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(54) HEAT EXCHANGER

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(73) Assignee: **Prodigy Energy Recovery Systems Inc.**, Montreal (CA)

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Related U.S. Application Data

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Publication Classification

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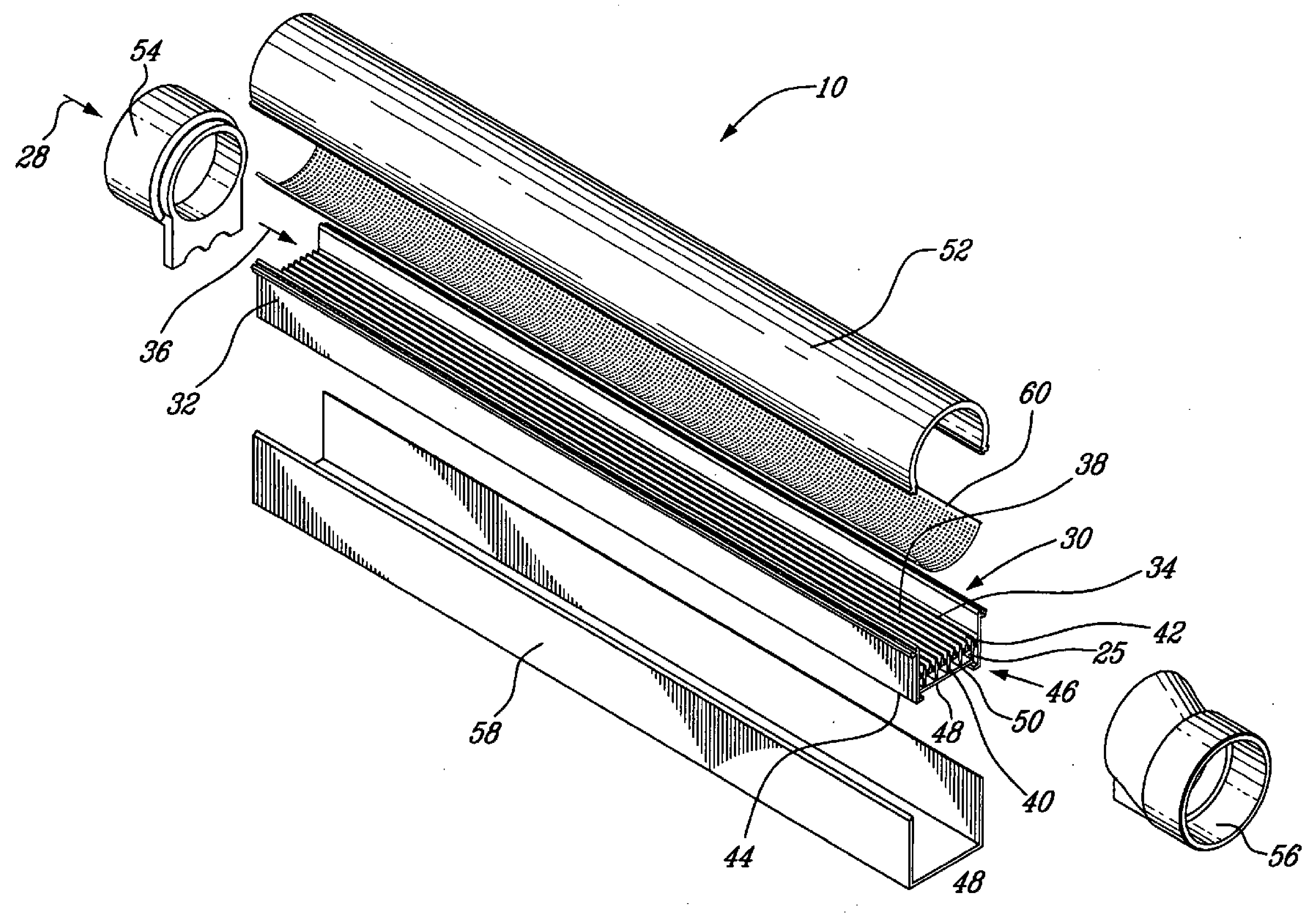
F28D 7/00 (2006.01)

(52) **U.S. Cl.** **165/109.1**; 165/164

(57) **ABSTRACT**

Disclosed herein is a heat exchange apparatus, which comprises a hollow blade member having a first fluid inlet and a first fluid outlet and a first fluid passageway for a first fluid that extends between the inlet and the outlet. The blade member is sized and shaped to be located in a second fluid passageway for a second fluid. The blade member is configured to enhance thermal energy transfer between the fluids as they flow along their respective passageways.



