 would be located within the liquid refrigerant cross-sectional profile 30.

[0020] While this invention has been described in terms of the preferred embodiments thereof, it is not intended to be so limited, but rather only to the extent set forth in the claims that follow.

Claims

1. A heat exchanger assembly (10) for use with a two-phase refrigerant, comprising;
an inlet header (12a);
an outlet header (12b) spaced from said inlet header (12a);
a plurality of refrigerant tubes (14) hydraulically connecting said inlet header (12a) to said outlet header (12b);
a distributor tube (20) having a plurality of orifices (22) disposed in said inlet header (12a), wherein said orifices (22) are arranged along said distributor tube (20) such that at least one orifice (22) is oriented in the liquid phase (24) of the refrigerant pressed against said internal surface of said distributor tube (20) regardless of orientation of said heat exchanger assembly (10).

2. A heat exchanger assembly (10) of claim 1, wherein each of said plurality of orifices (22) is randomly positioned along said distributor tube (20).

3. A heat exchanger assembly (10) of claim 1, wherein said plurality of orifices (22) is spirally positioned along said distributor tube (20) about a substantially center axis.

4. A heat exchanger assembly (10) of claim 3, wherein each of said plurality of orifices (22) is off-set 45 to 180 degrees from adjacent said orifices (22), preferably 90 degrees from adjacent orifices (22).

5. A heat exchanger assembly (10) of claim 3, wherein each of said plurality of orifices (22) is off-set 90 degrees or 180 degrees from adjacent orifices (22).

6. A heat exchanger assembly (10) of claim 1,
wherein said distributor tube (20) extends along a substantially center axis and includes pairs of said orifices (22) spaced along said distributor tube (20);
wherein each of said pairs of orifices (22) is located about a respective point on said center axis.

7. A heat exchanger assembly (10) of claim 6, wherein said pair of orifices (22) includes one orifice that is 90 to 180 degrees apart from the other orifice.

8. A heat exchanger assembly (10) of claim 6, wherein said pair of orifices (22) includes one orifice that is 90 degrees from the other orifice.

9. A heat exchanger assembly (10) of claim 8, wherein each of said pairs of orifices (22) is 90 degrees rotated from adjacent said pairs of orifices (22).

10. A heat exchanger assembly (10) of claim 8, wherein each of said pairs of orifices (22) is 180 degrees ro-

tated from adjacent said pairs of orifices (22).

11. A heat exchanger assembly (10) of claim 6, wherein said pair of orifices (22) includes one orifice that is 180 degrees from the other orifice.

12. A heat exchanger assembly (10) of claim 11, wherein each of said pairs of orifices (22) is 90 degrees rotated from adjacent said pairs of orifices (22).

13. A heat exchanger assembly (10) of claim 1, wherein said distributor tube (20) extends along a substantially center axis and includes groups of 4 orifices (22) spaced along said distributor tube (20).

14. A heat exchanger assembly (10) of claim 13, wherein each orifice within said group of 4 orifices (22) is 90 degrees from said adjacent orifices (22).

15. A heat exchanger assembly (10) of claim 14, wherein each group of 4 orifices (22) is 45 degrees rotated from adjacent group of 4 orifices (22).