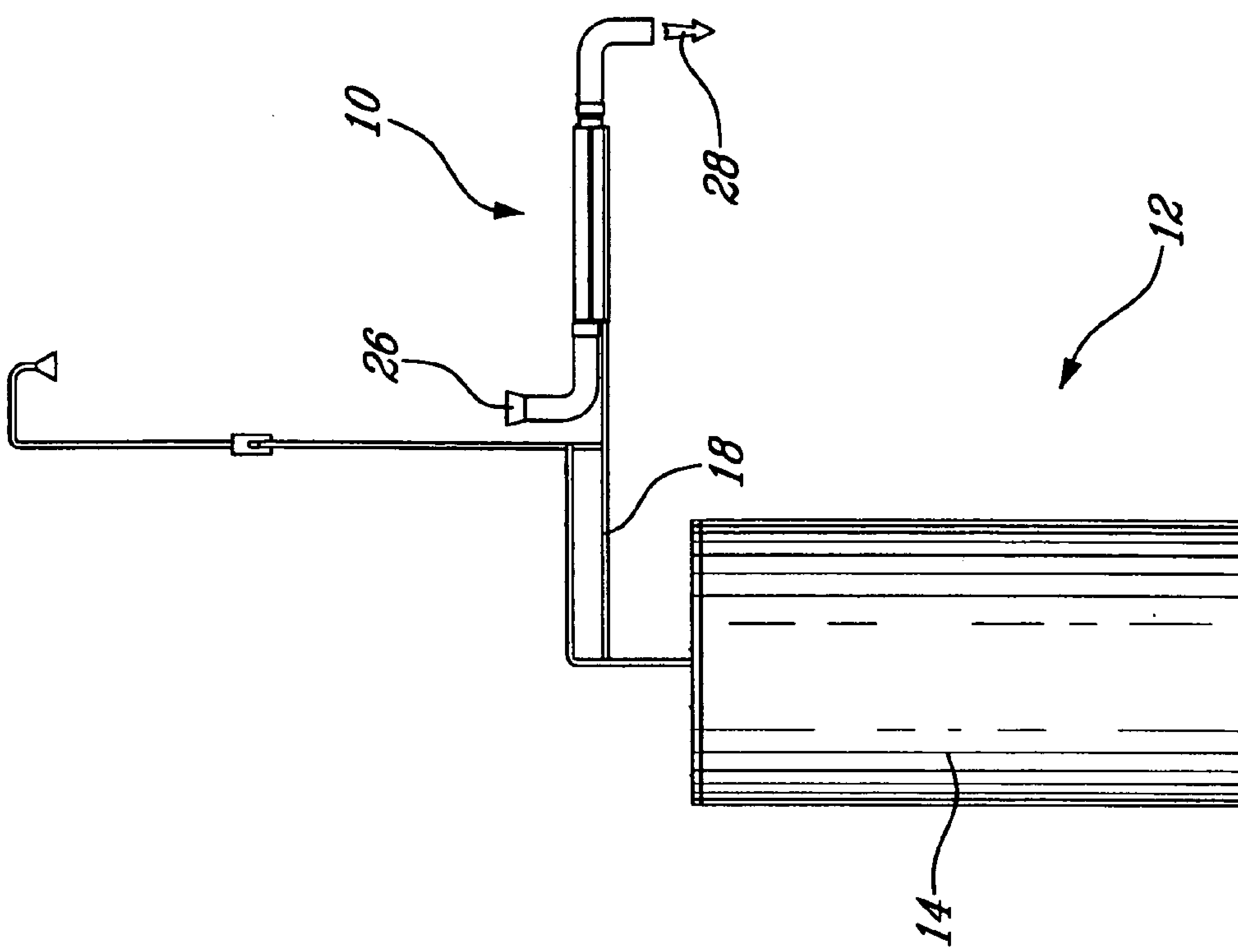


FIG-1B

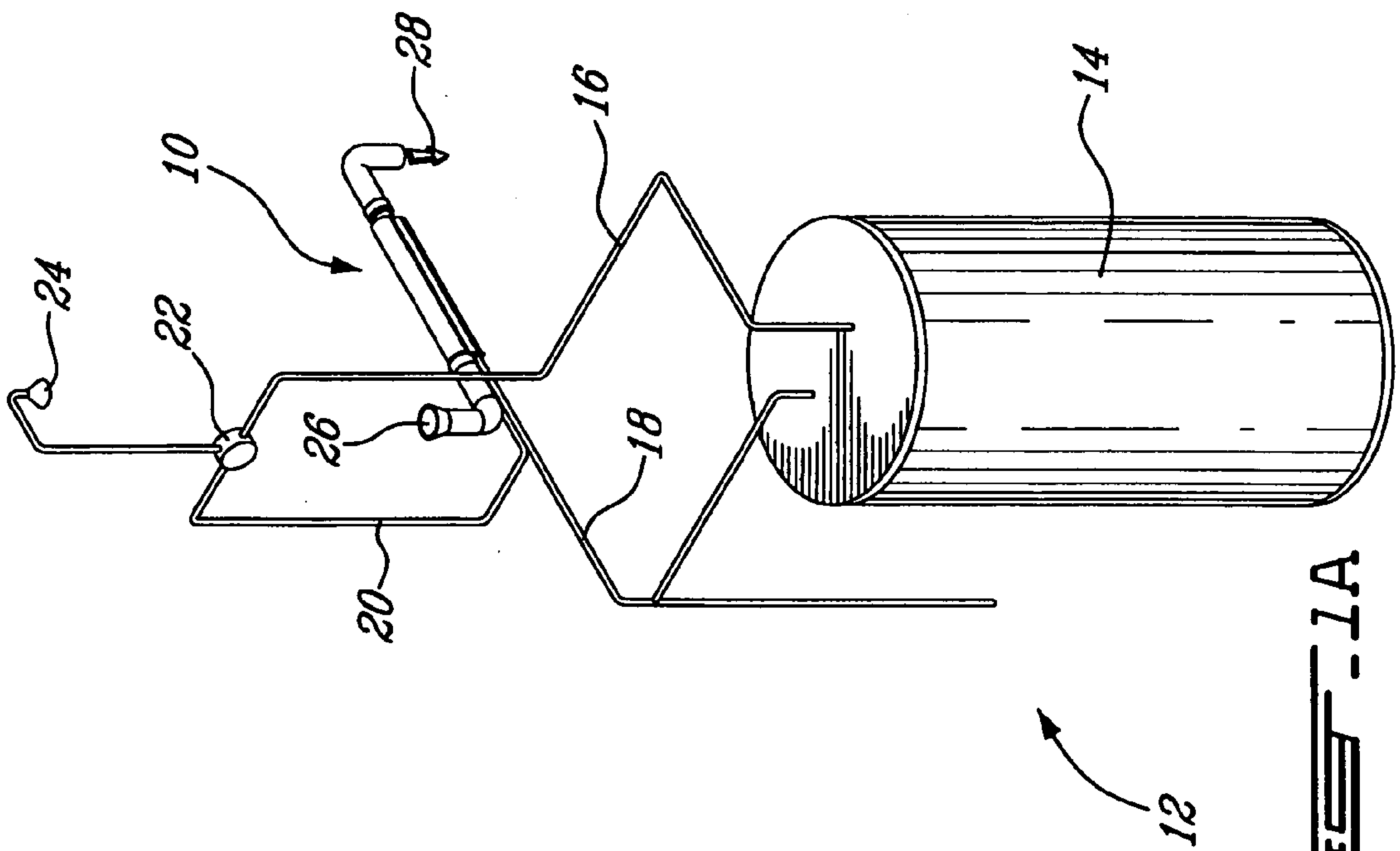


FIG-1A

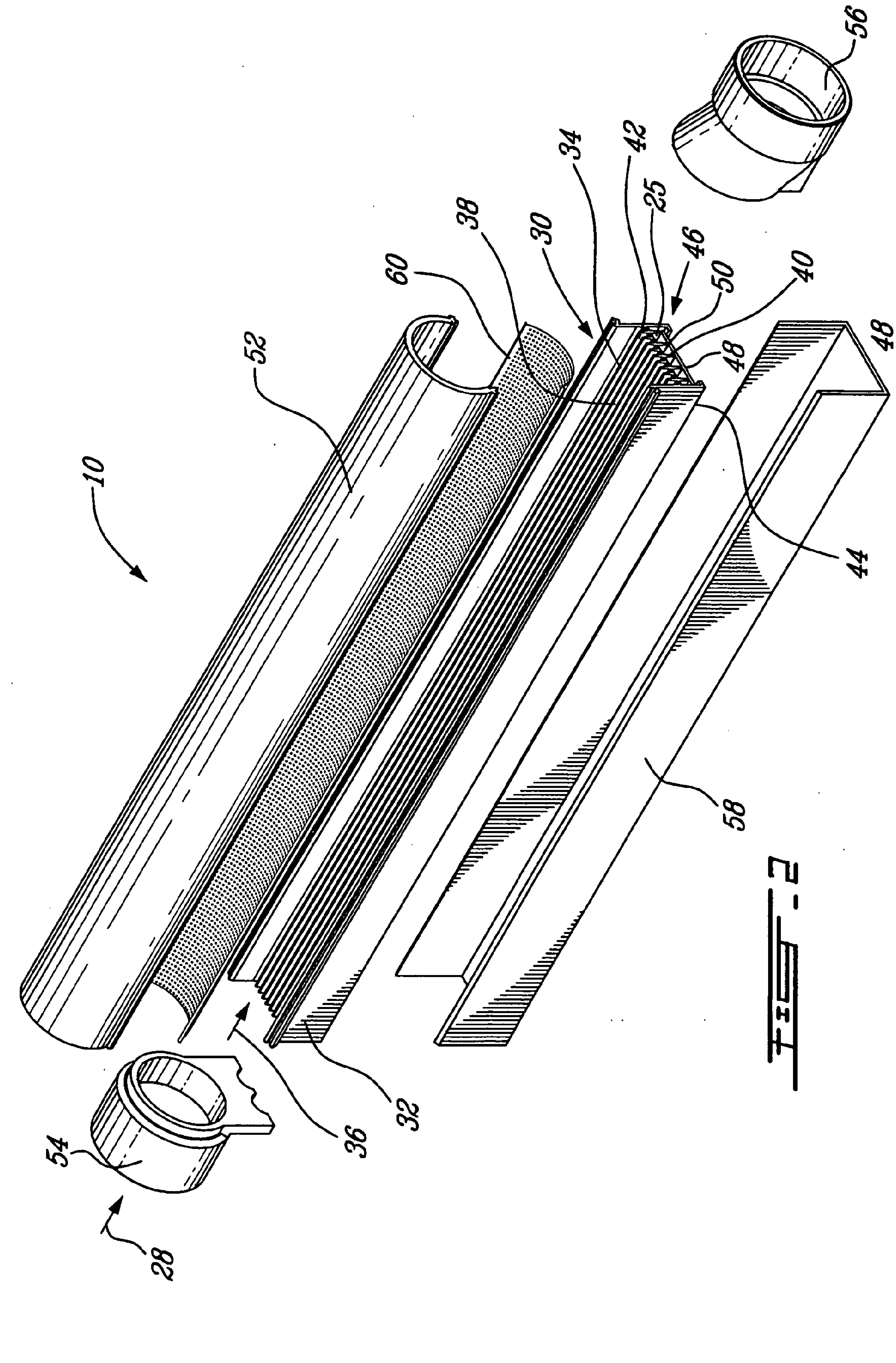


FIG-2

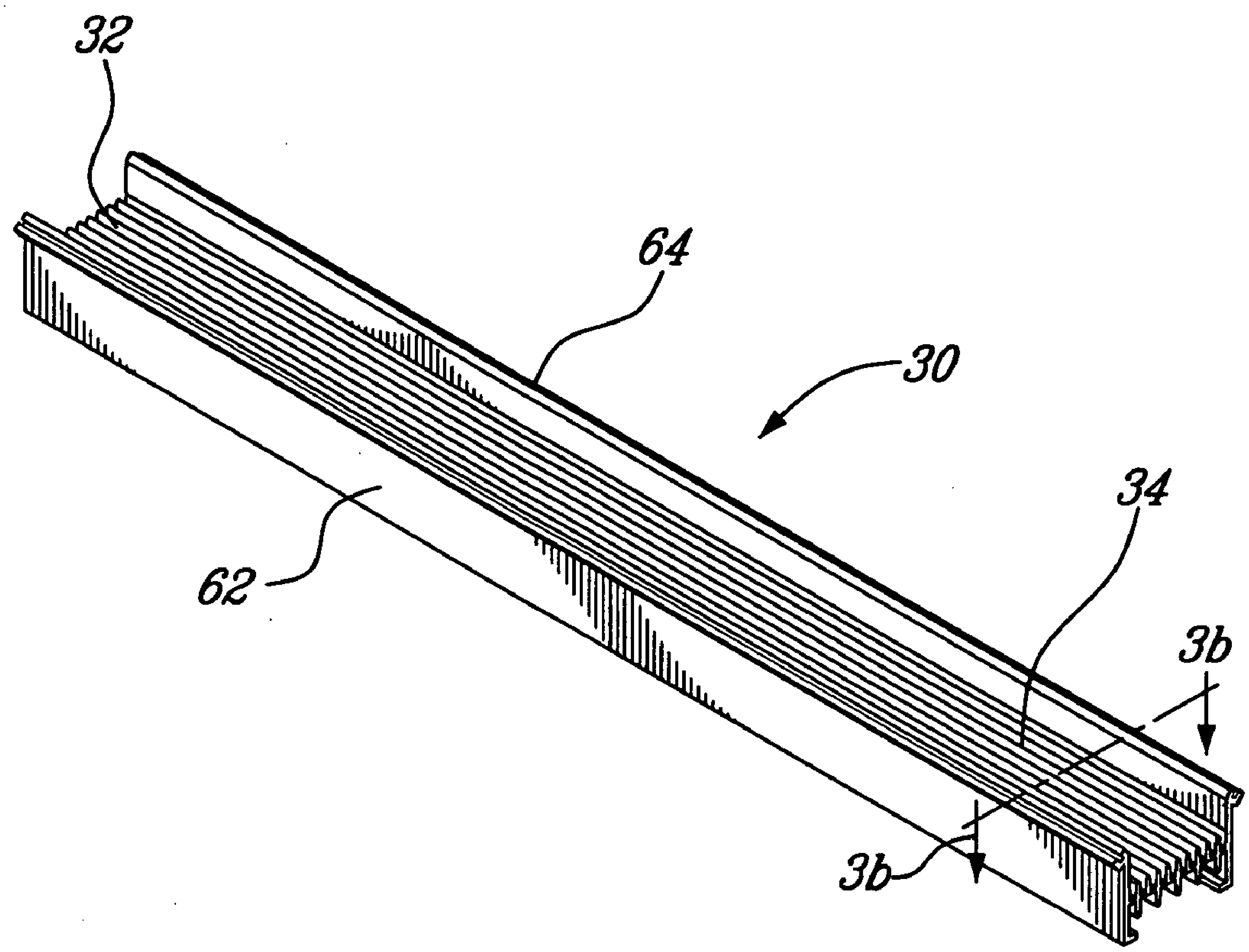


FIG. 3A

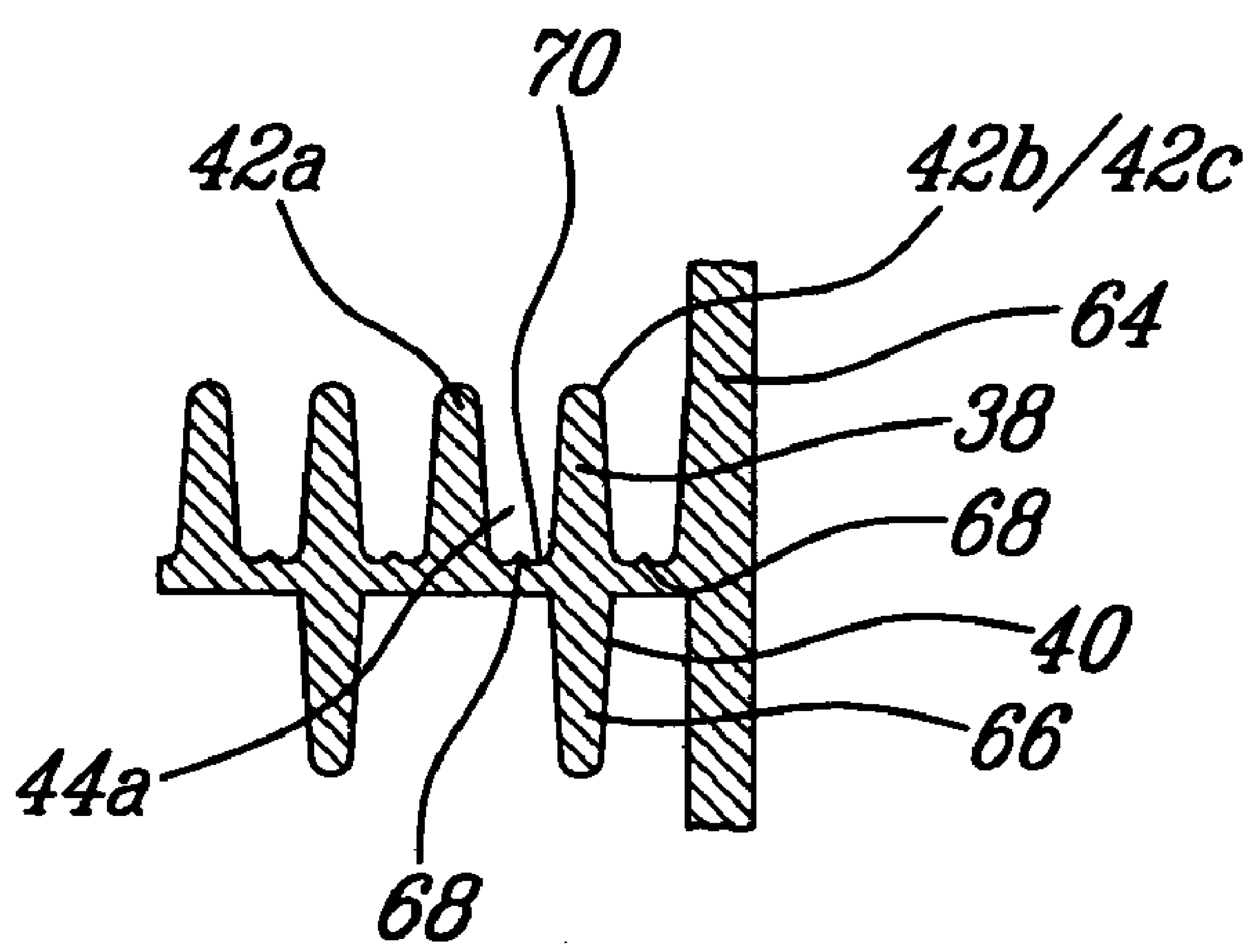


FIG. 3B

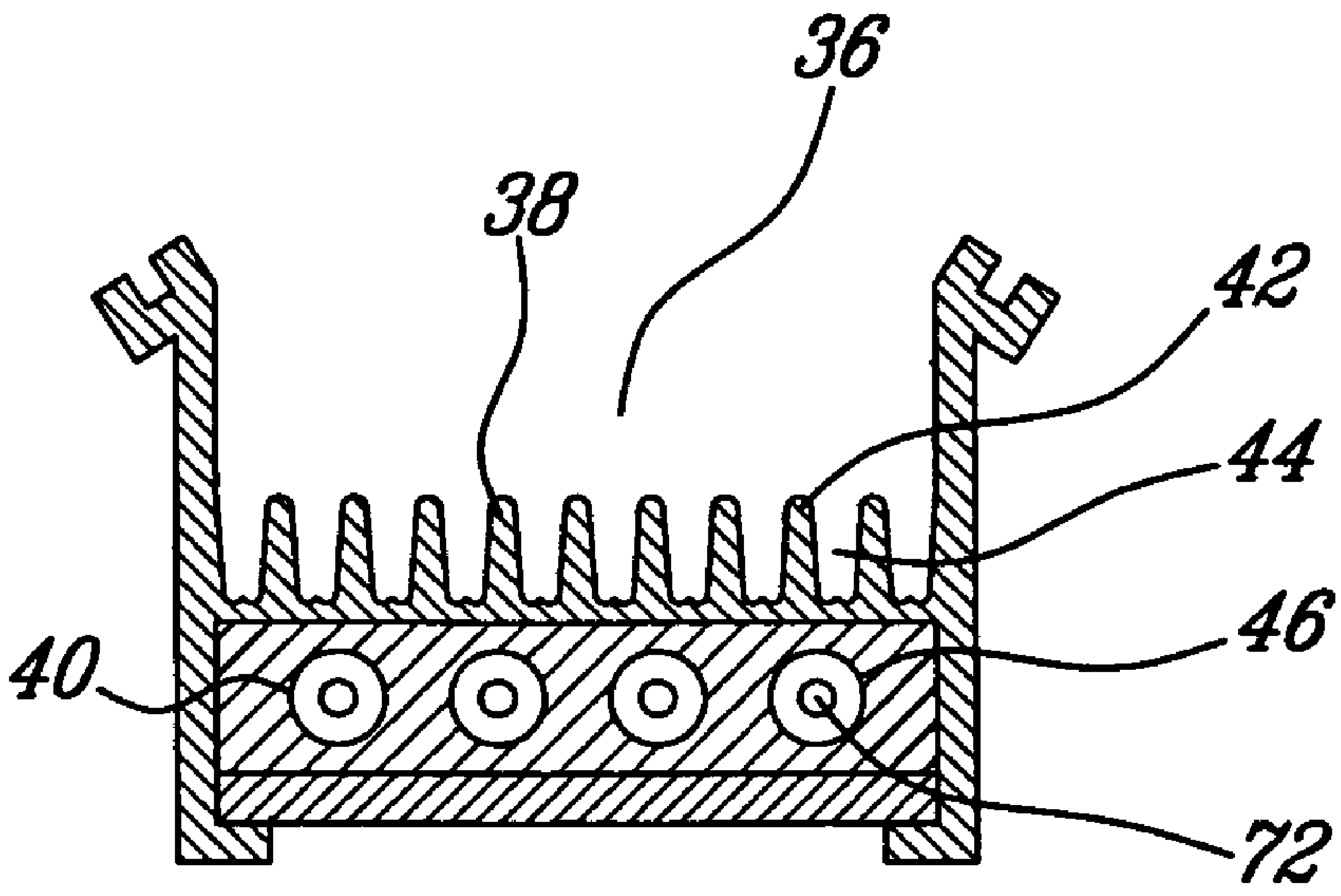


FIG. 4A

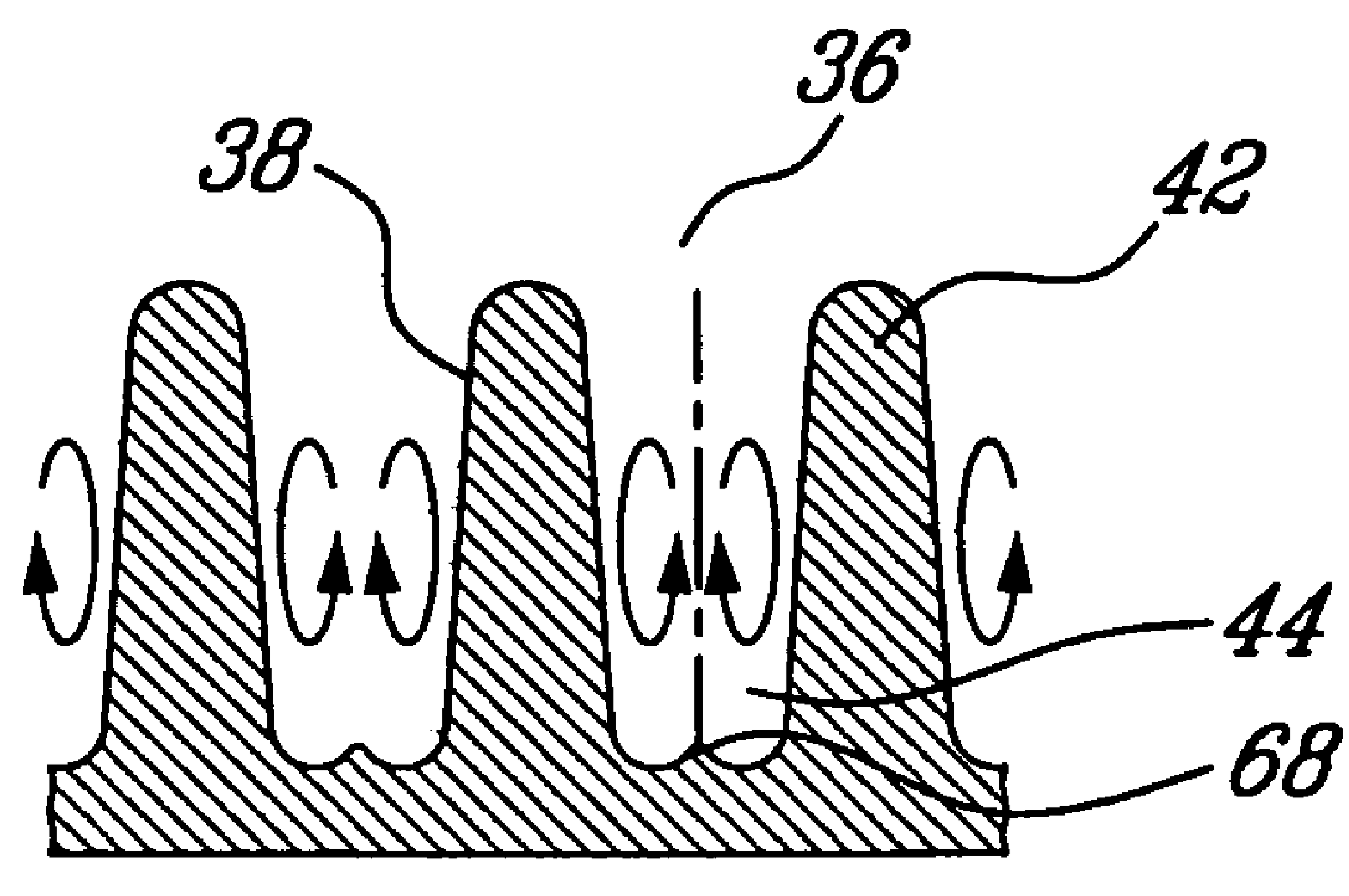


FIG. 4B

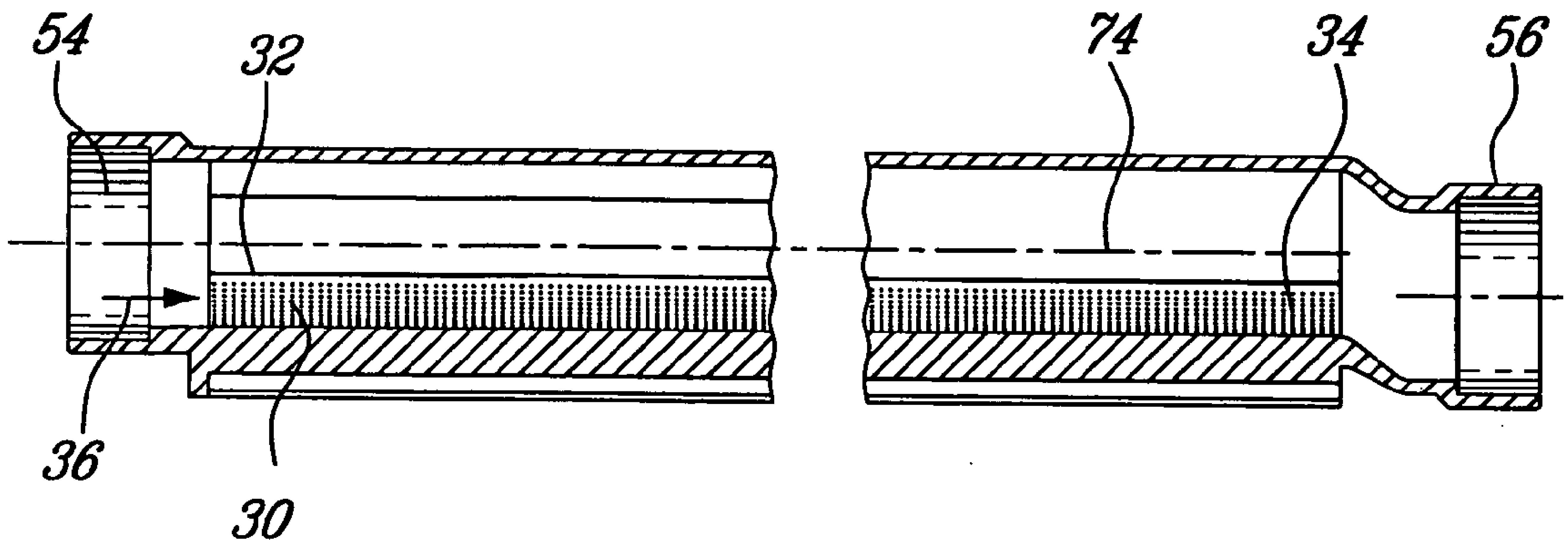


FIG. 5A

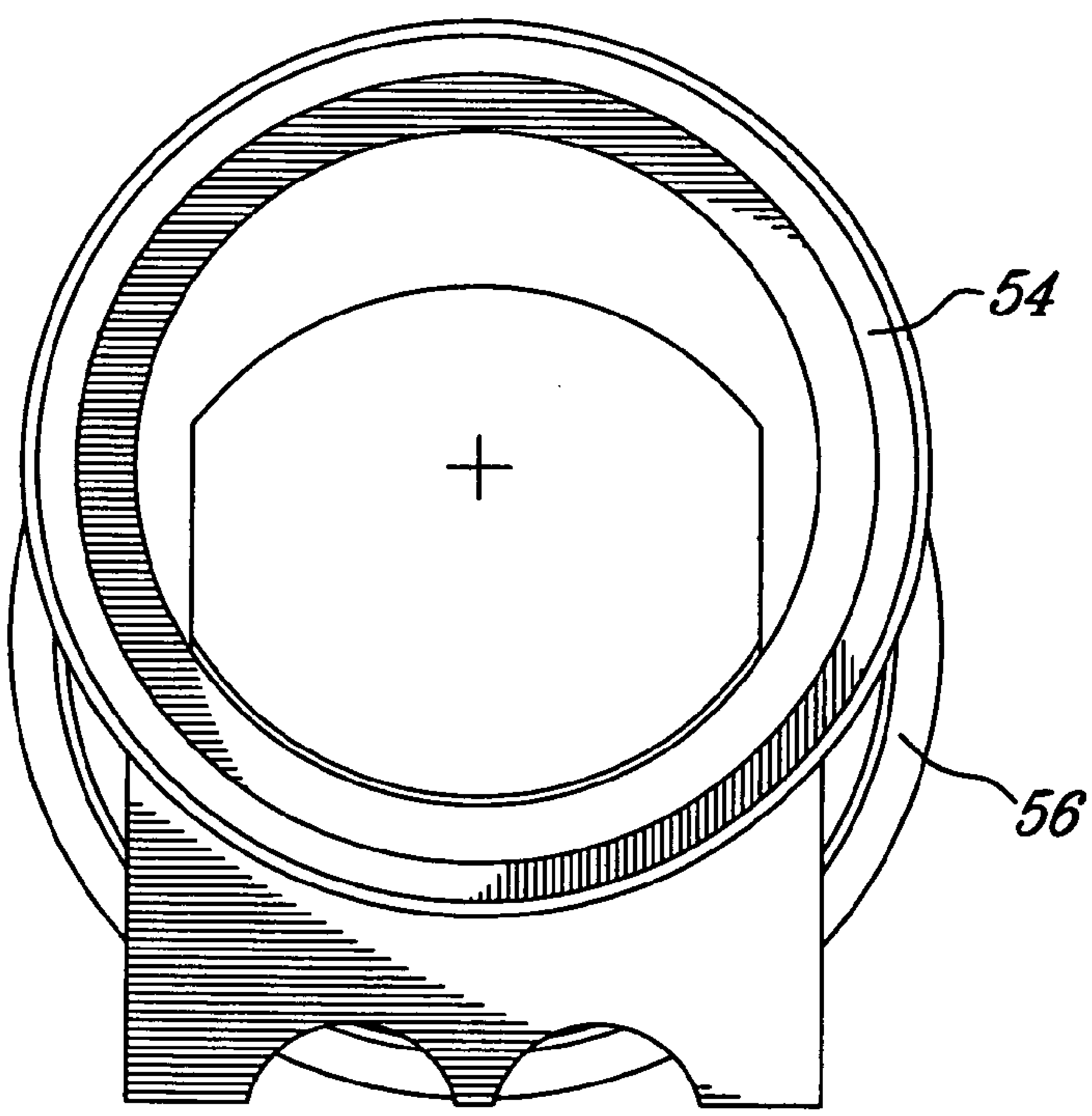


FIG. 5B

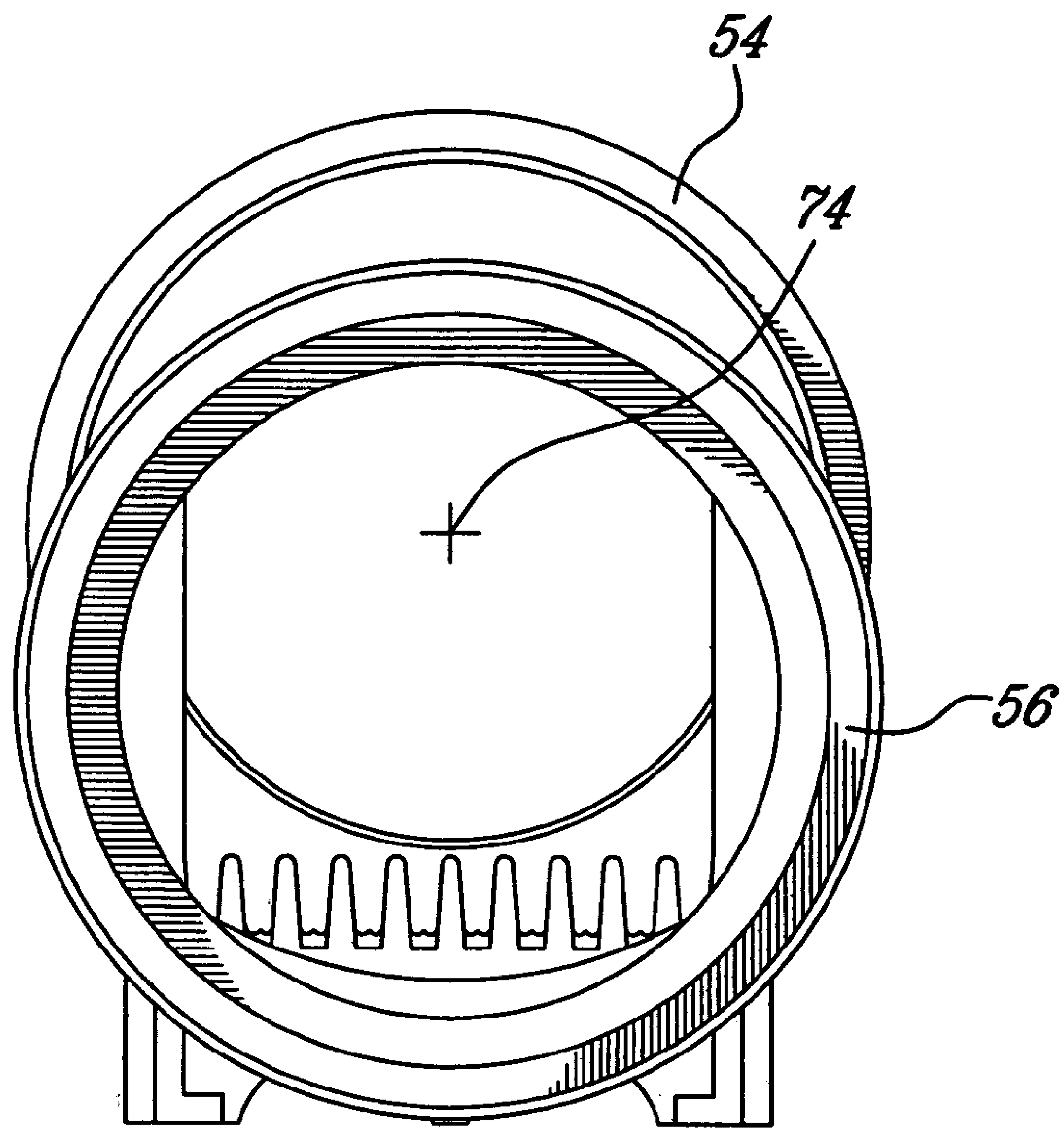


FIG. 5C

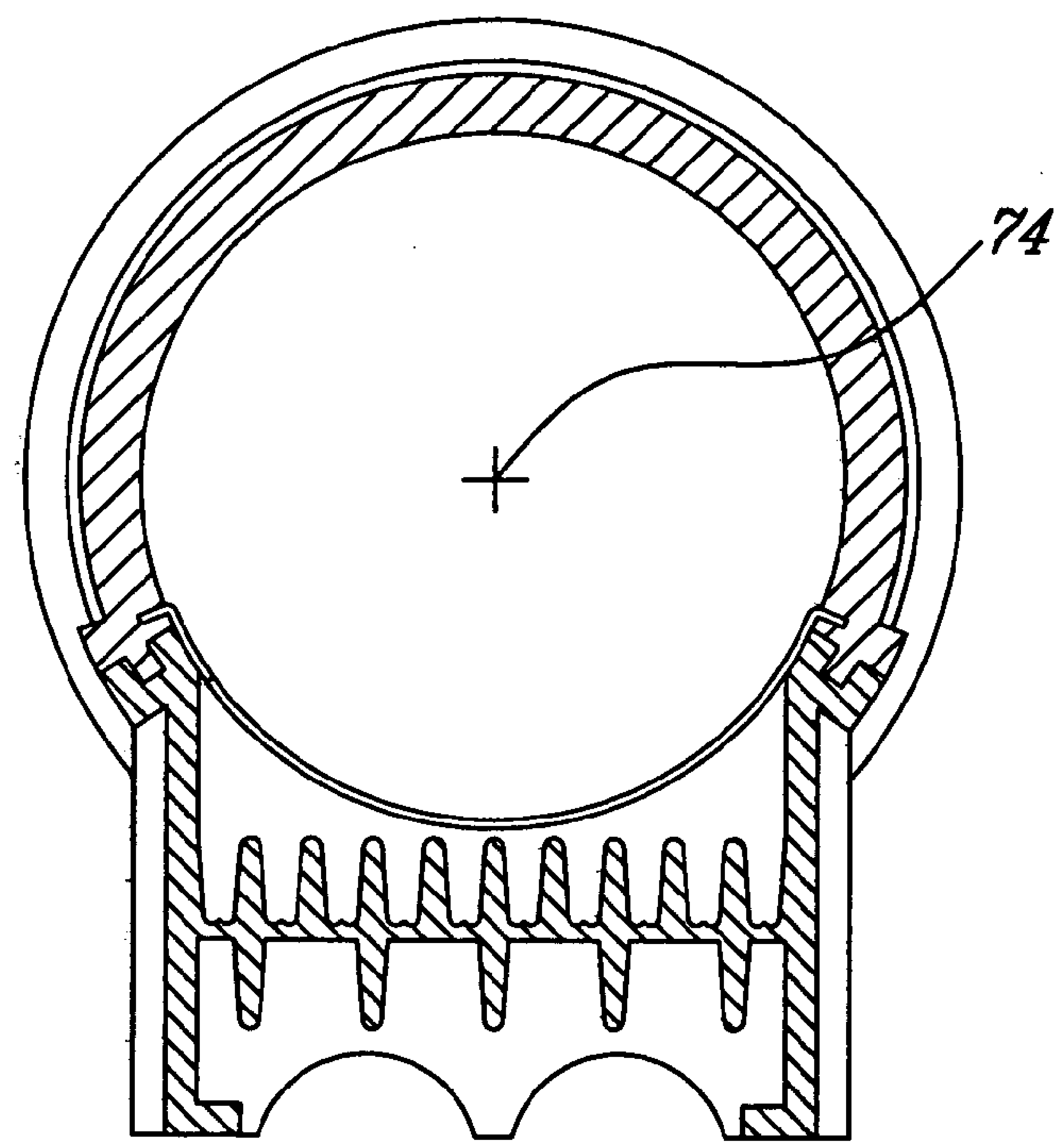


FIG. 5D

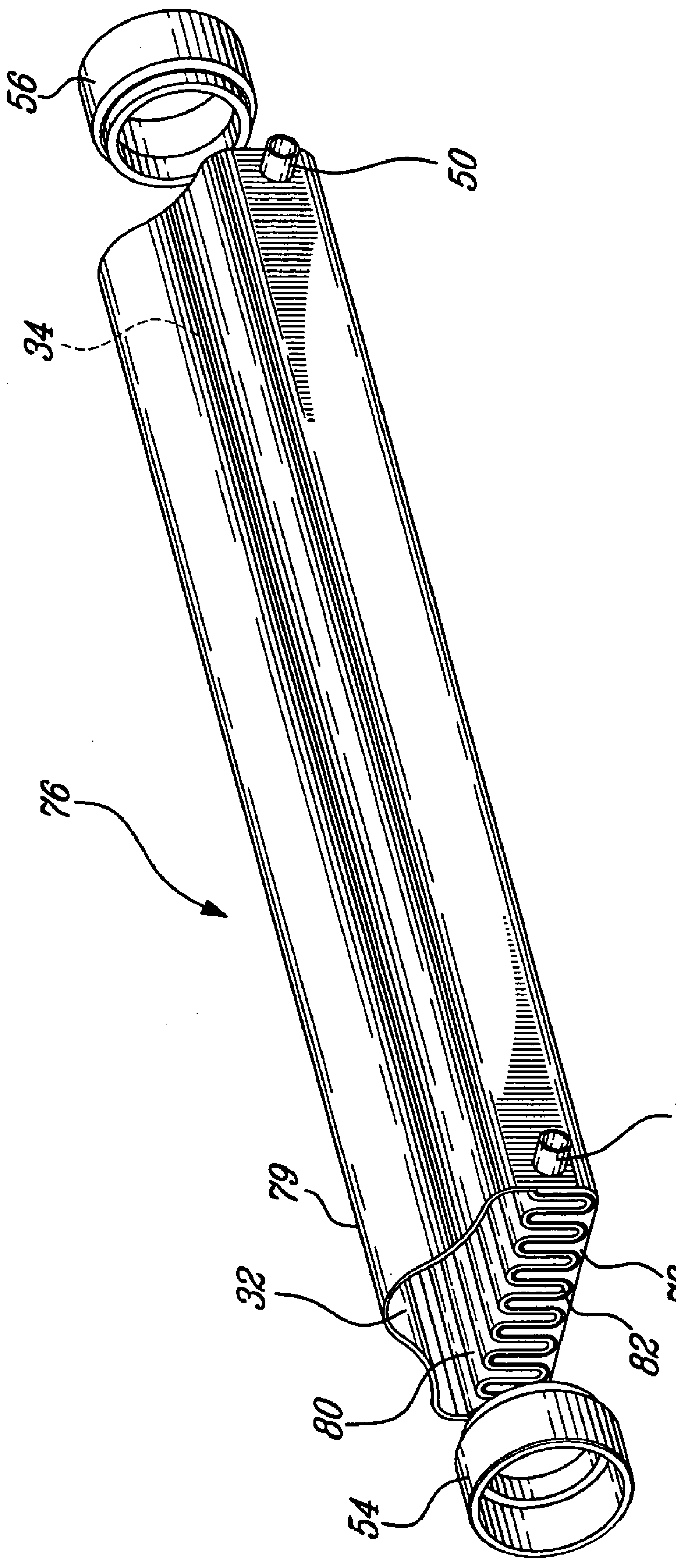


FIG. 6

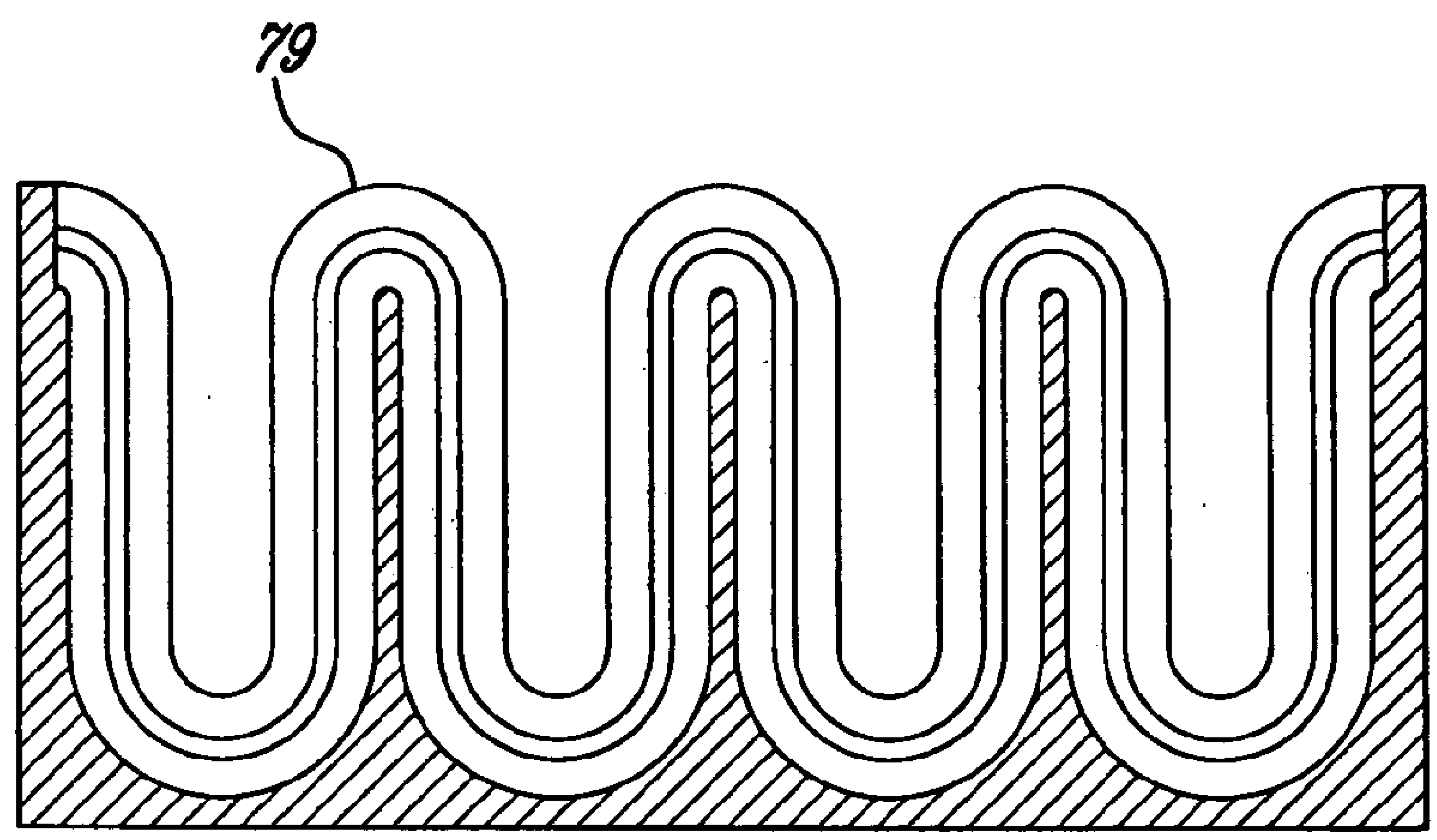


FIG. 7A

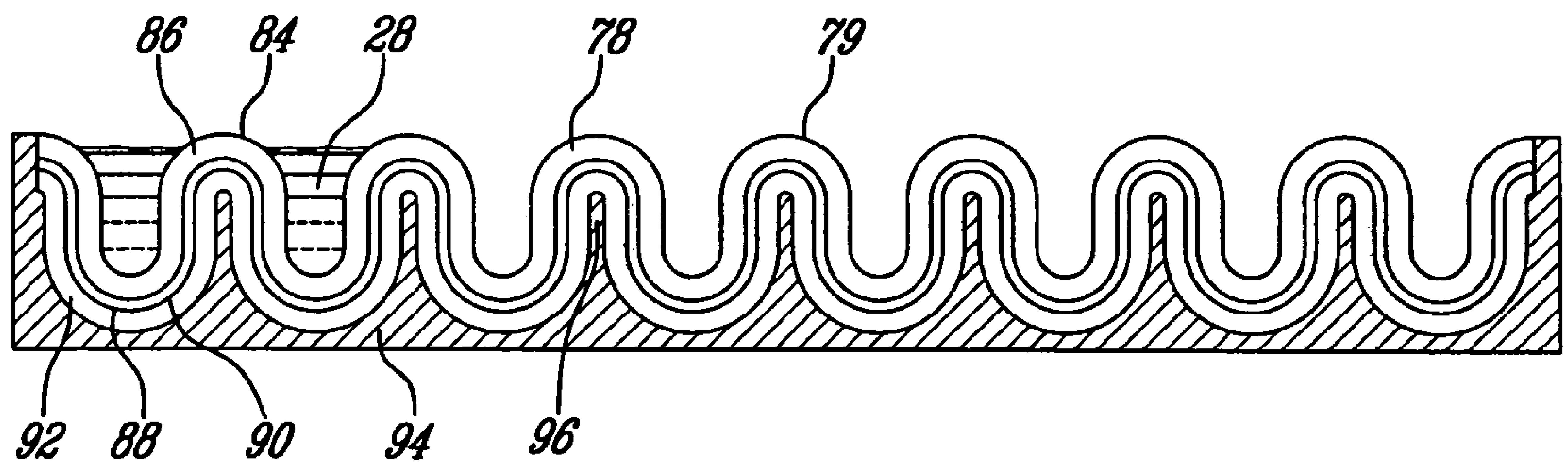


FIG. 7B

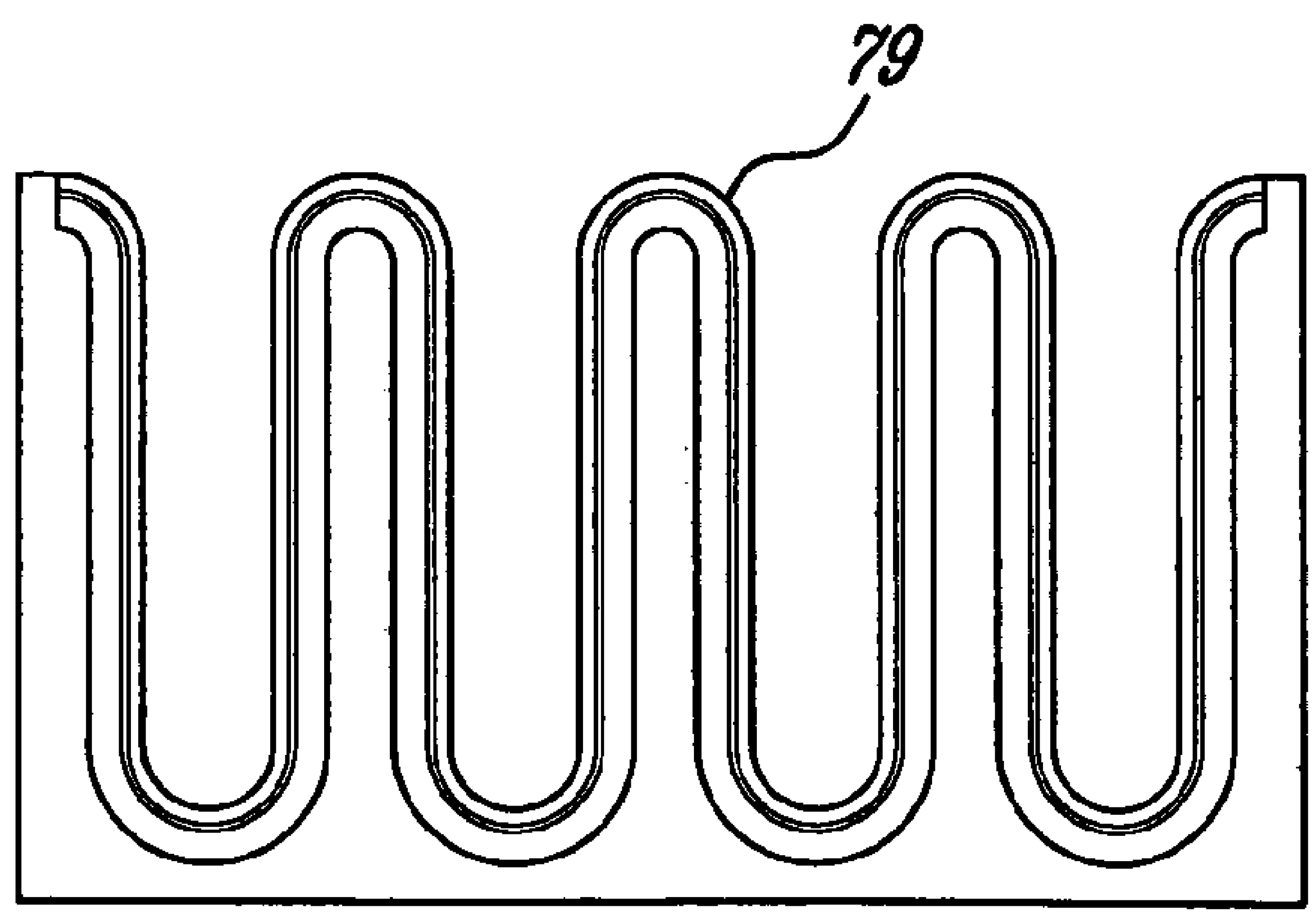