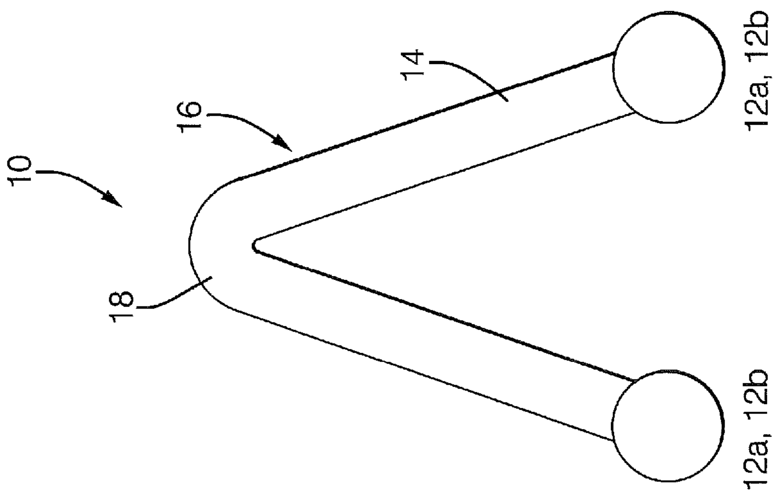

FIG. 1 A

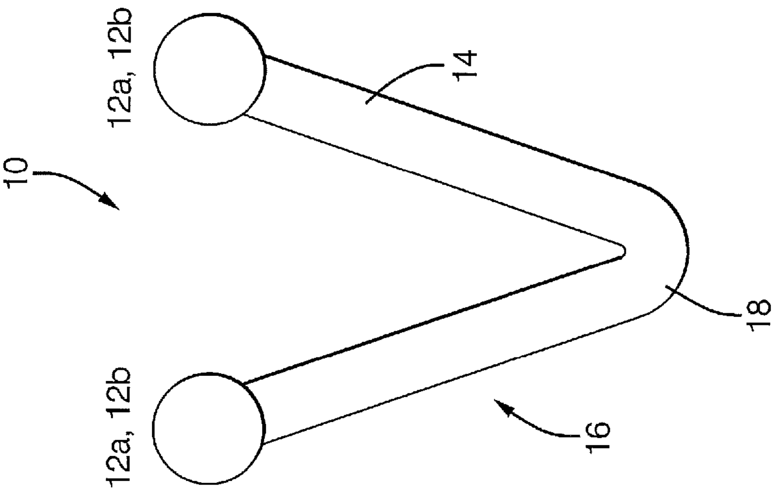