FIG. 7C

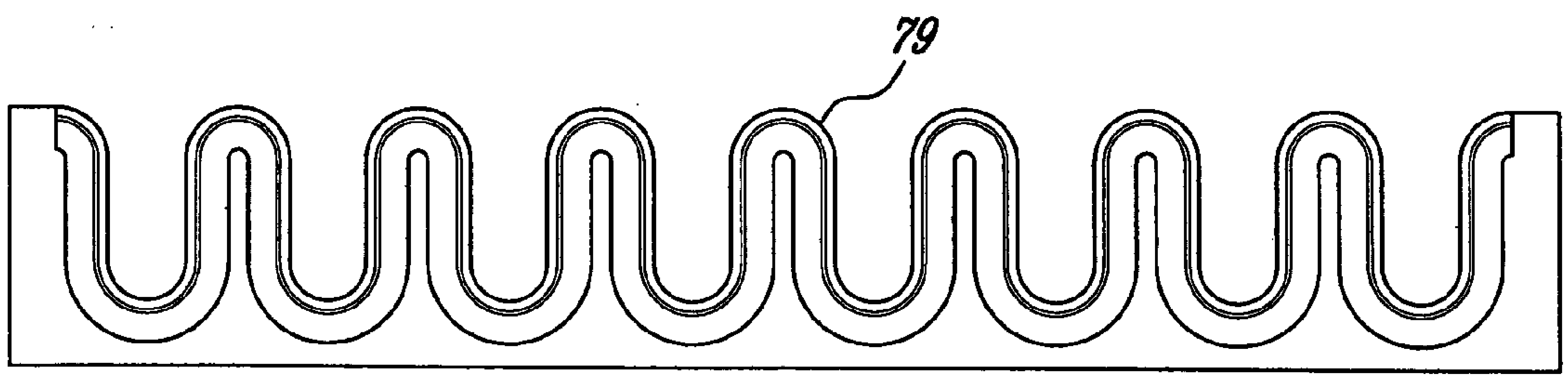


FIG. 7D

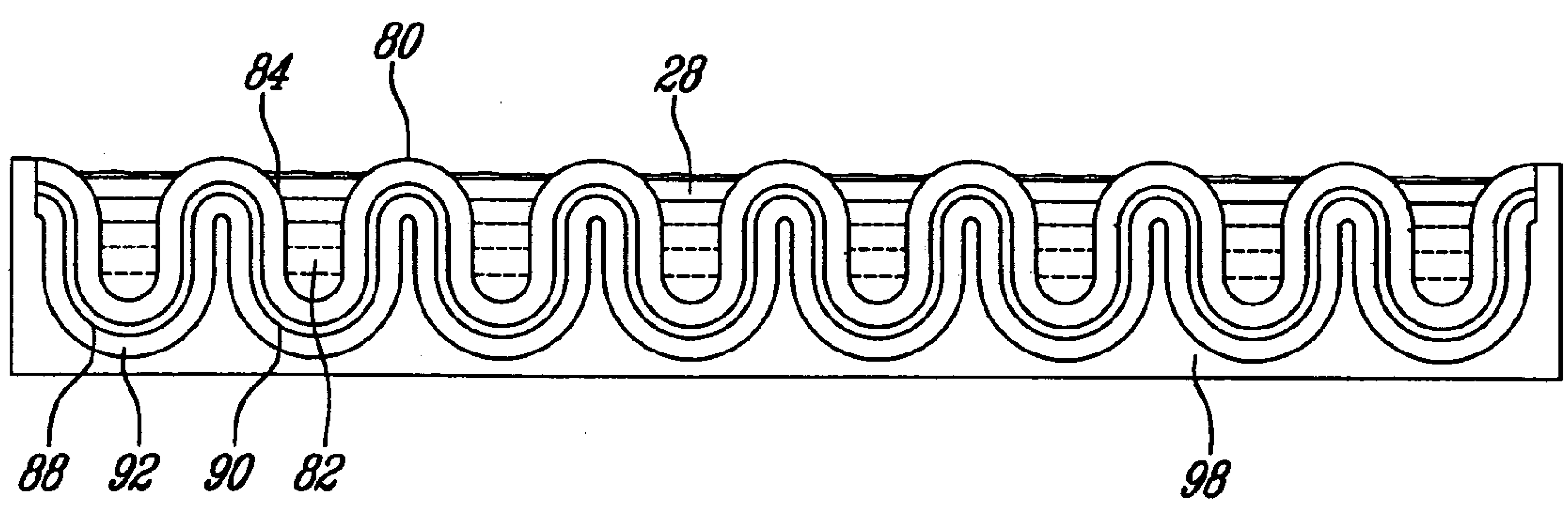


FIG. 8

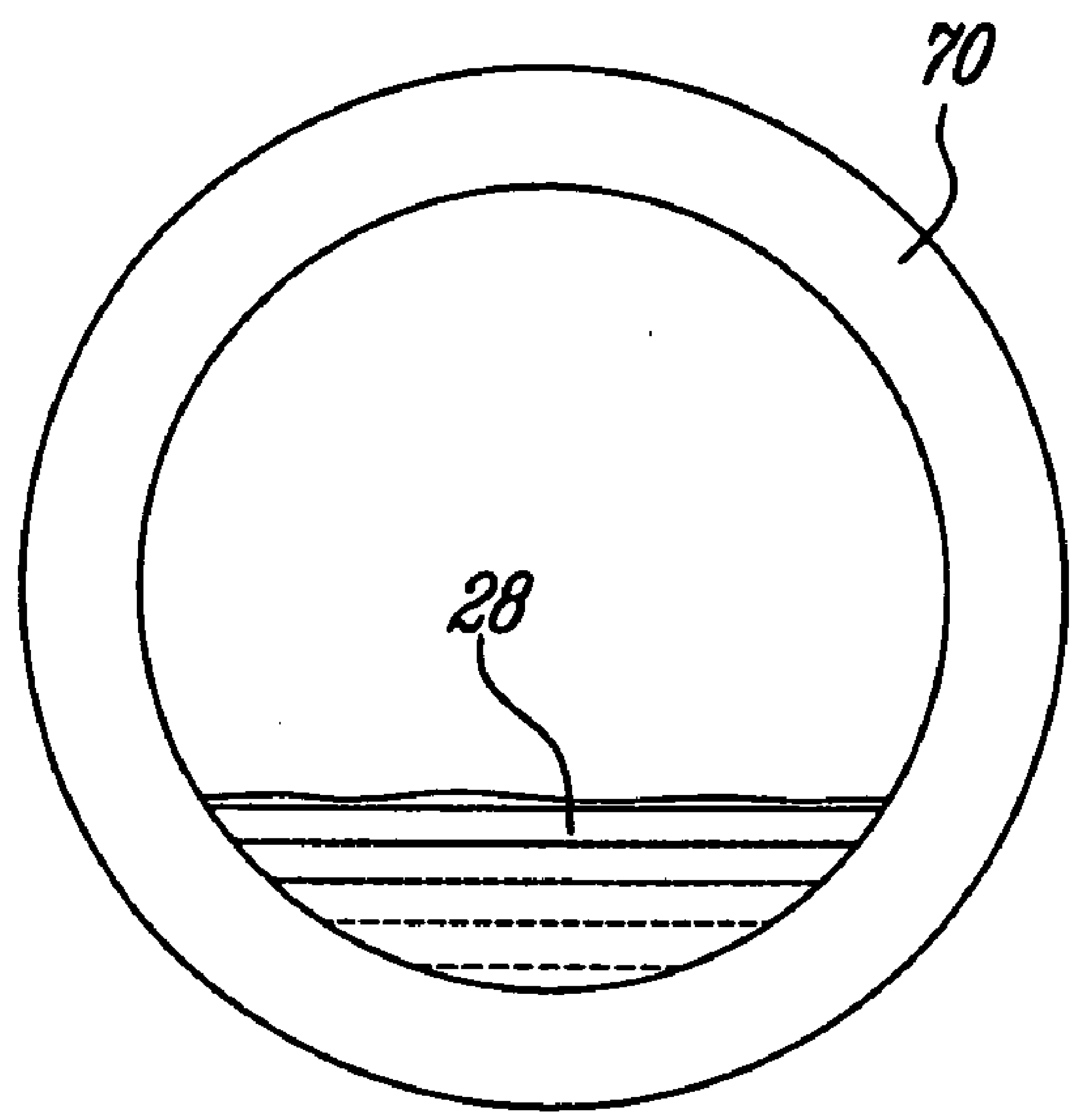


FIG. 9A

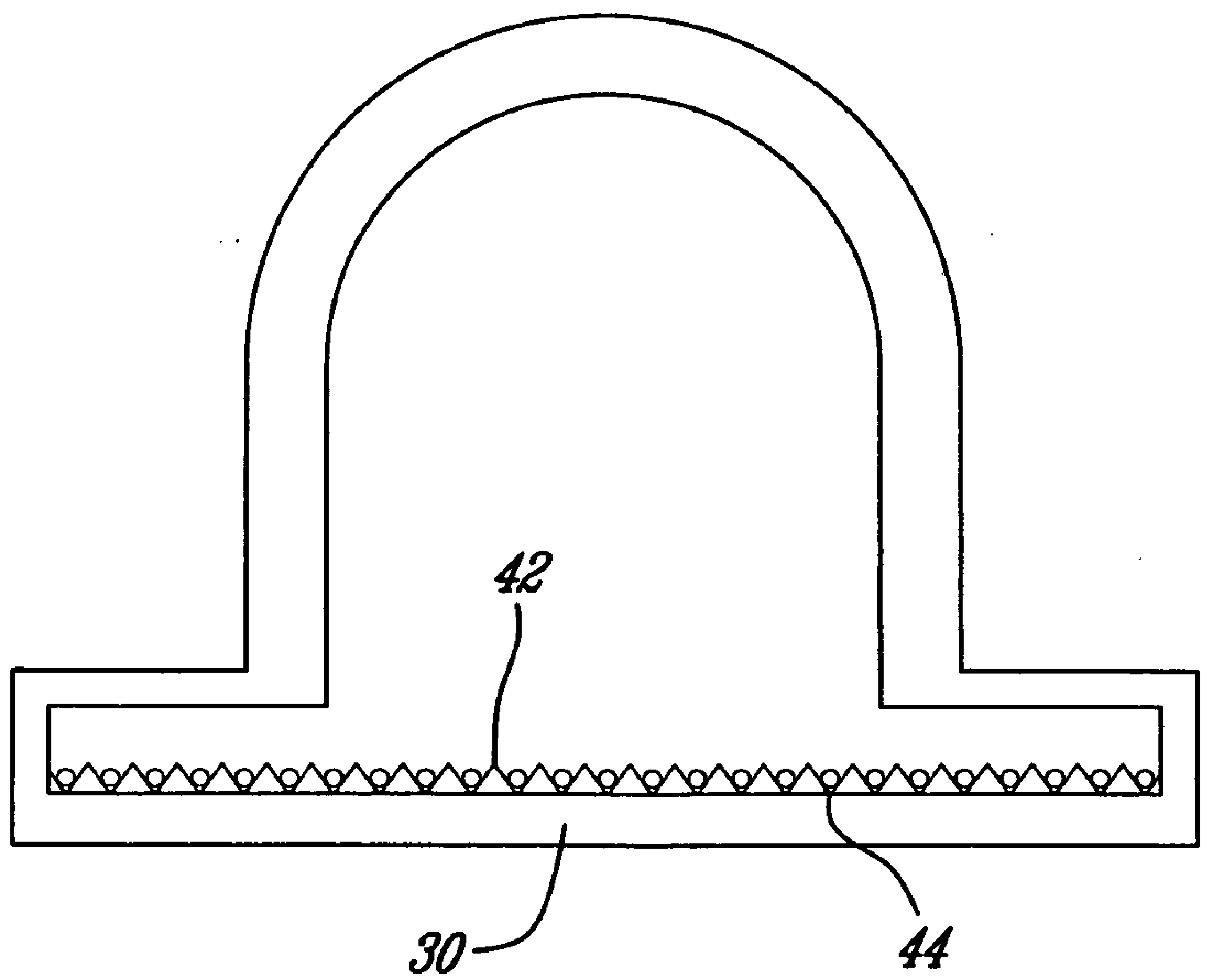


FIG. 9B

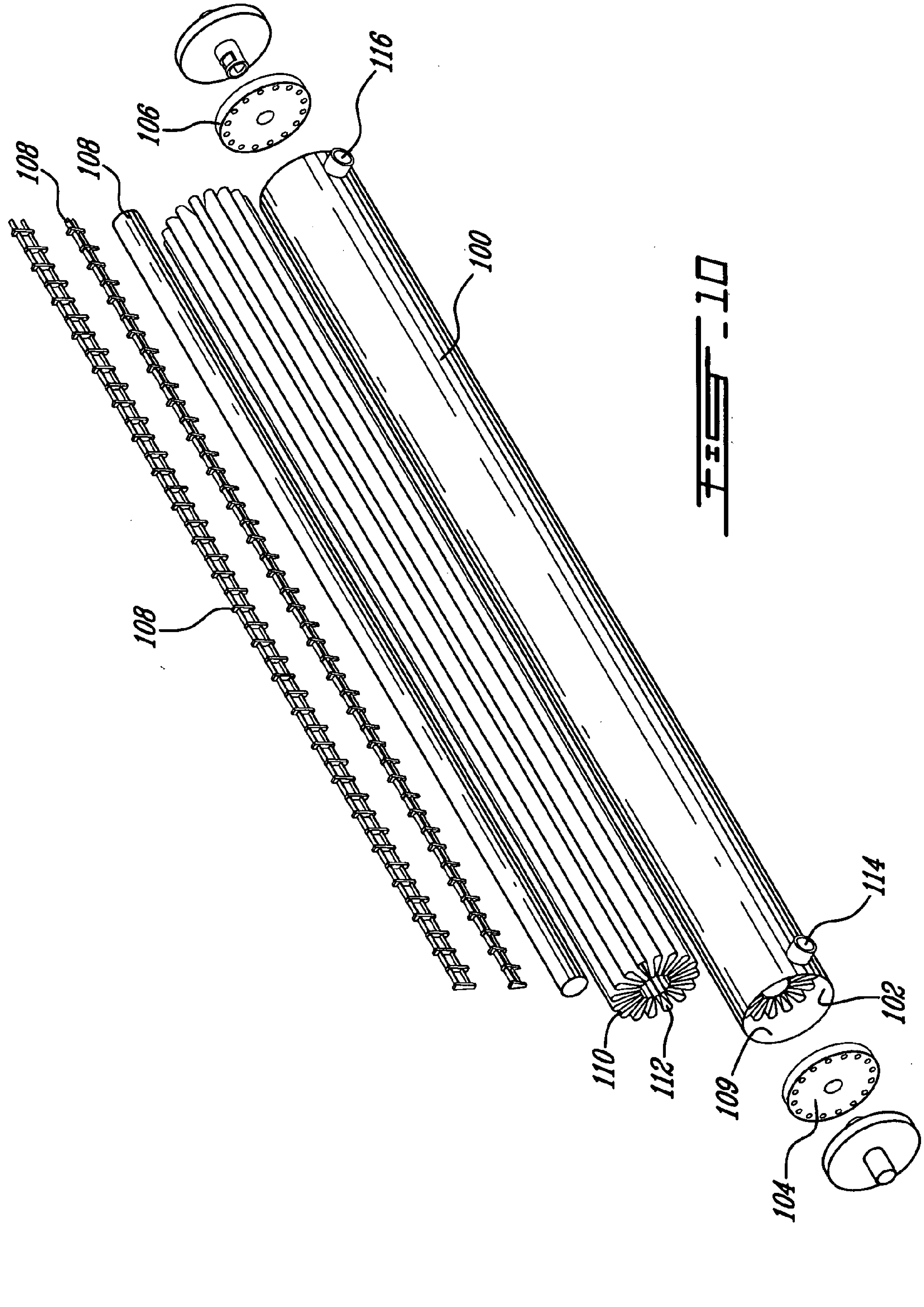


FIG-10

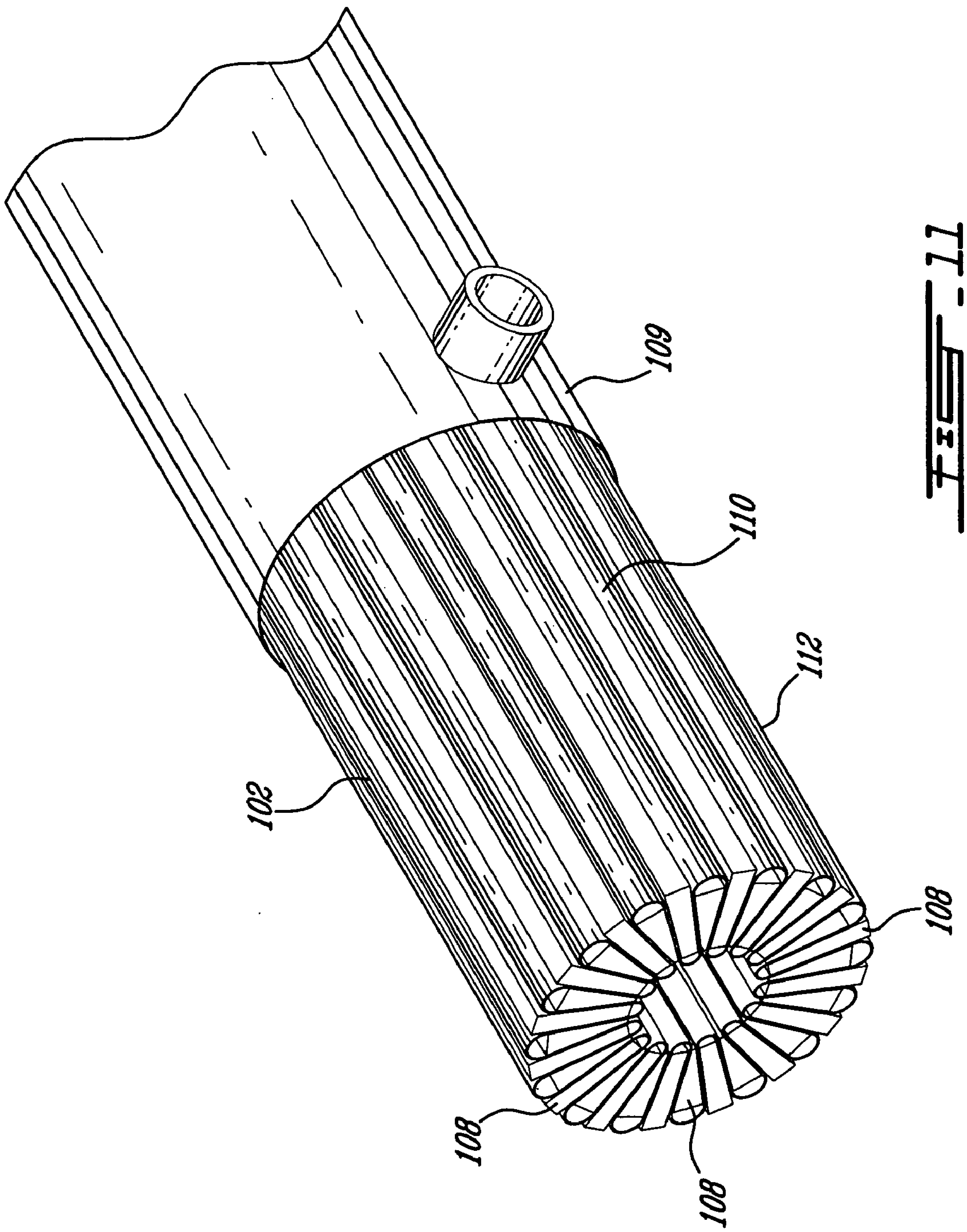


FIG - 11

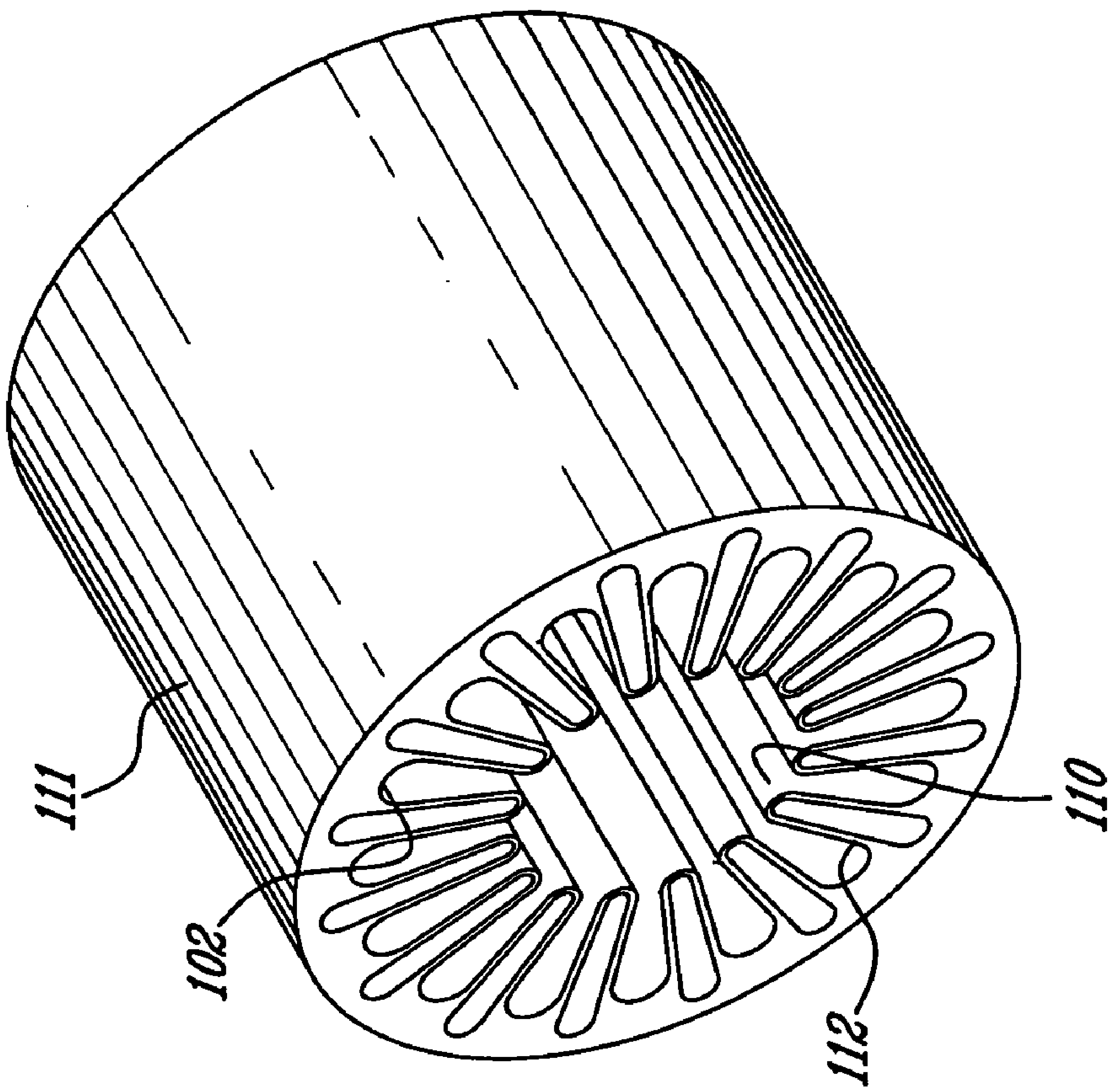


FIG-12B

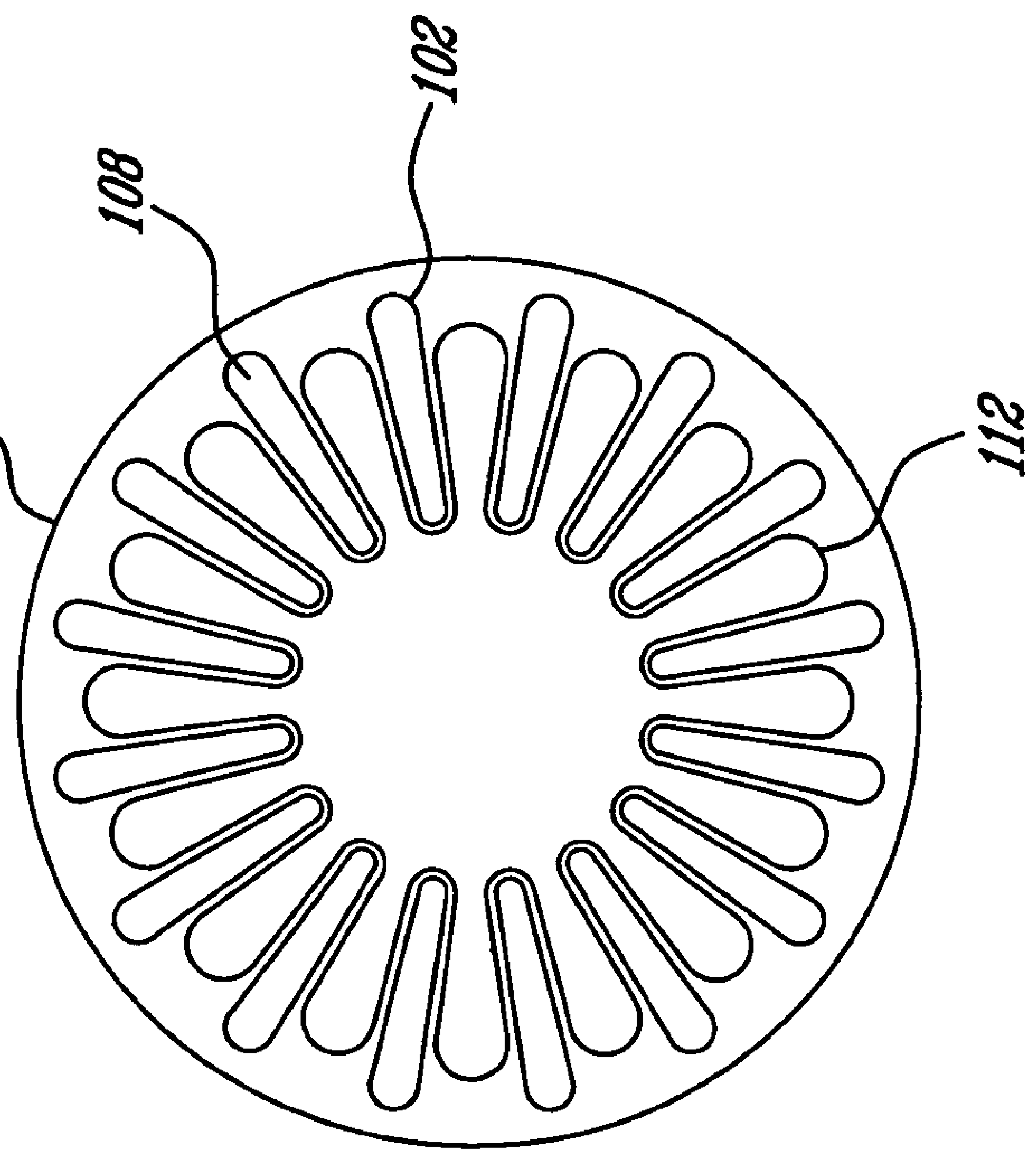


FIG-12A

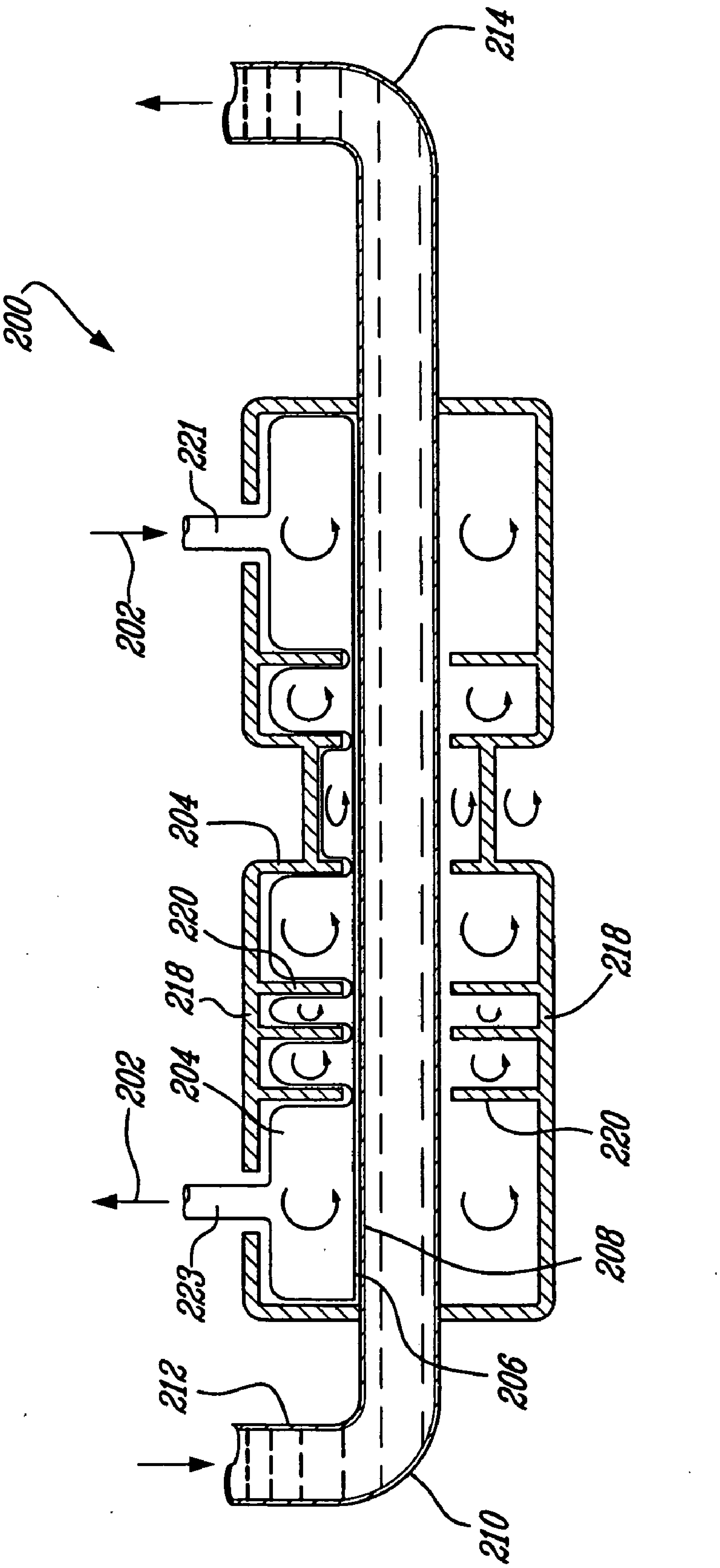


FIG. 13

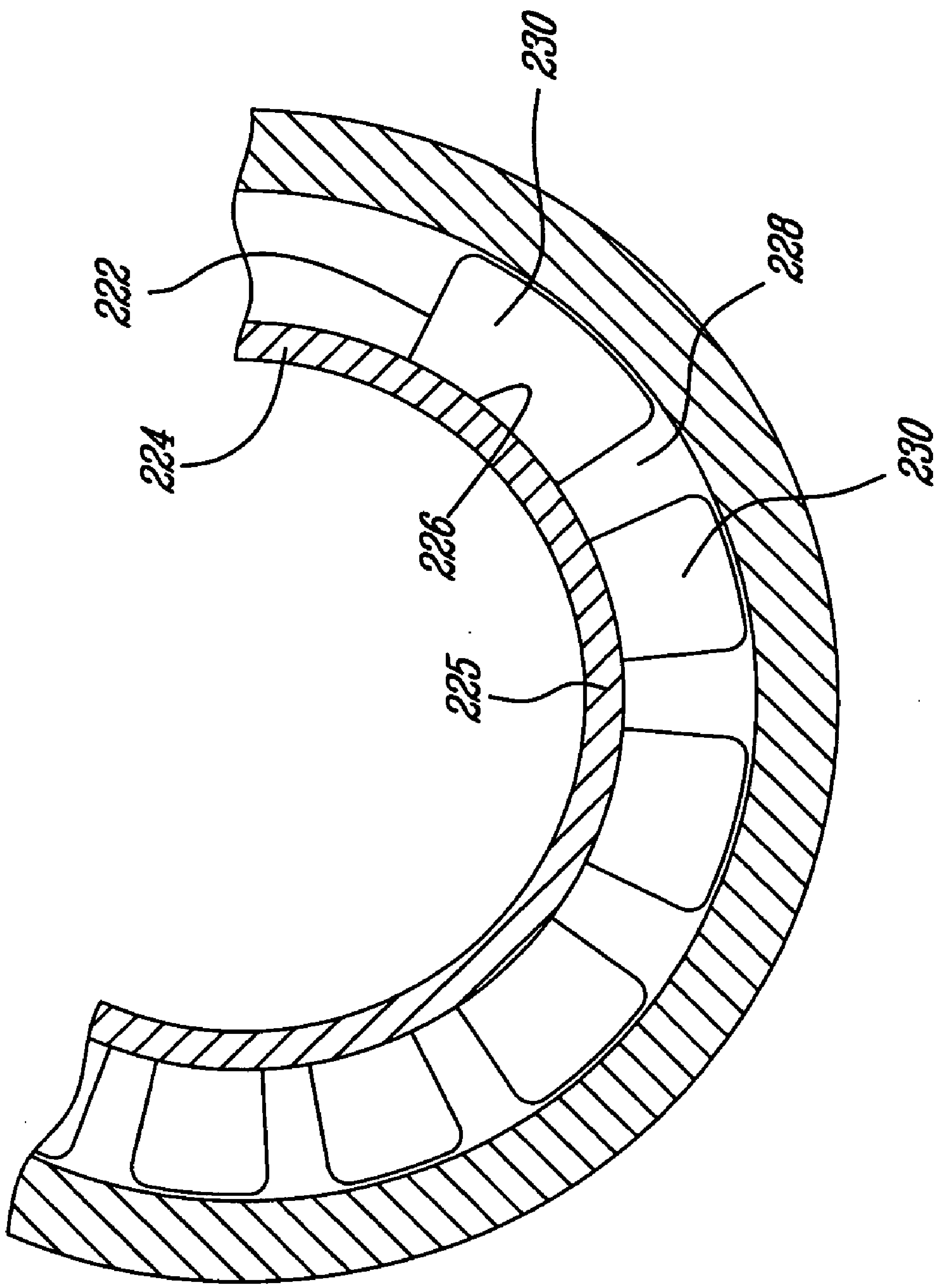


FIG-14

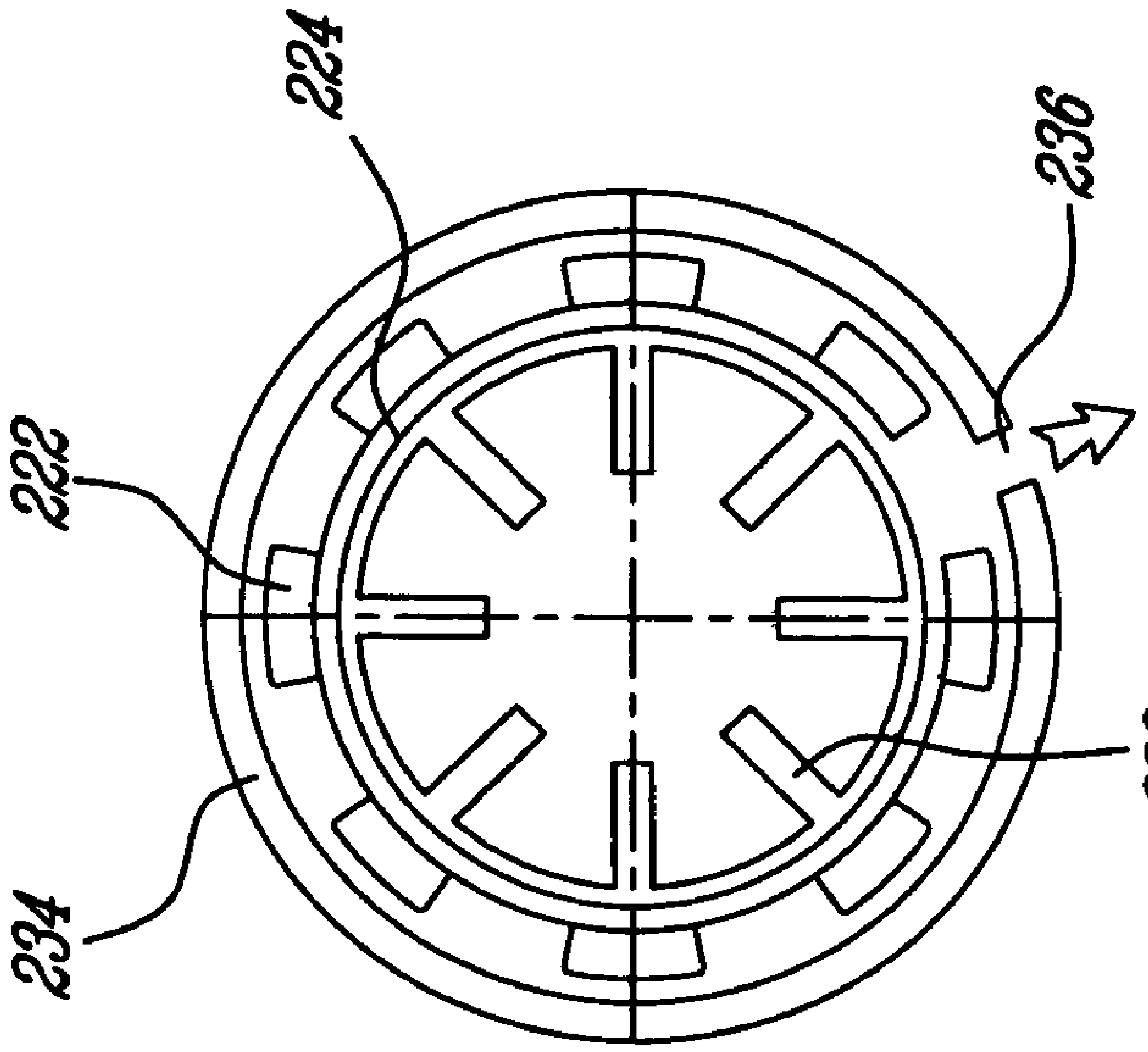


FIG. 15B

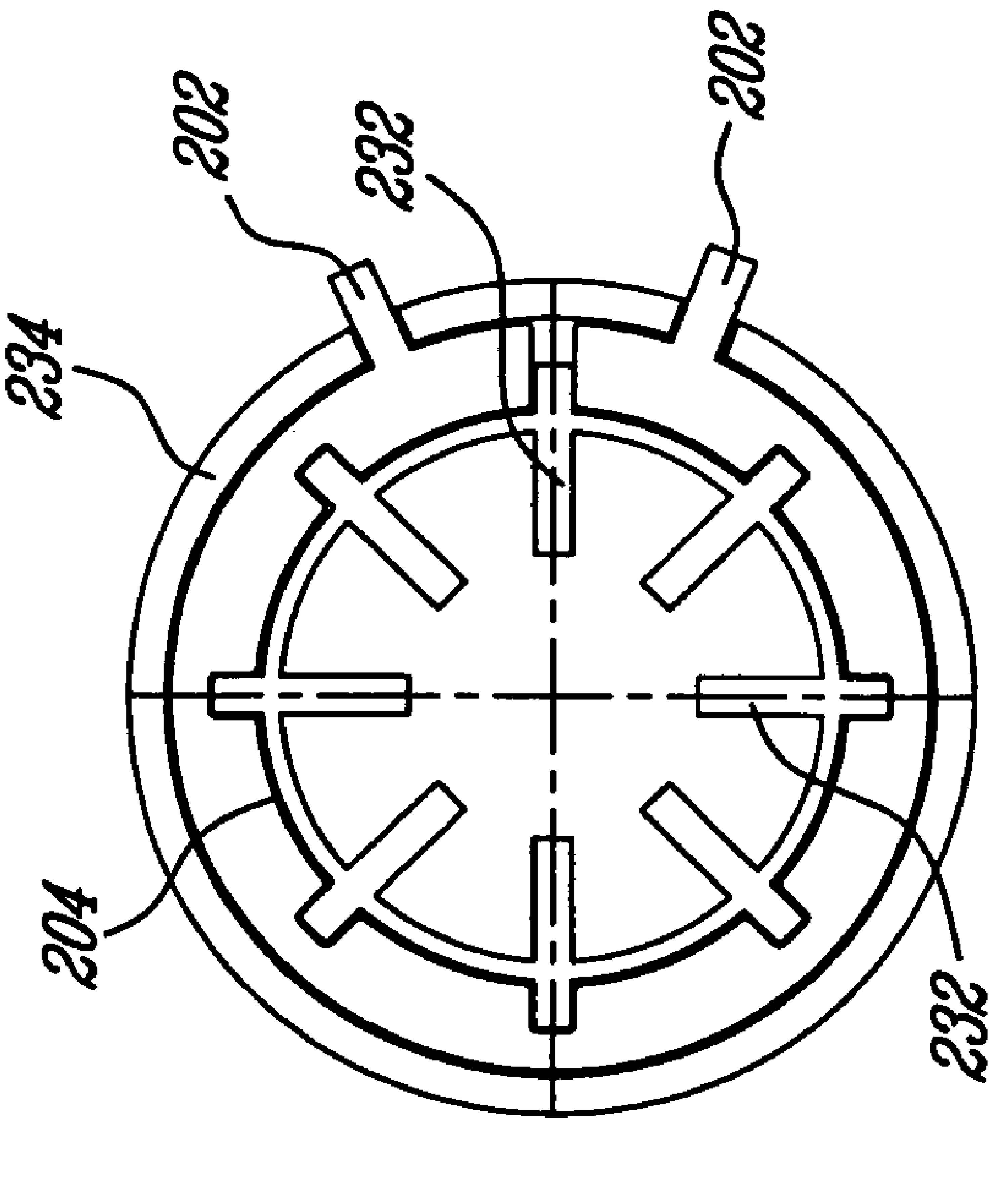


FIG. 15A

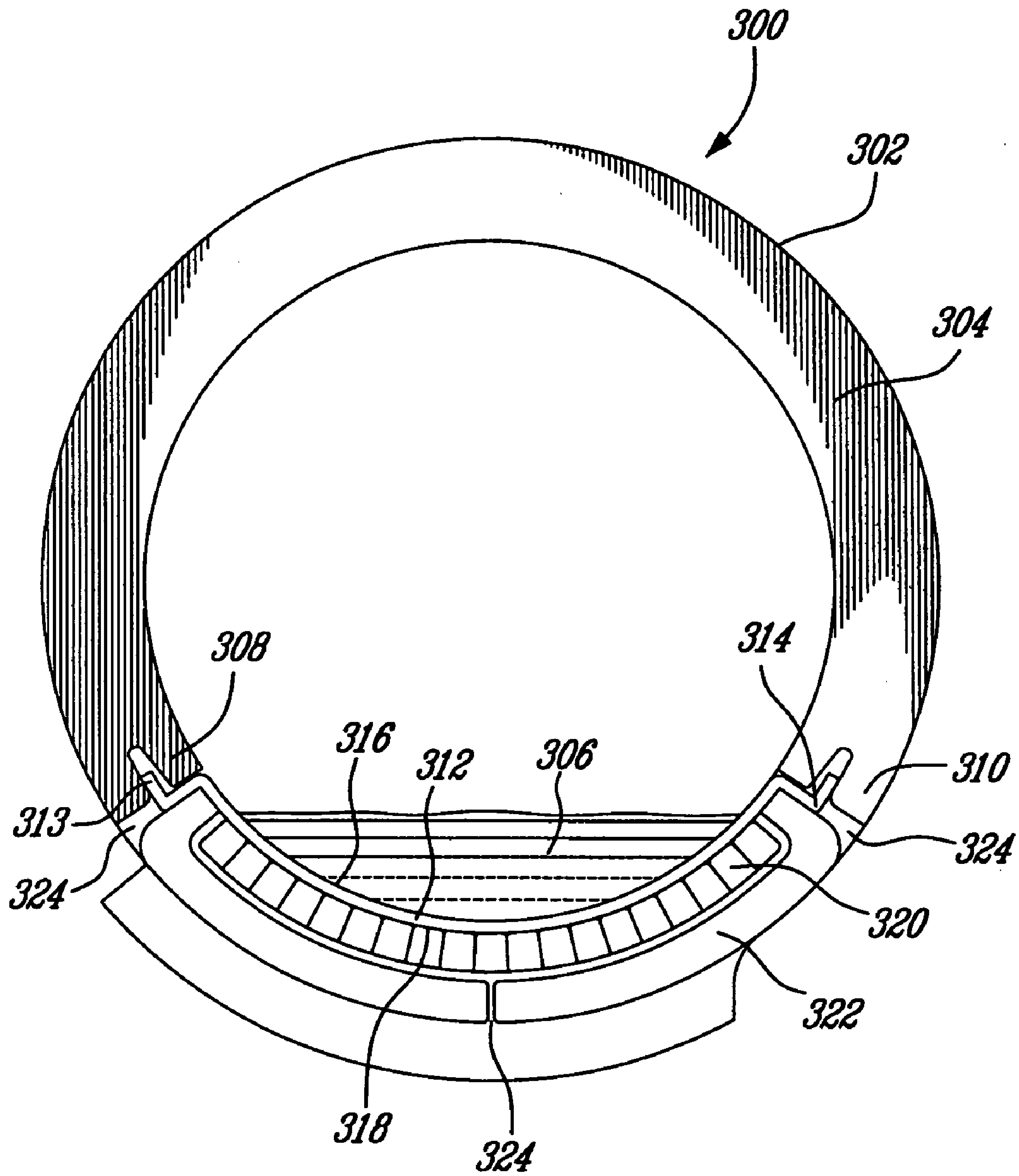


FIG. 16

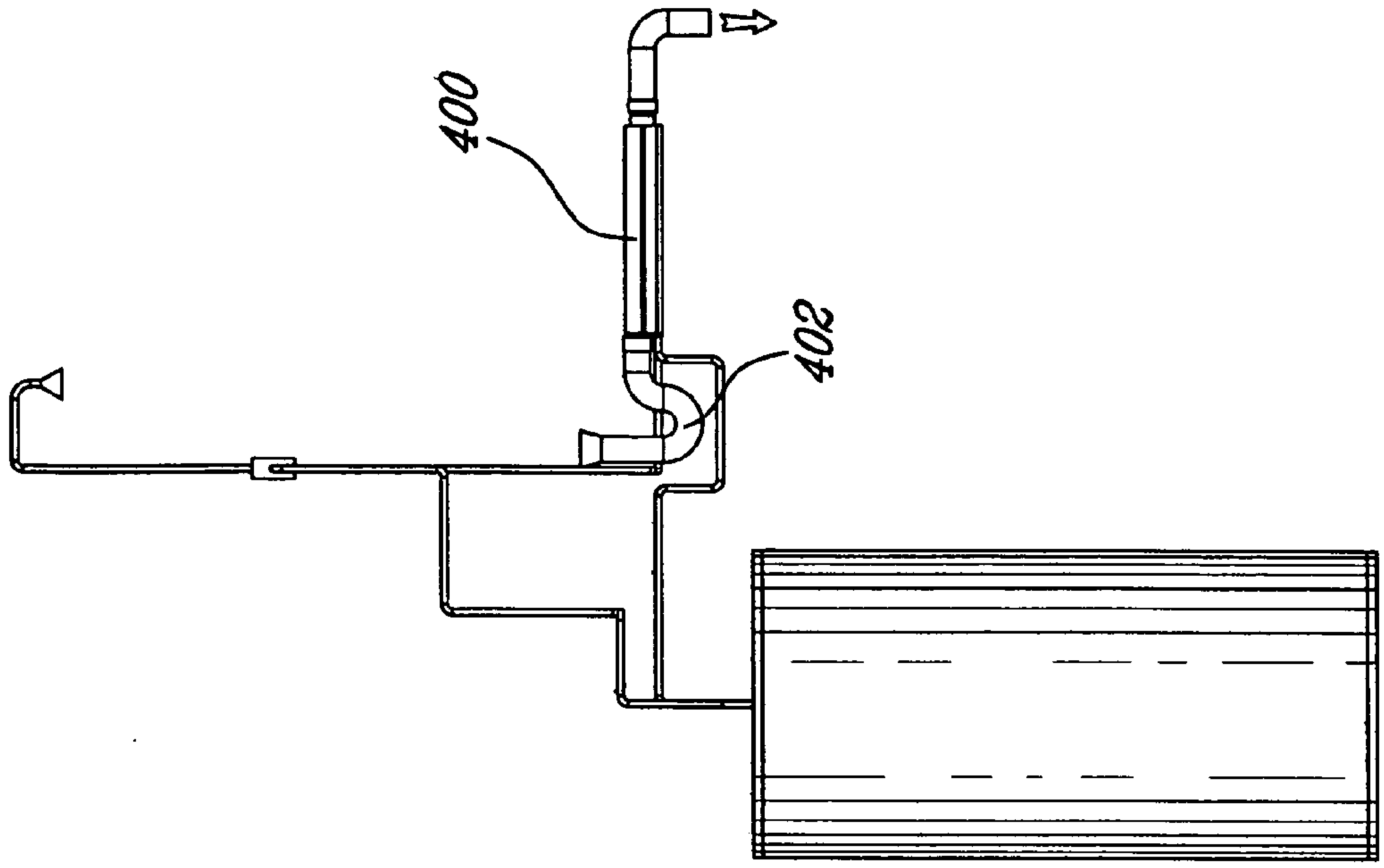


FIG.-17B