FIG. 1 B

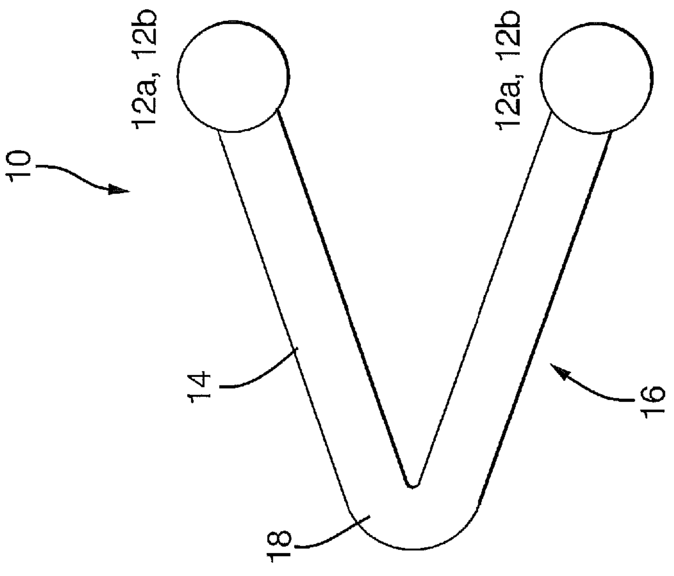

FIG. 1 C