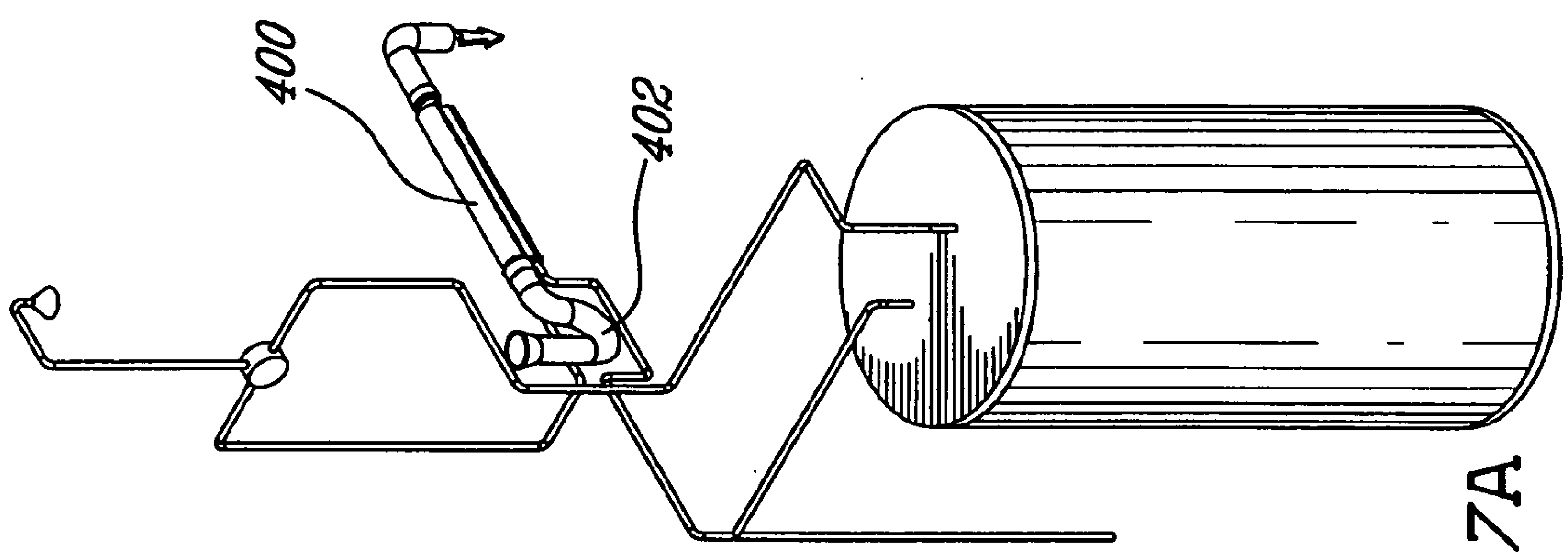


FIG.-17A

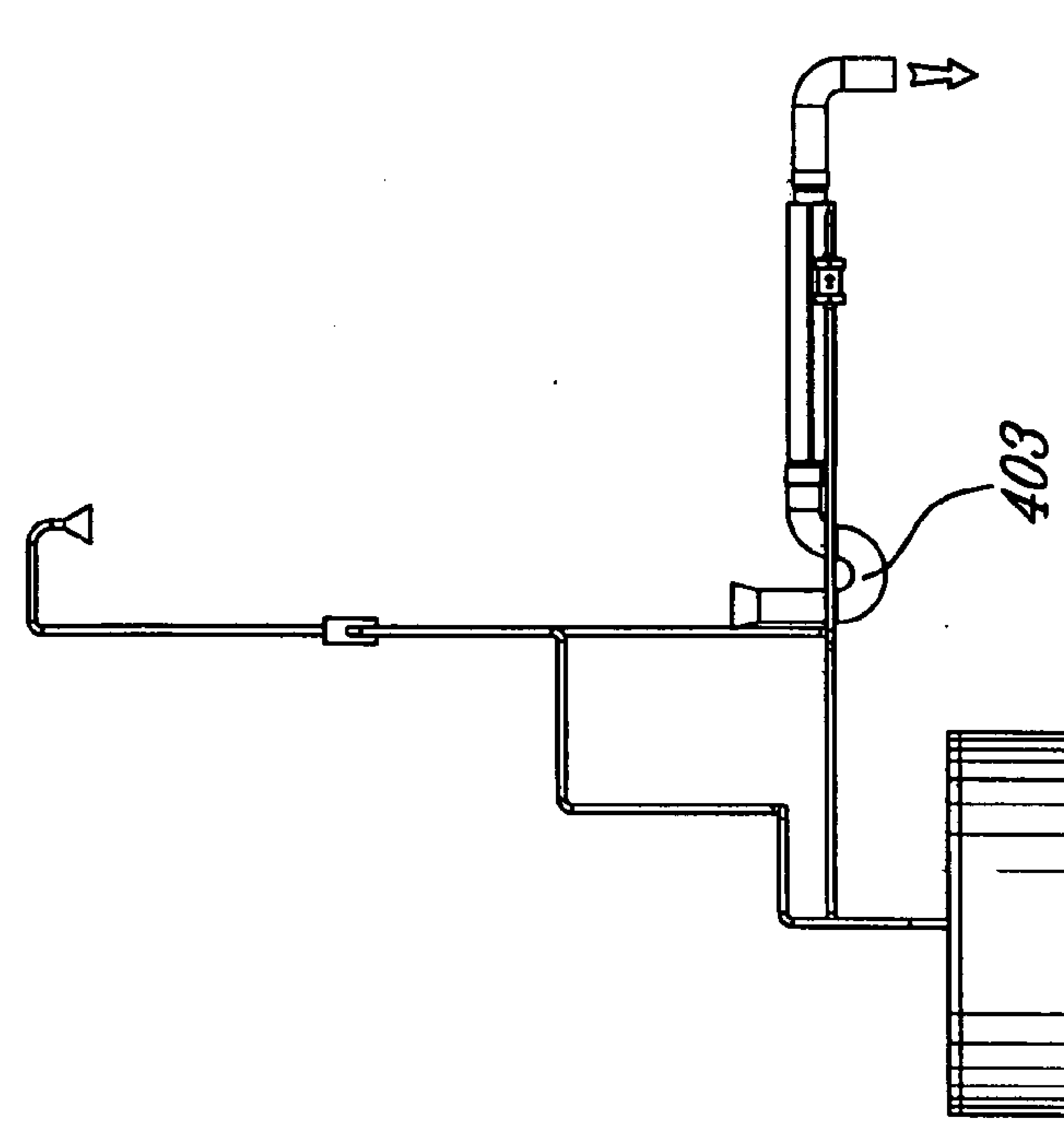


FIG-18B

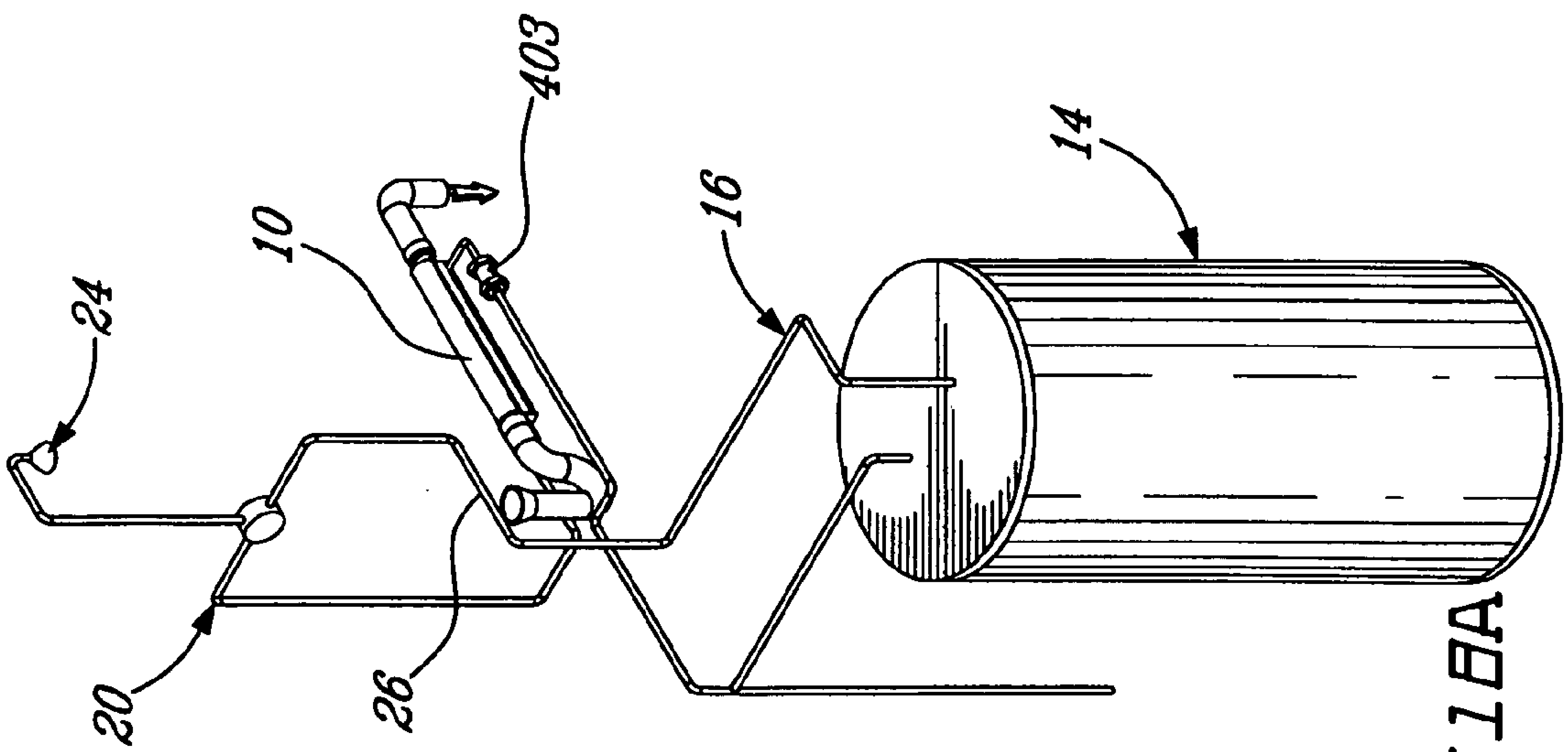


FIG-18A

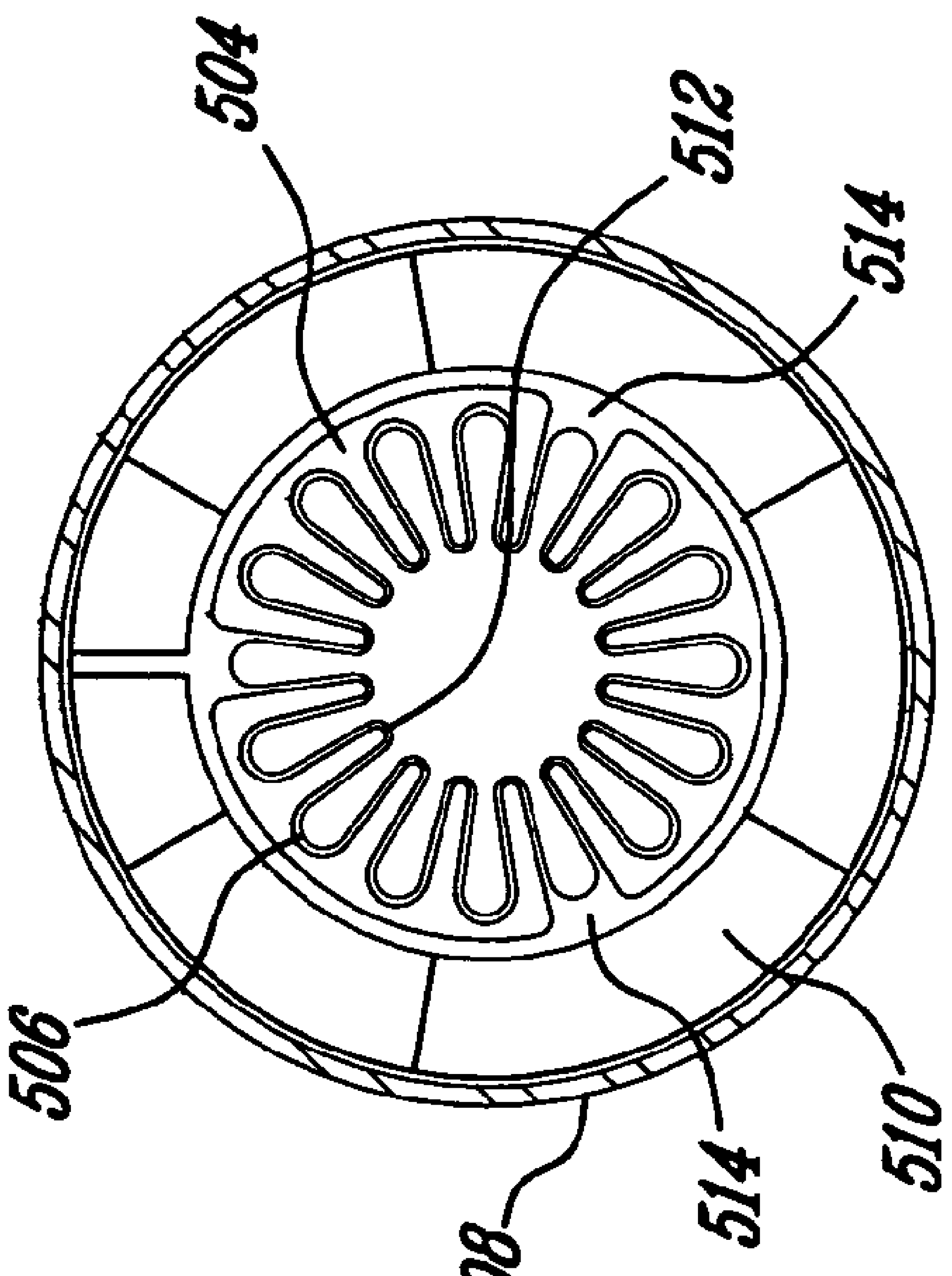


FIG-19B

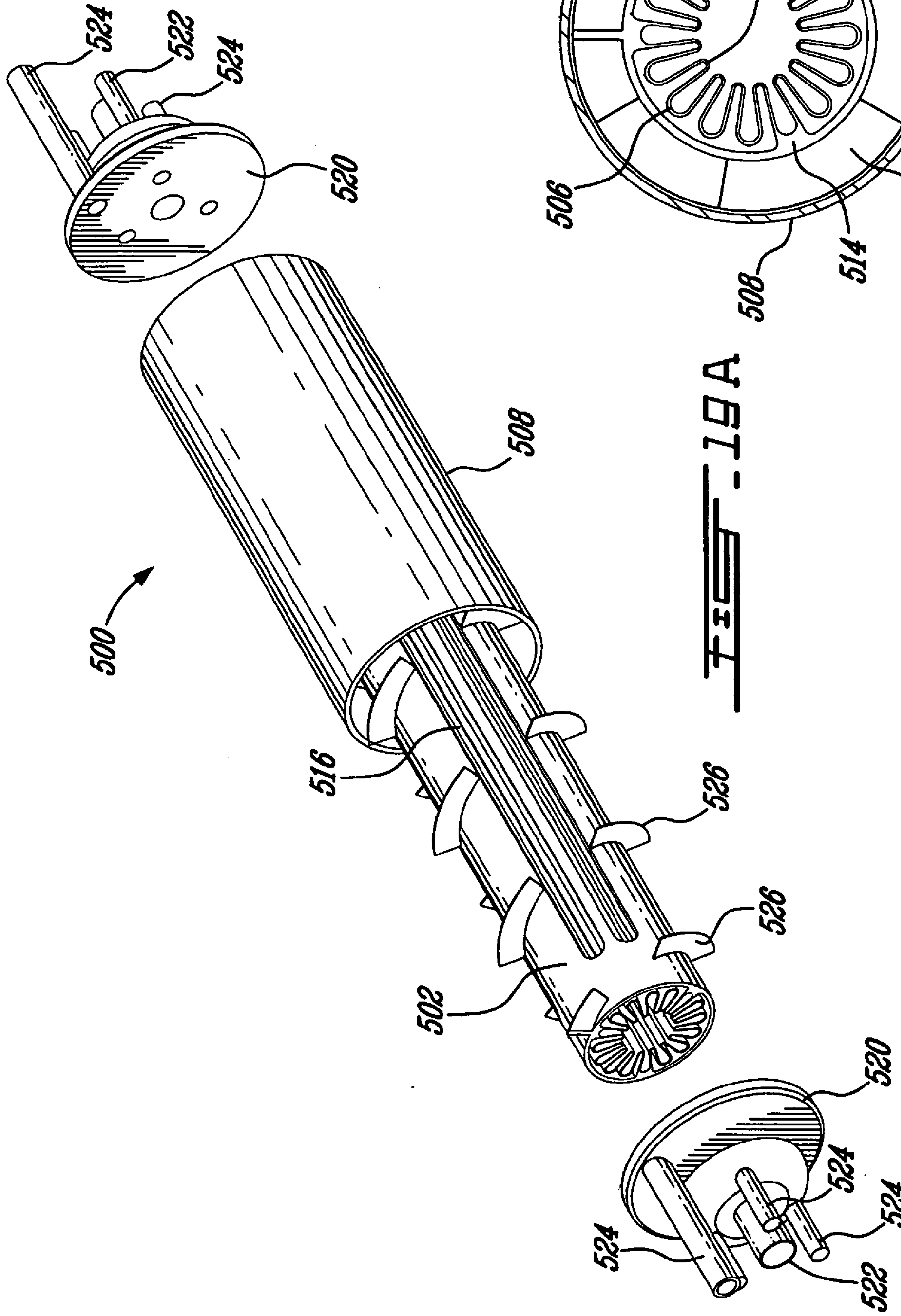


FIG-19A

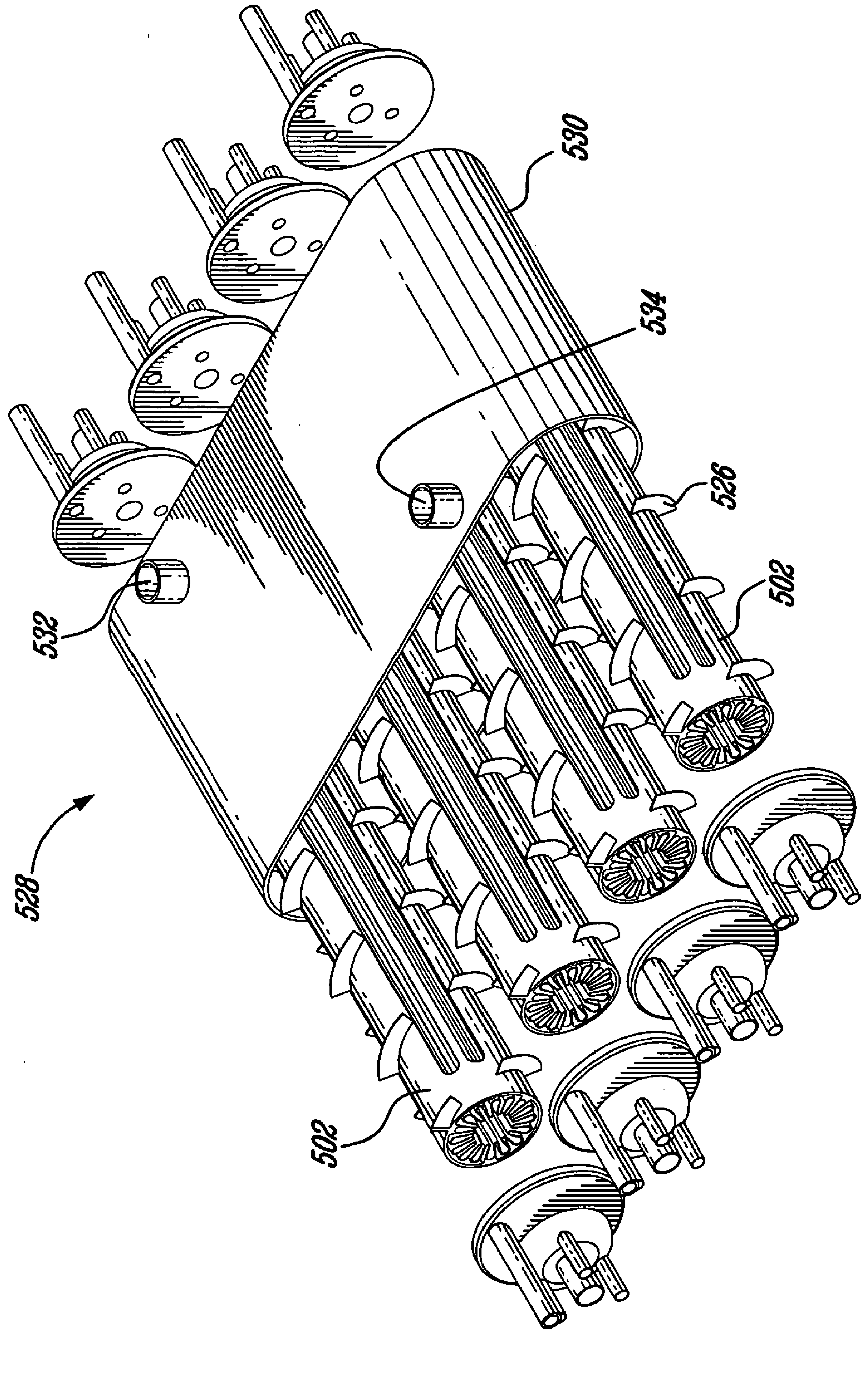


FIG. 20A

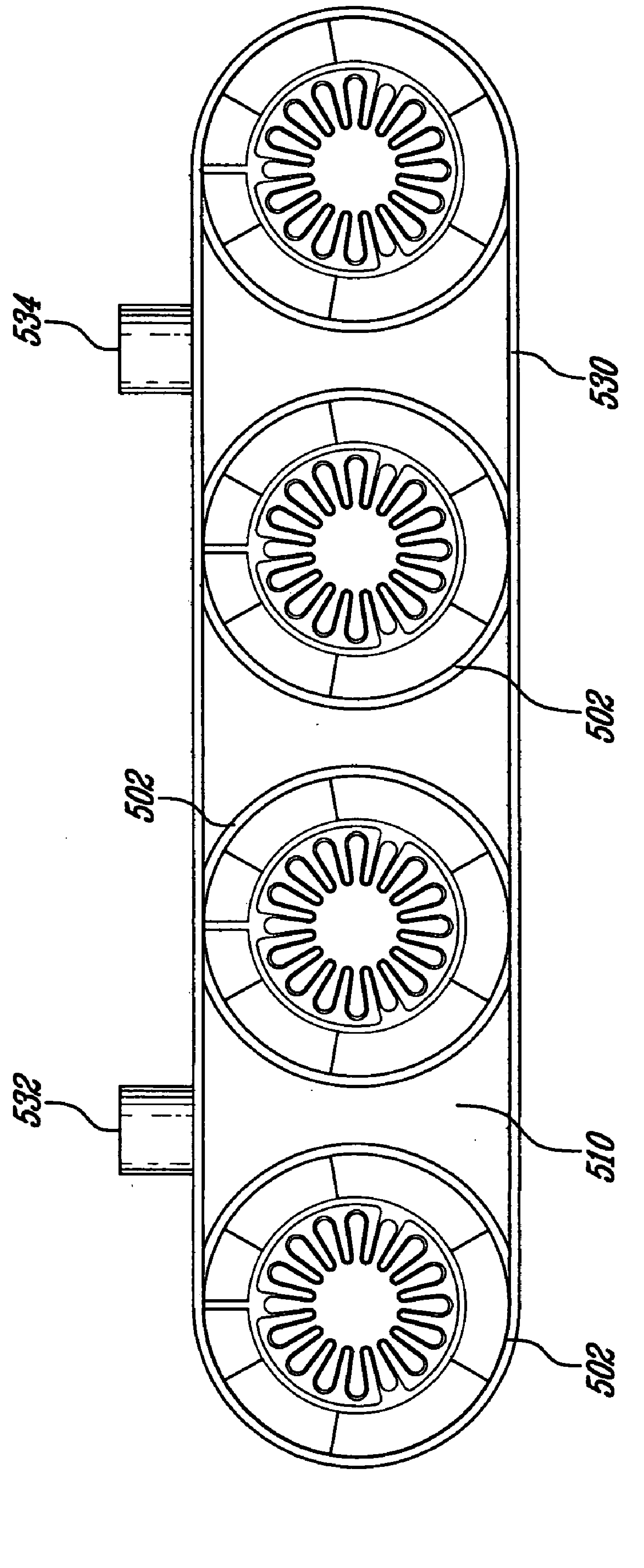


FIG - 20B

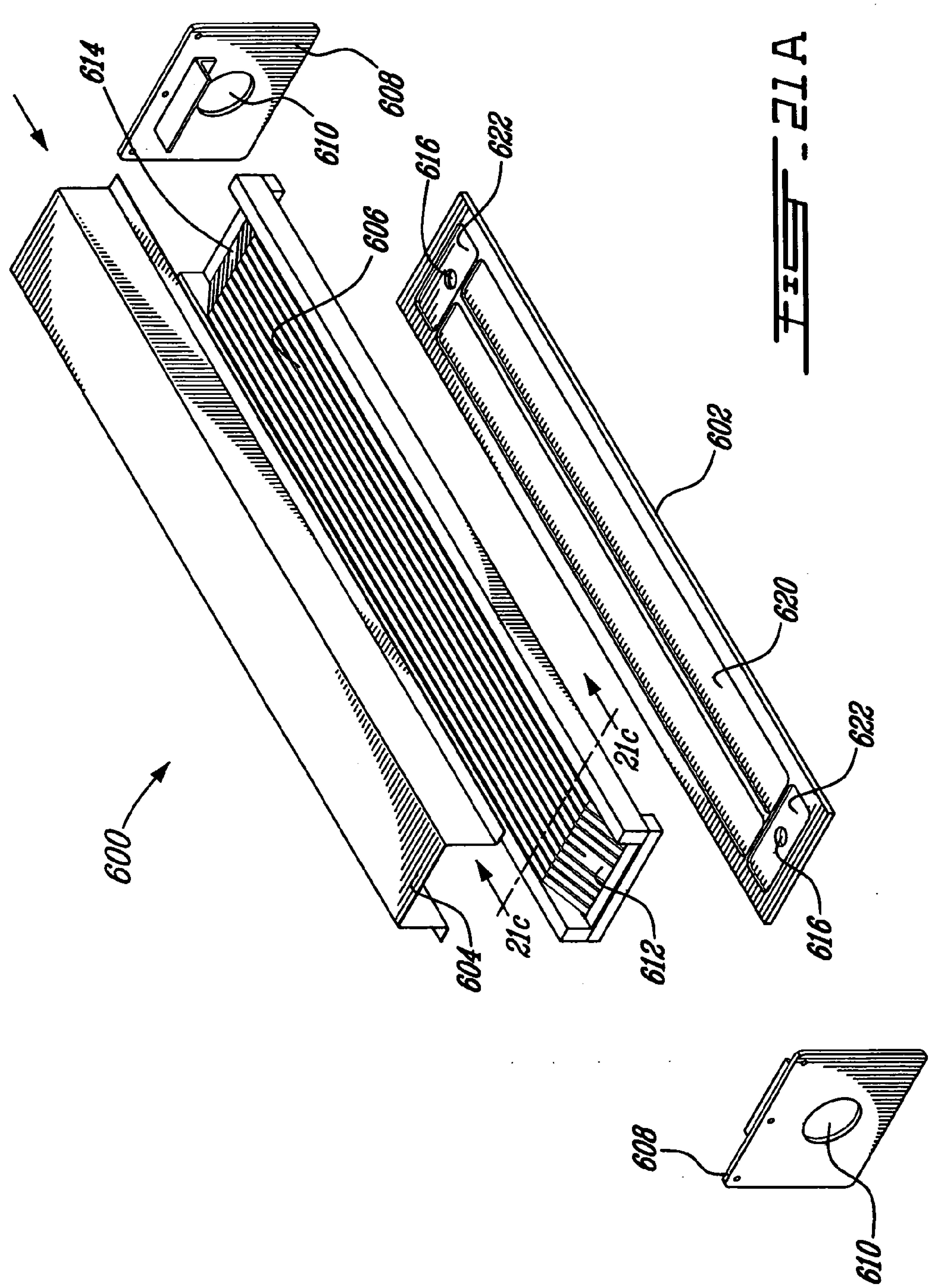


FIG. 21A

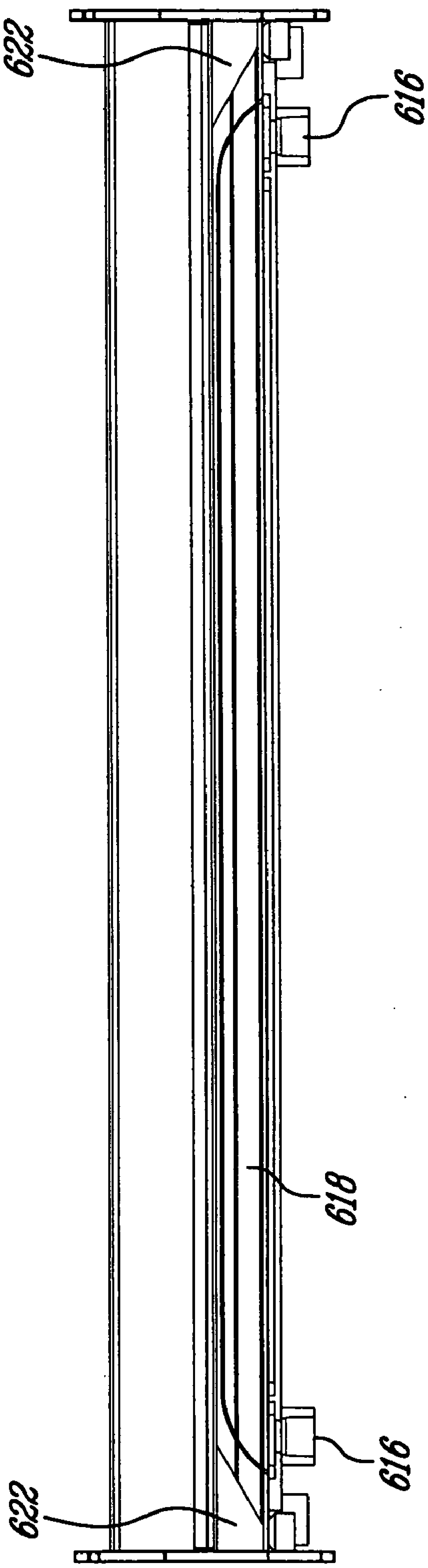


FIG - 21B

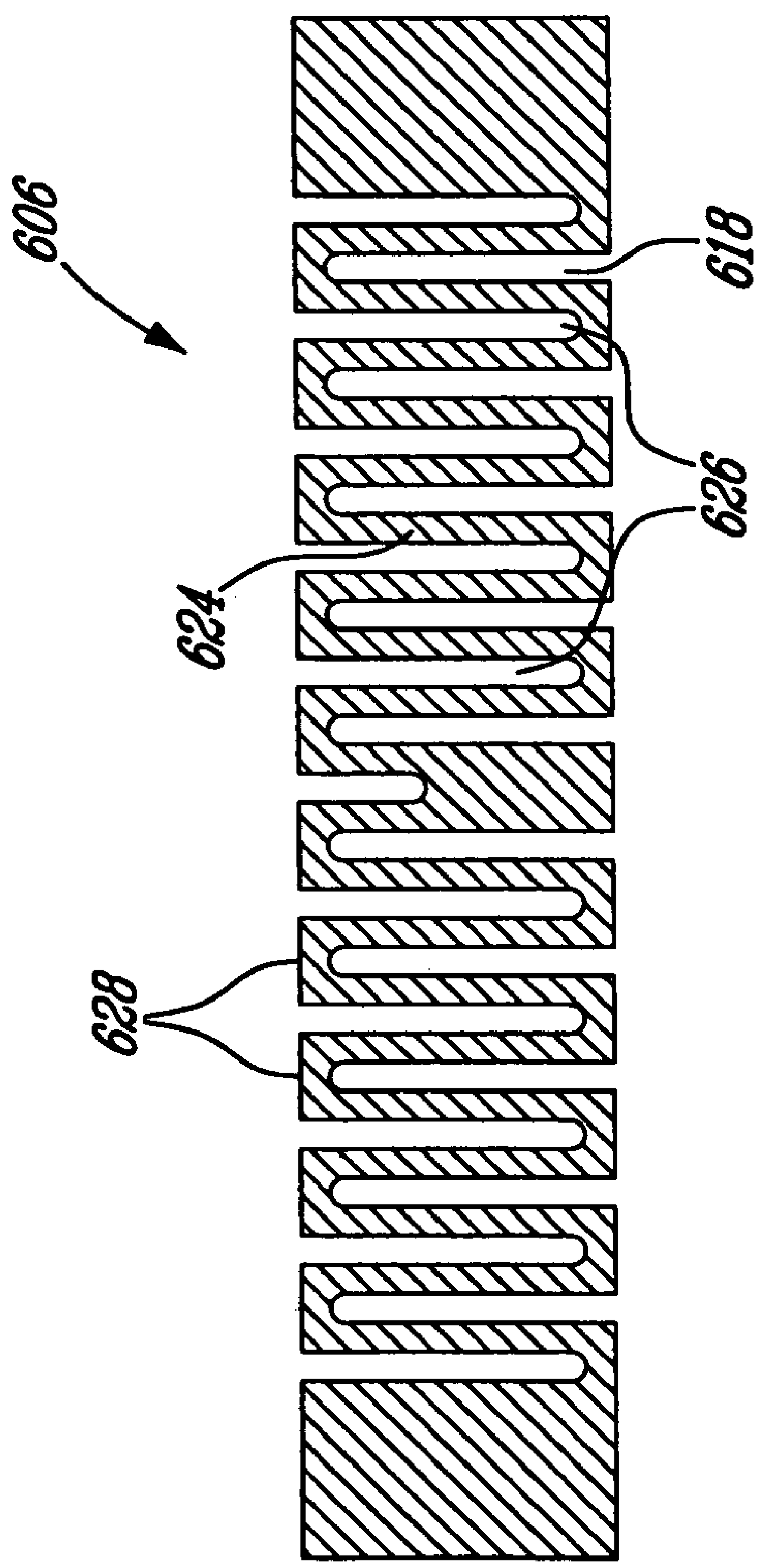


FIG - 21C

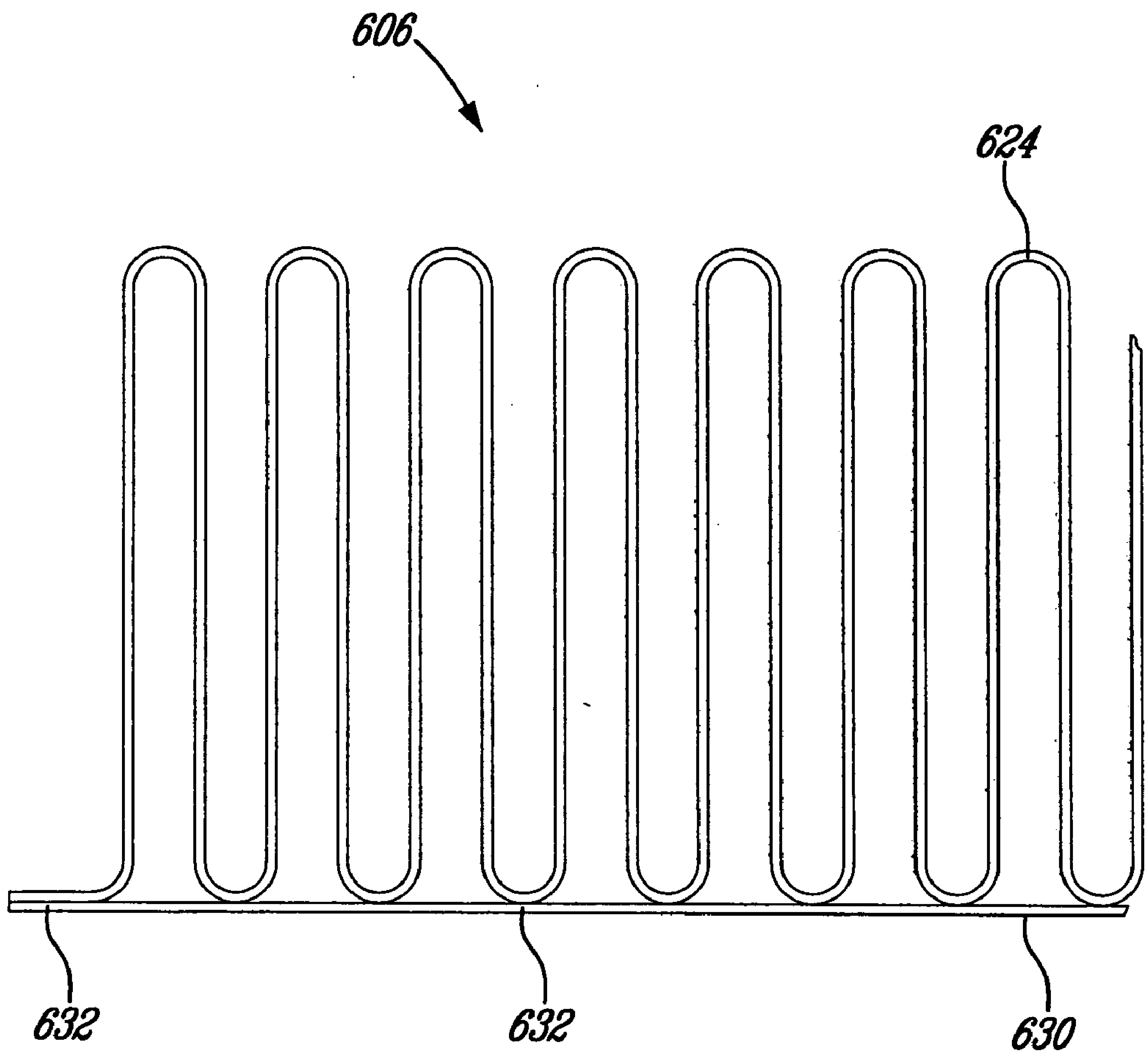


FIG. 22A

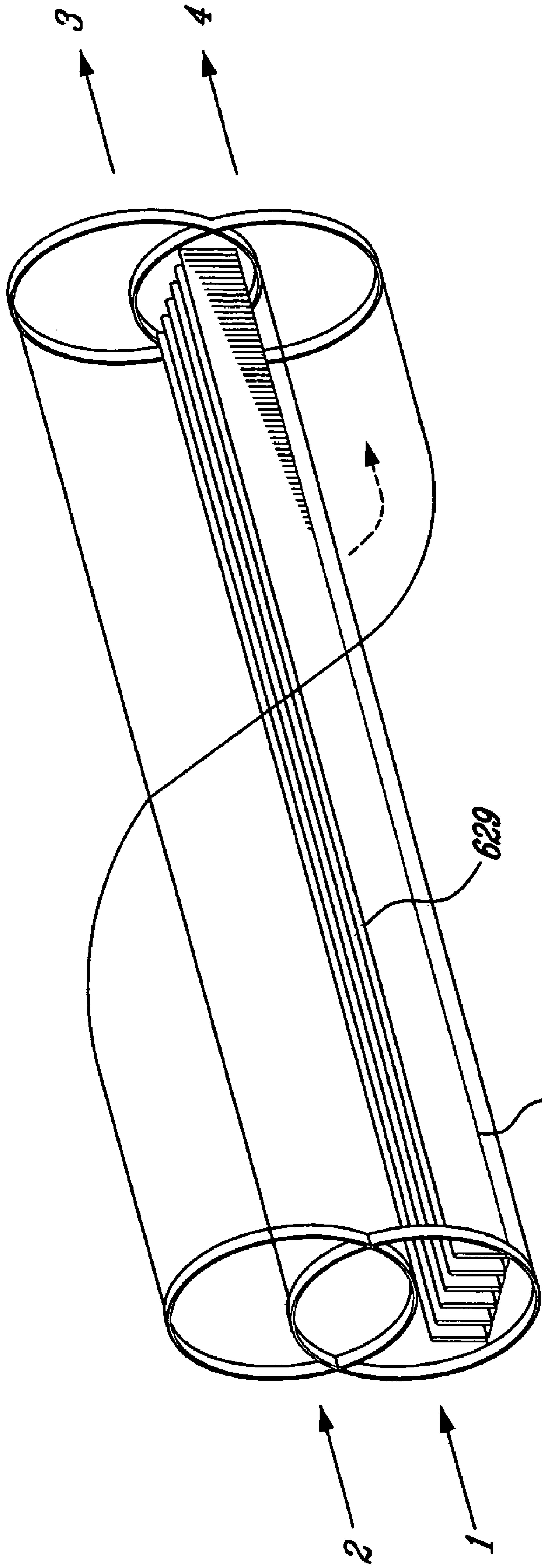


FIG-22B

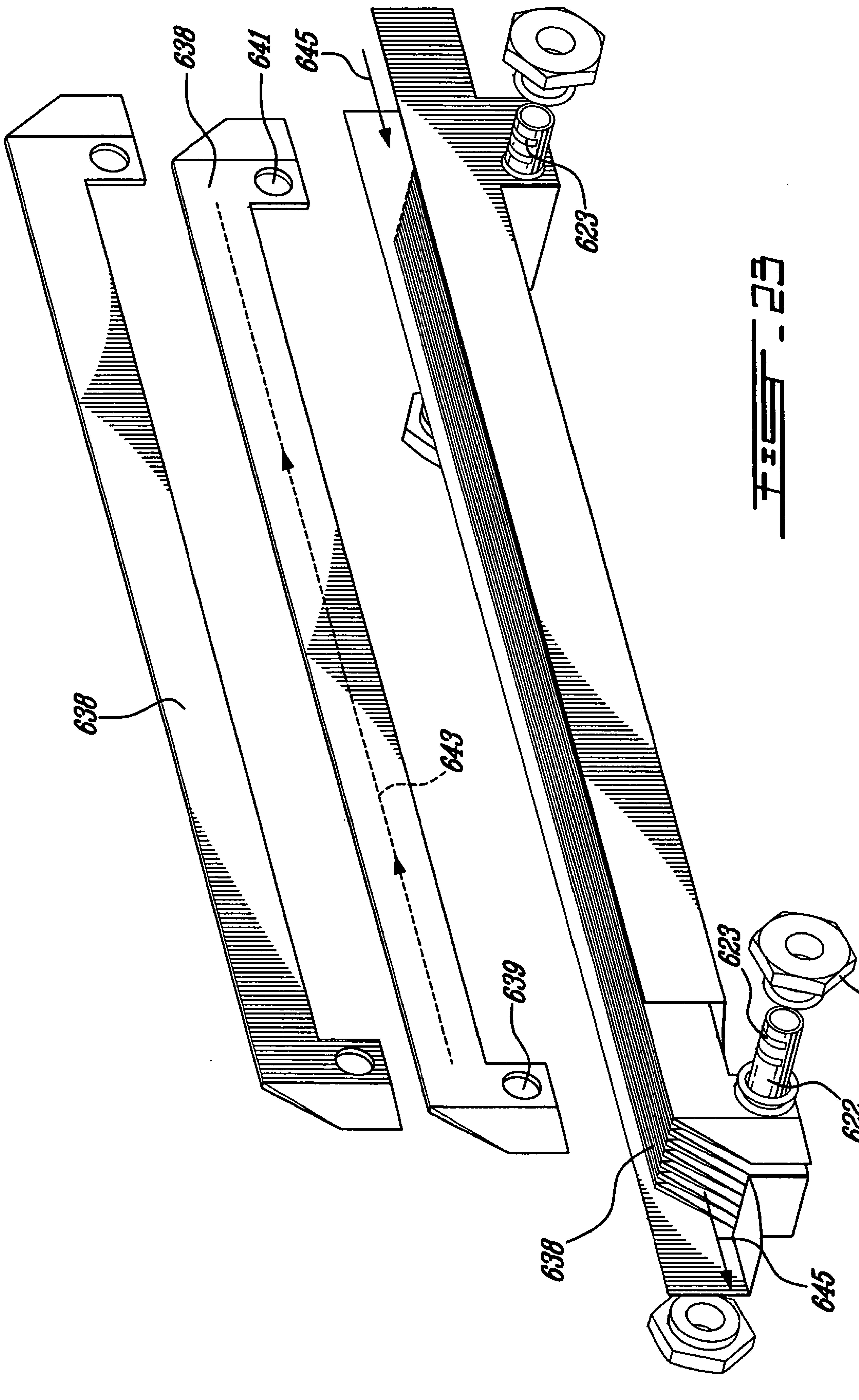


FIG-23

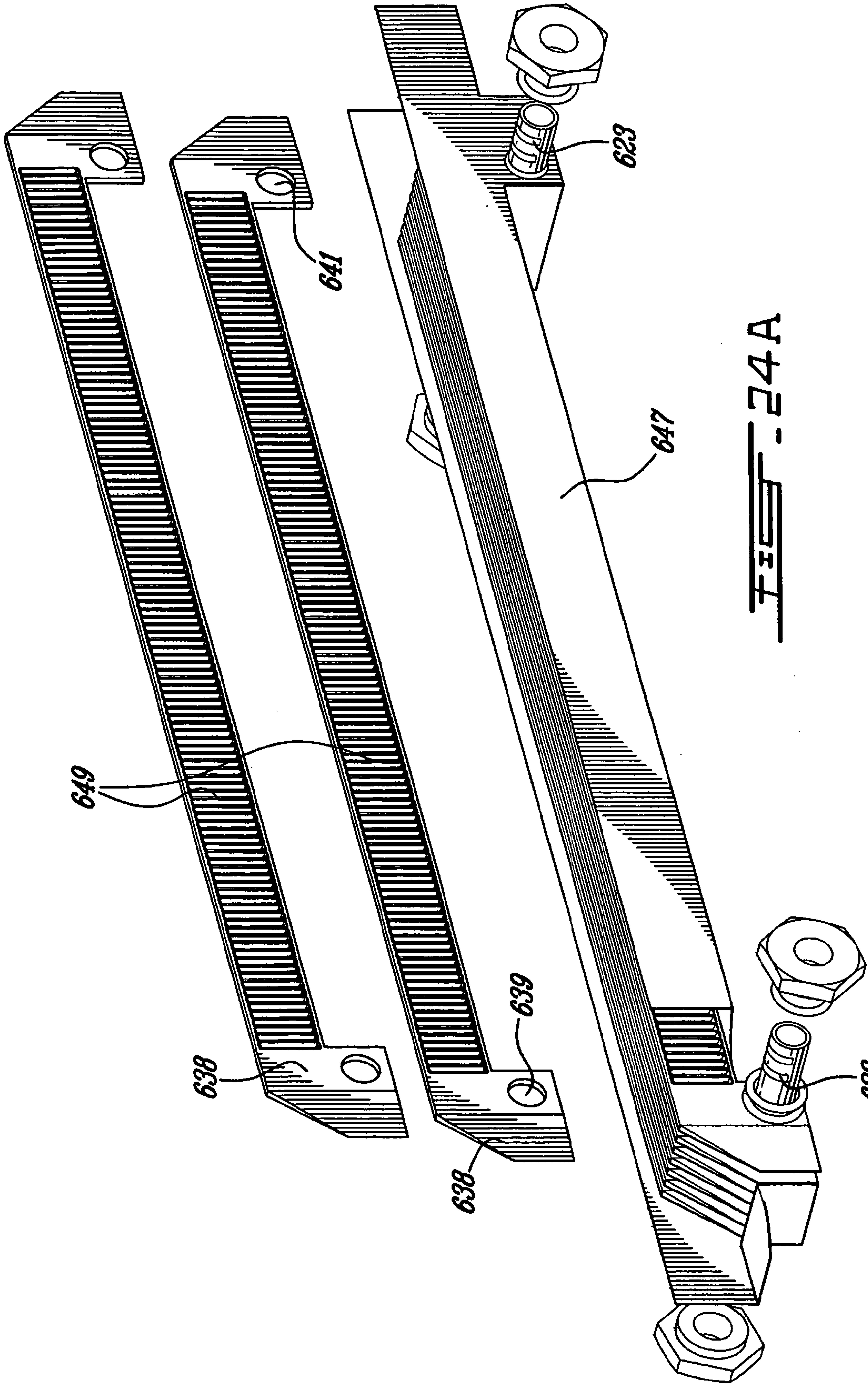


FIG. 24A

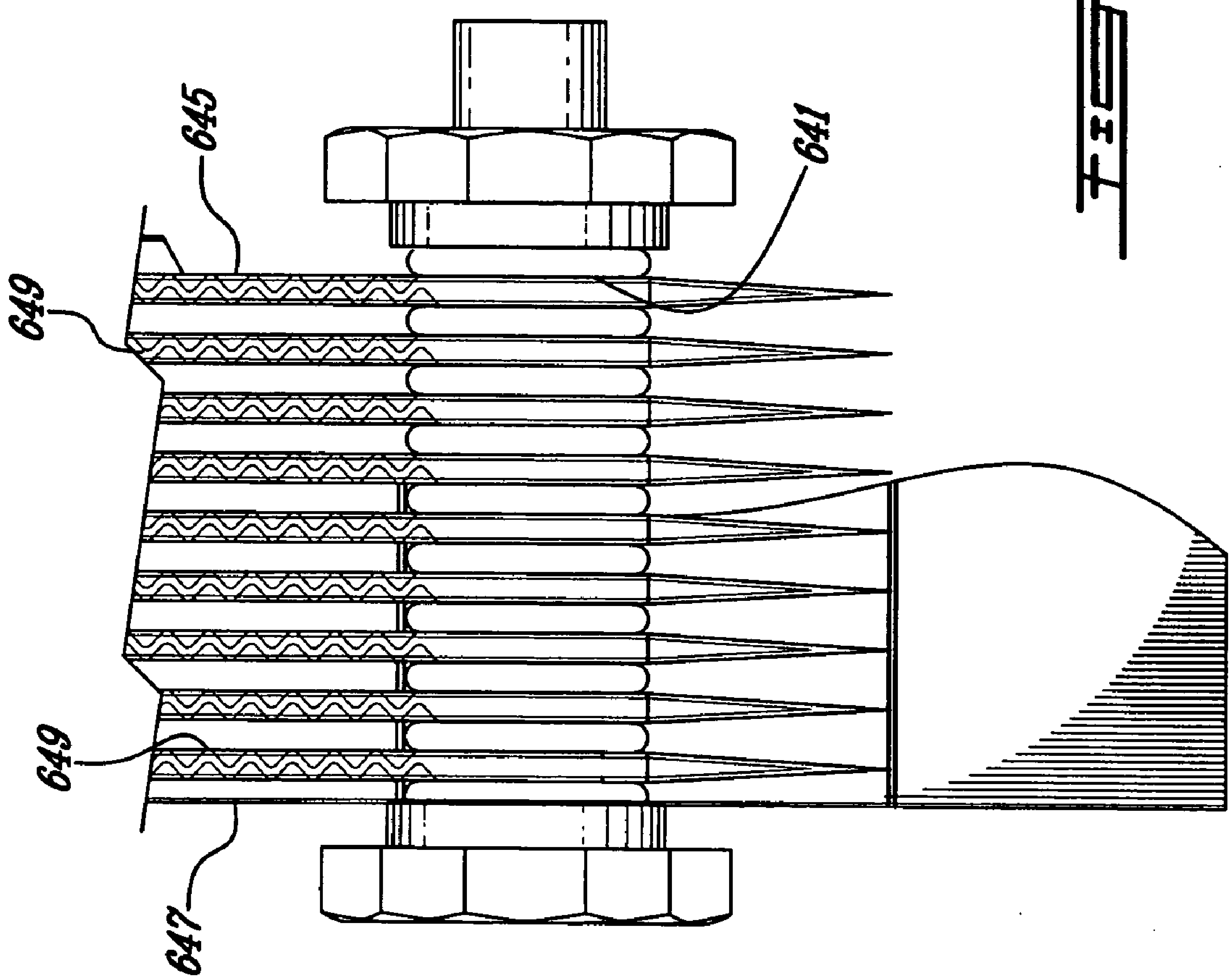