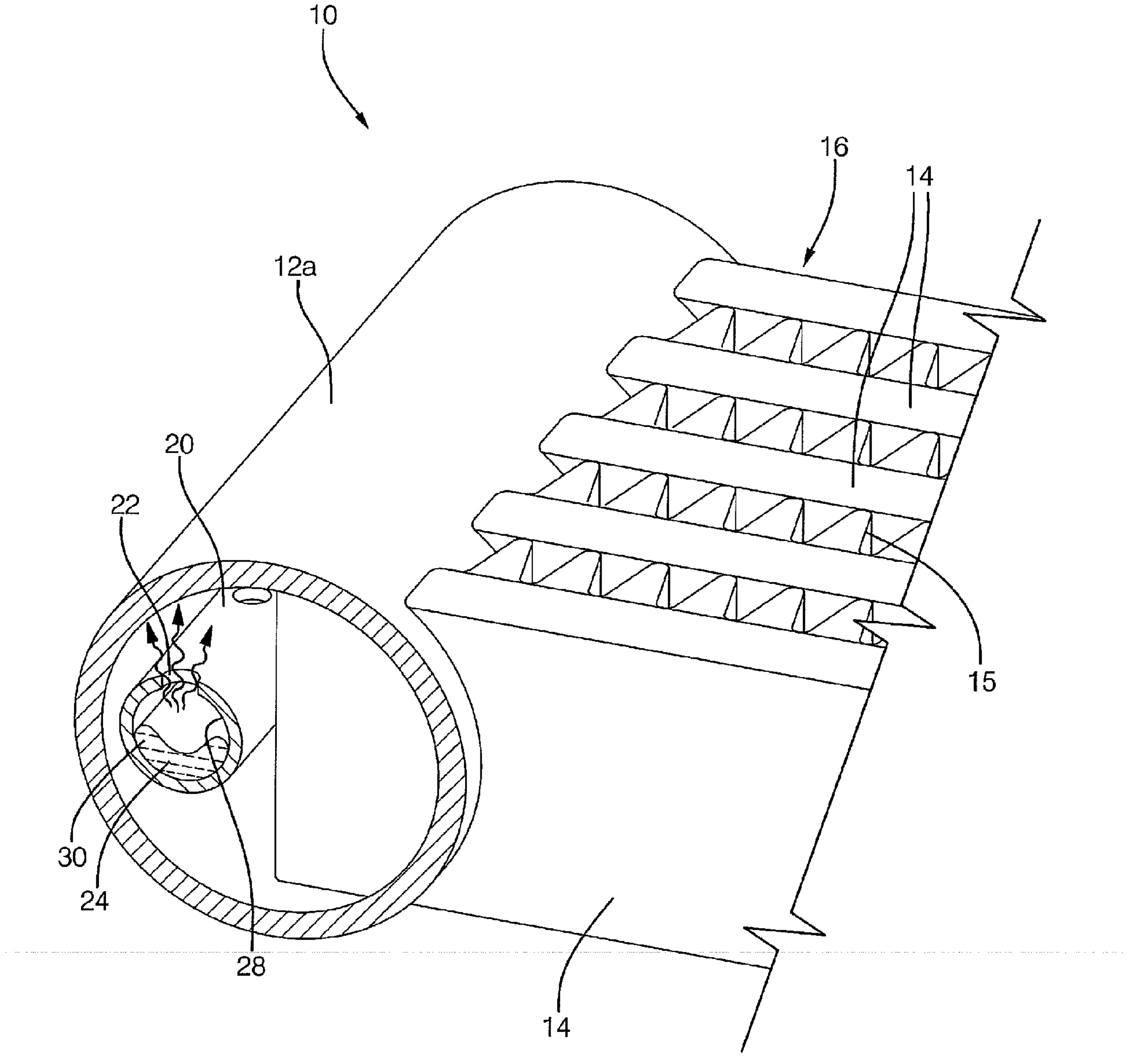

FIG. 2

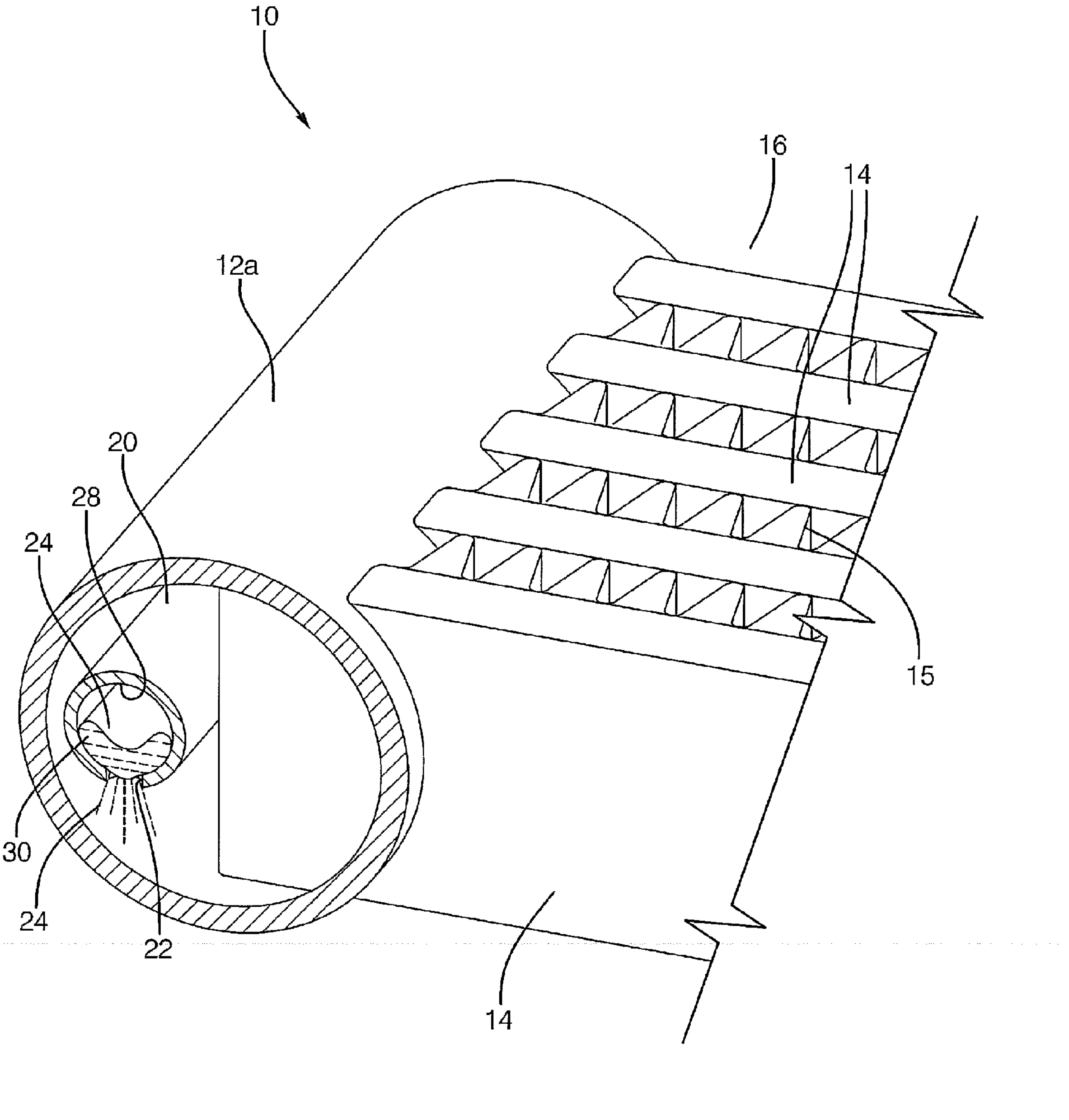

FIG. 3

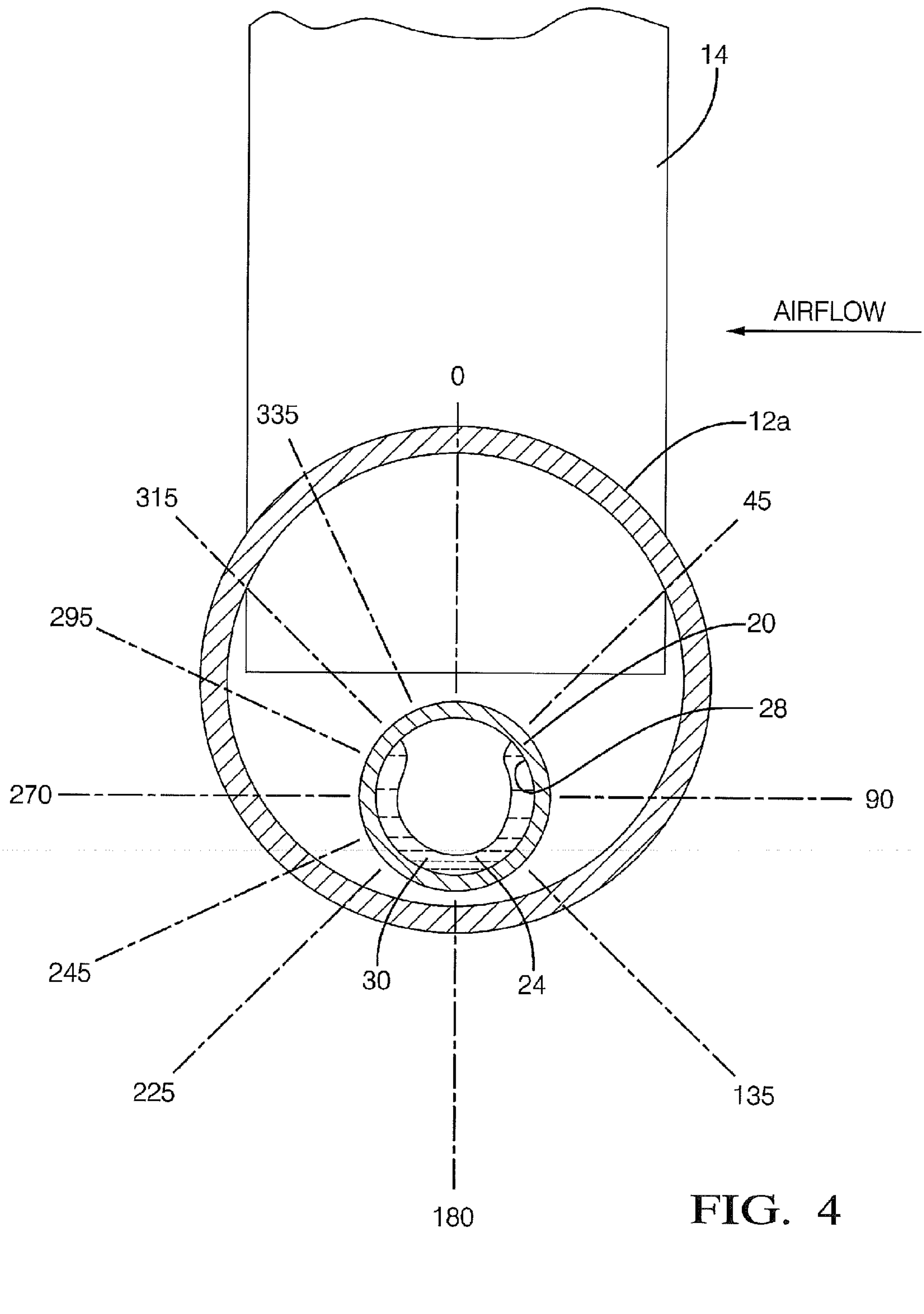

FIG. 4

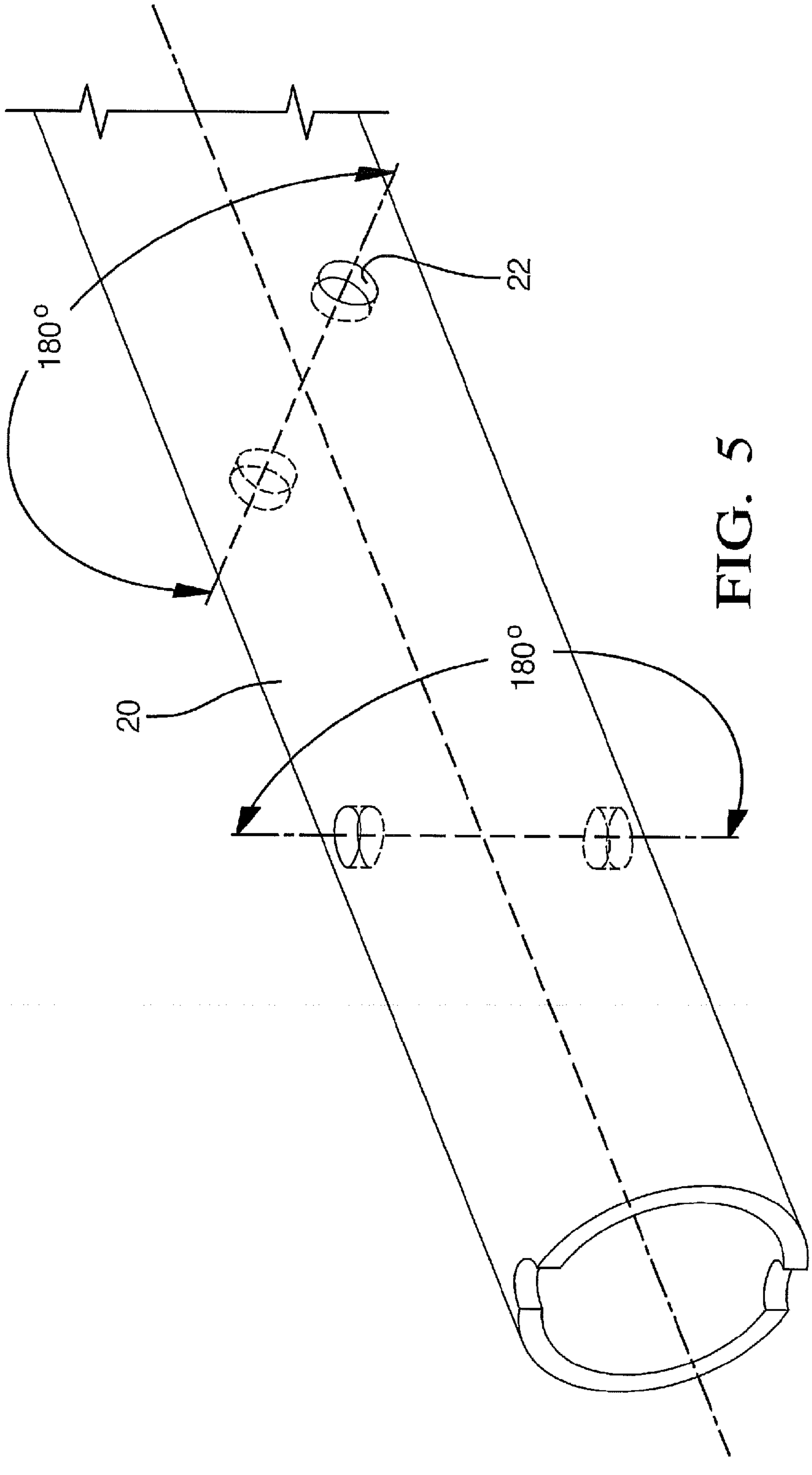

FIG. 5

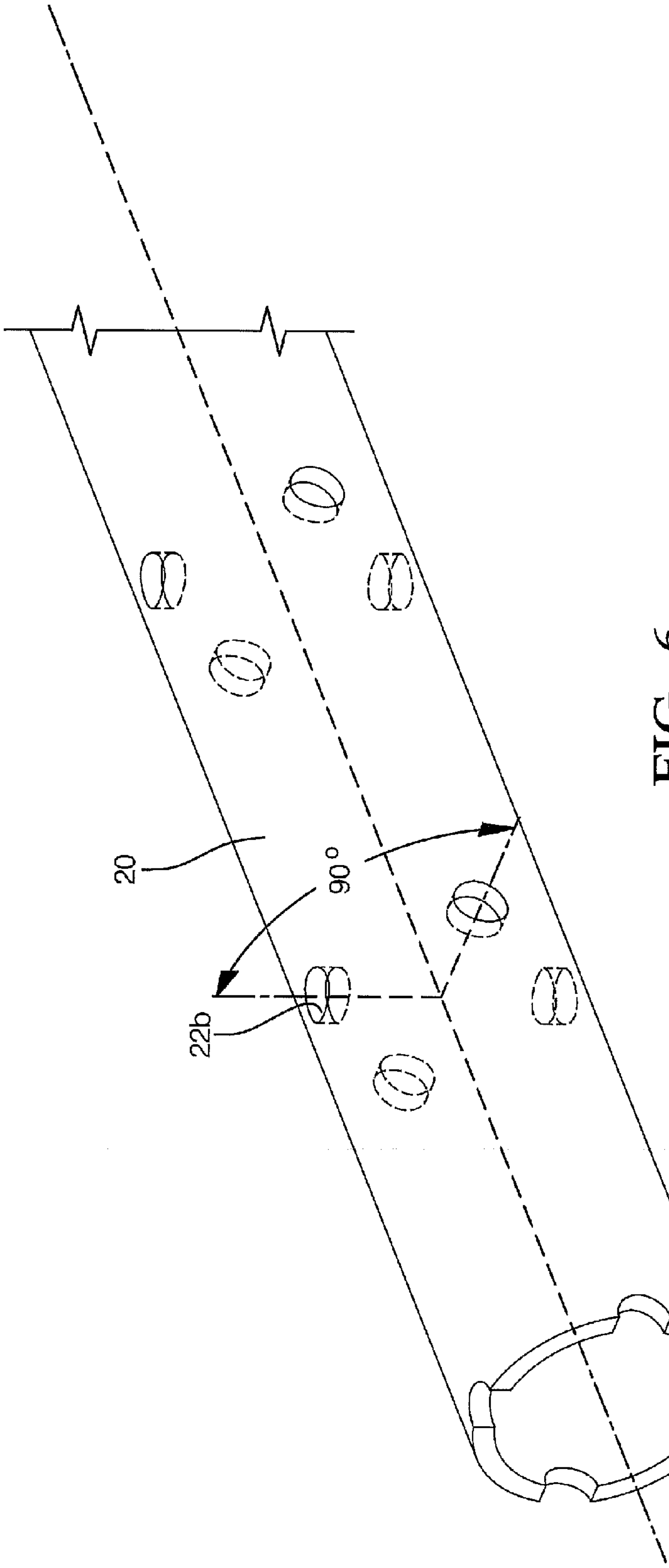

FIG. 6

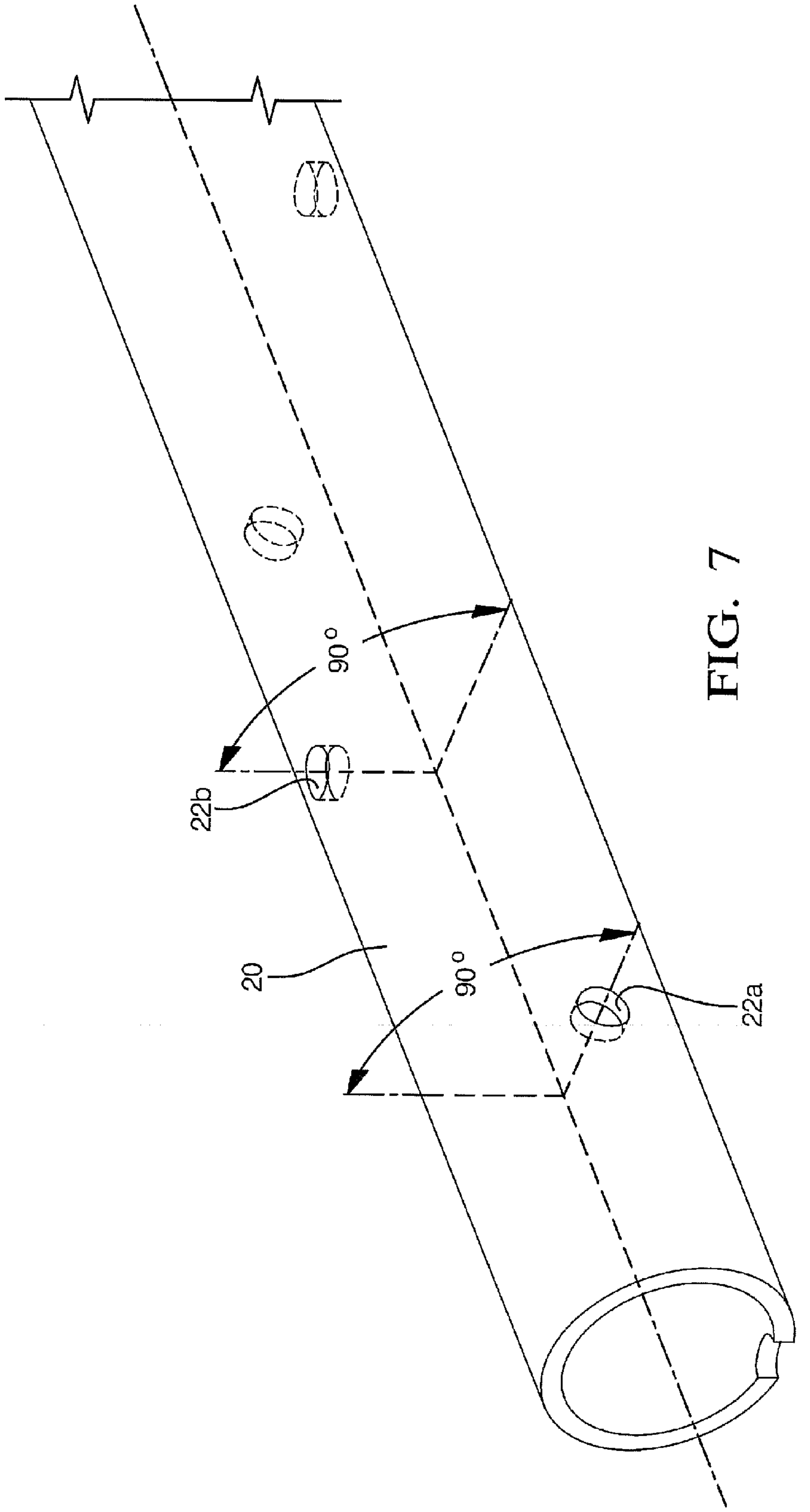

FIG. 7