FIG. 24B

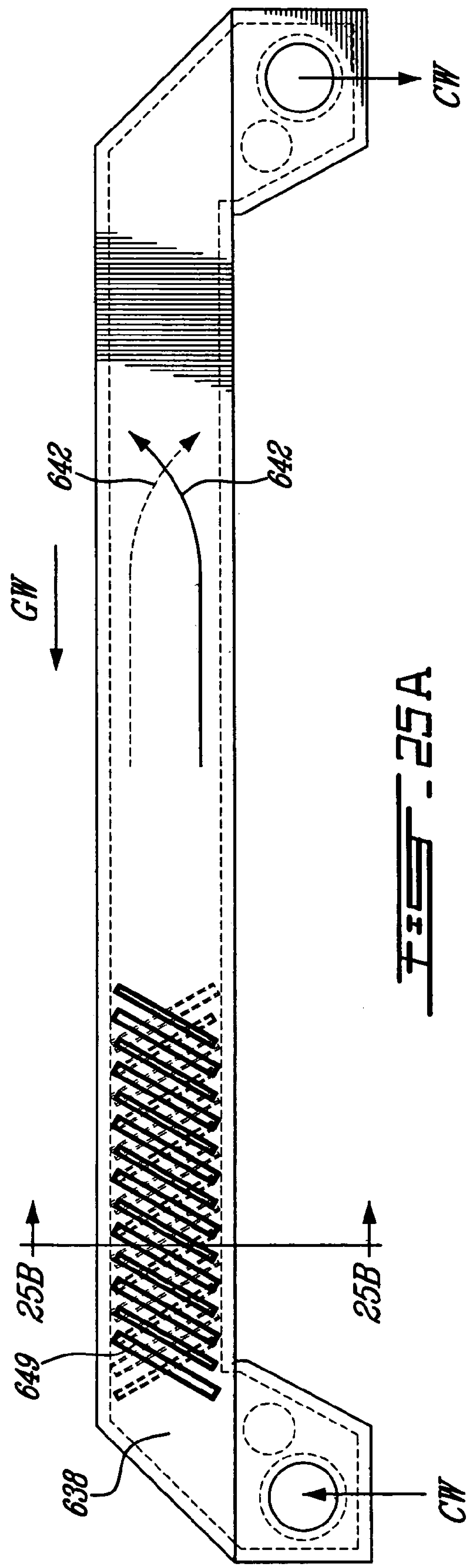


FIG - 25A

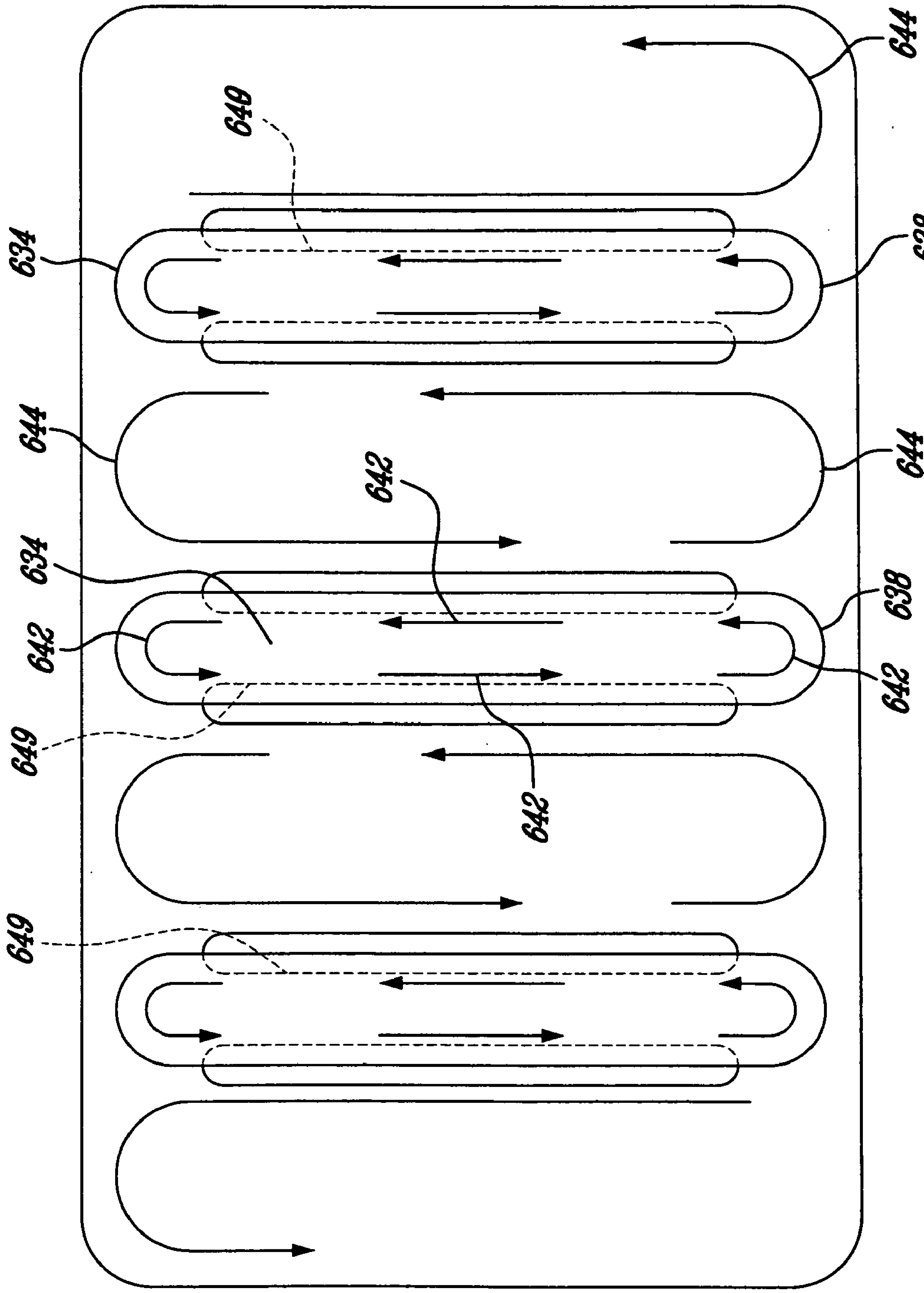


FIG. 25B

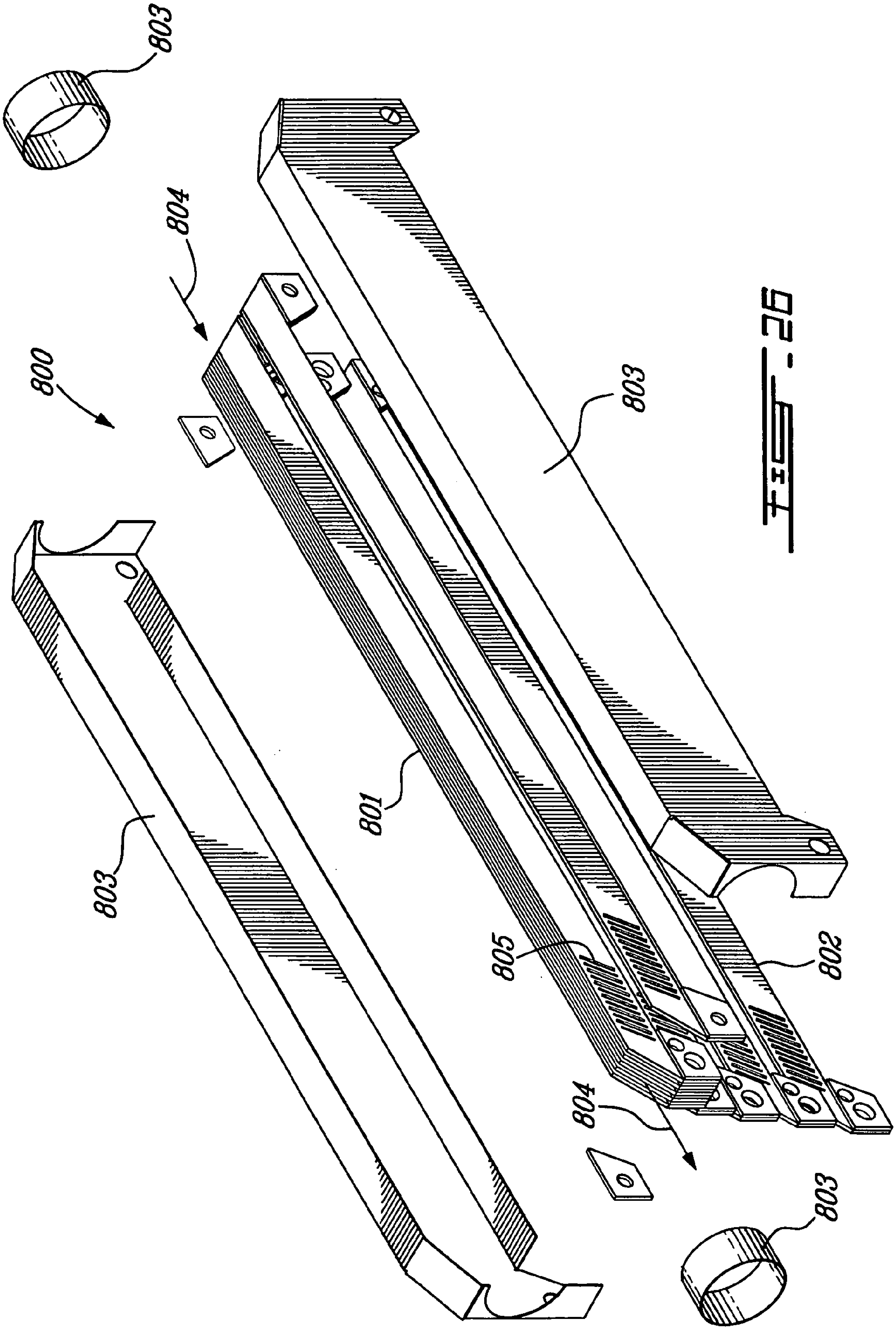


FIG-26

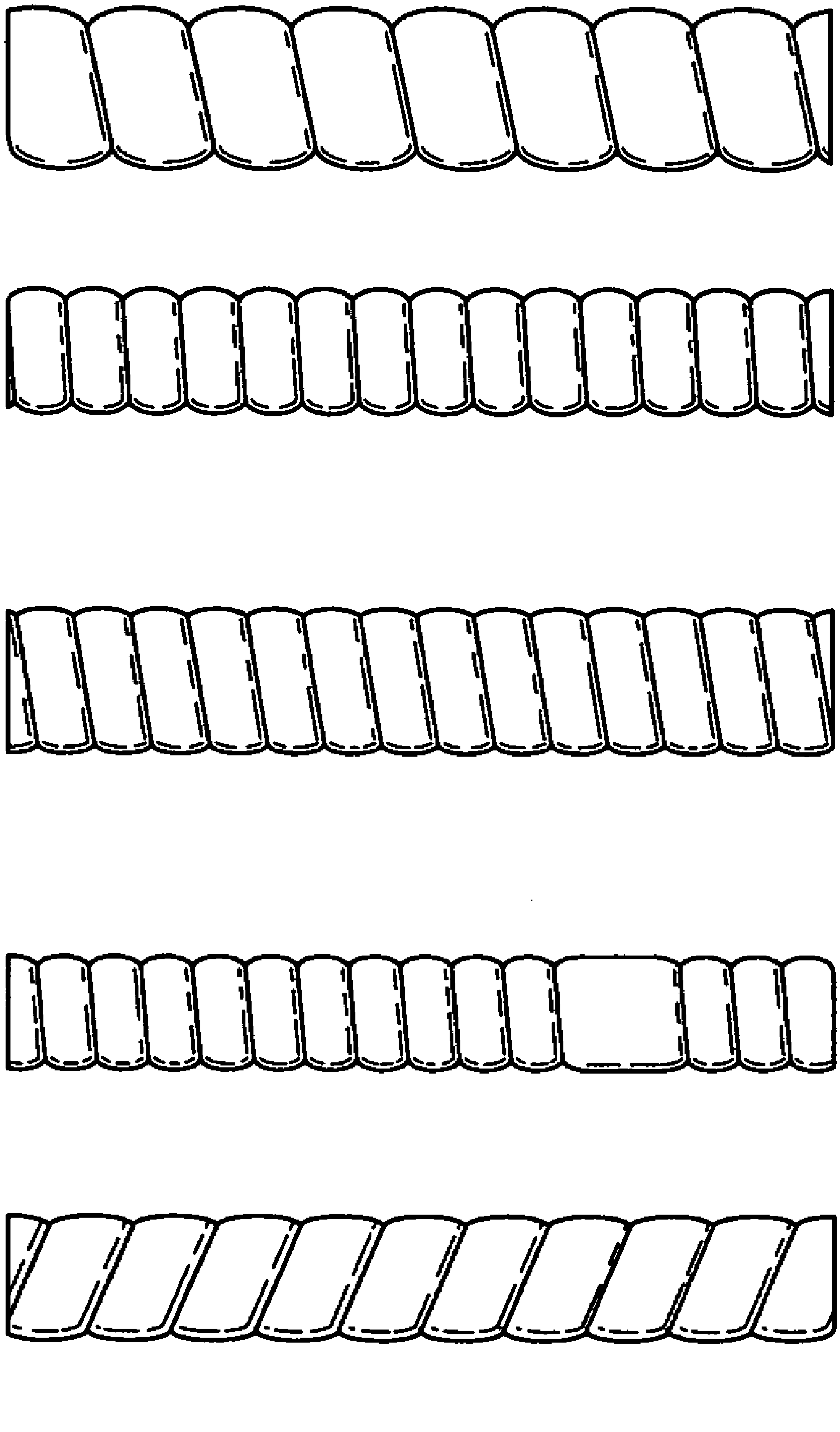


FIG. 27

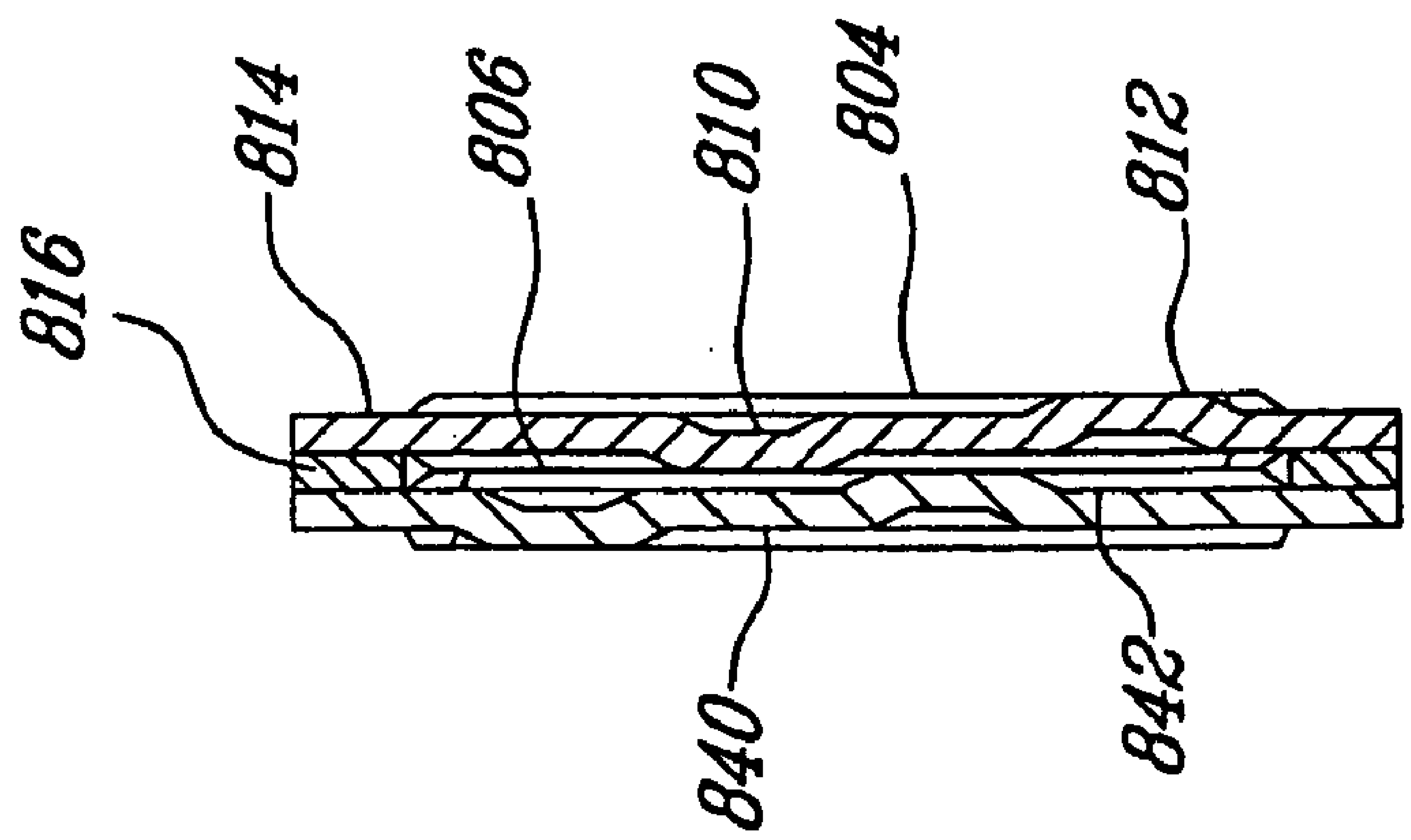


FIG. 28B

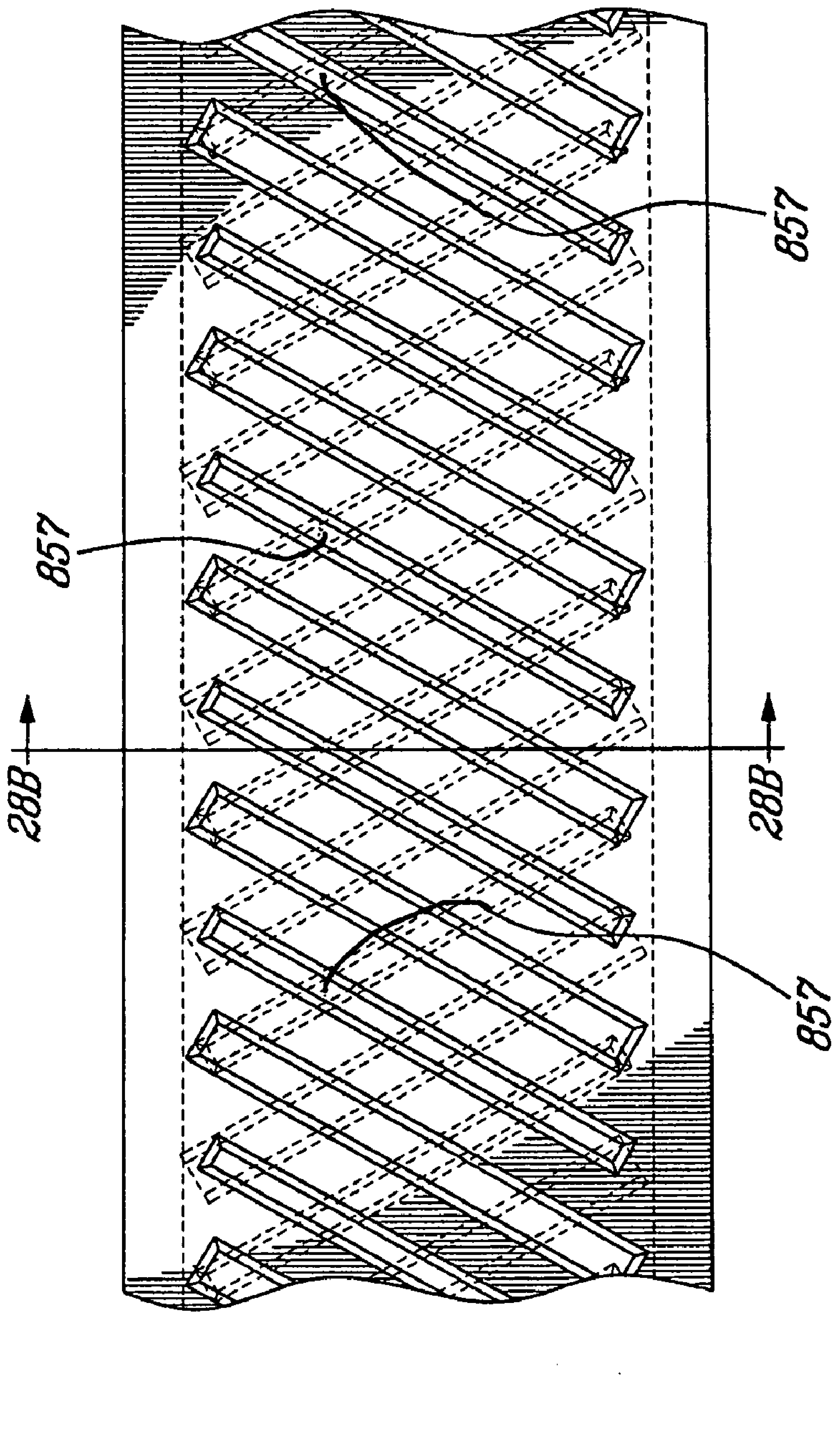


FIG. 28A

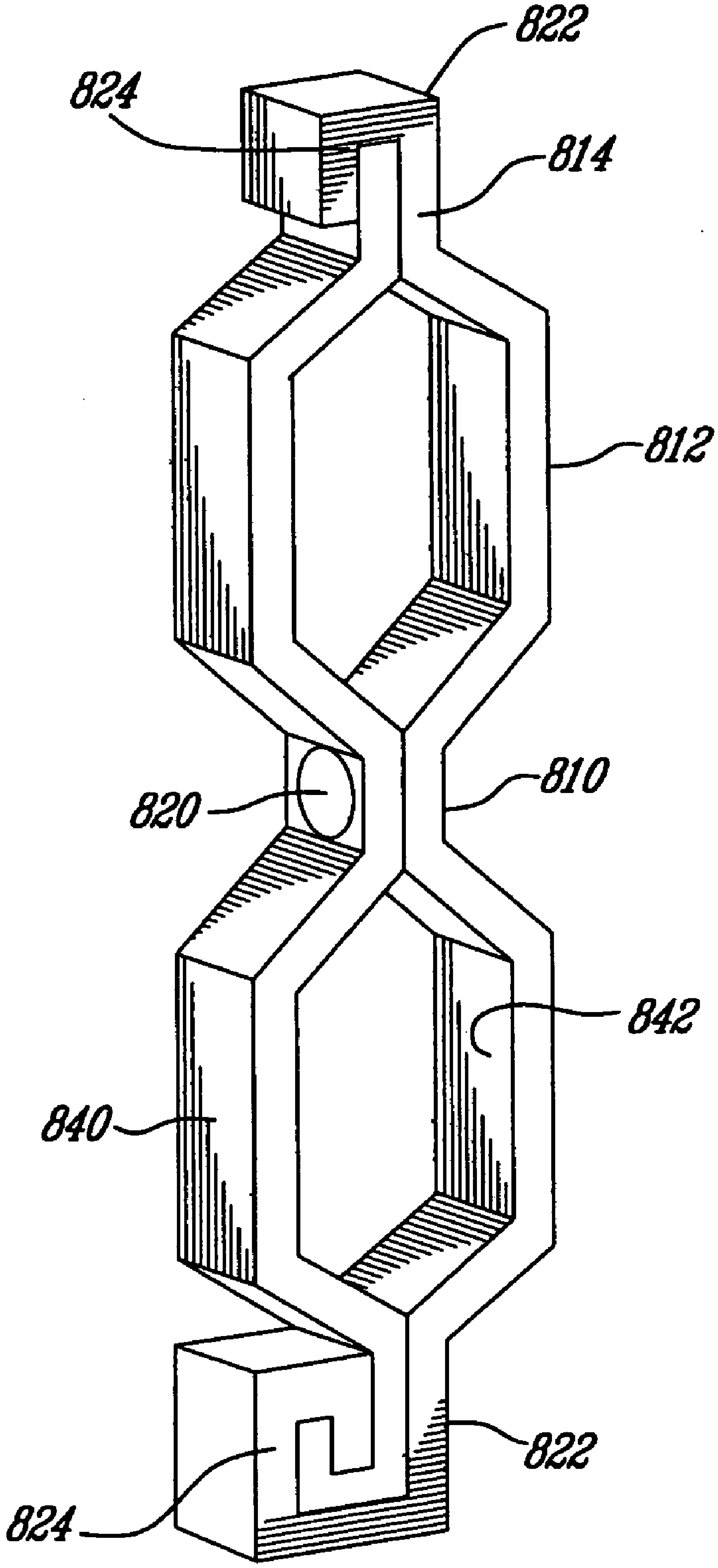


FIG. 29

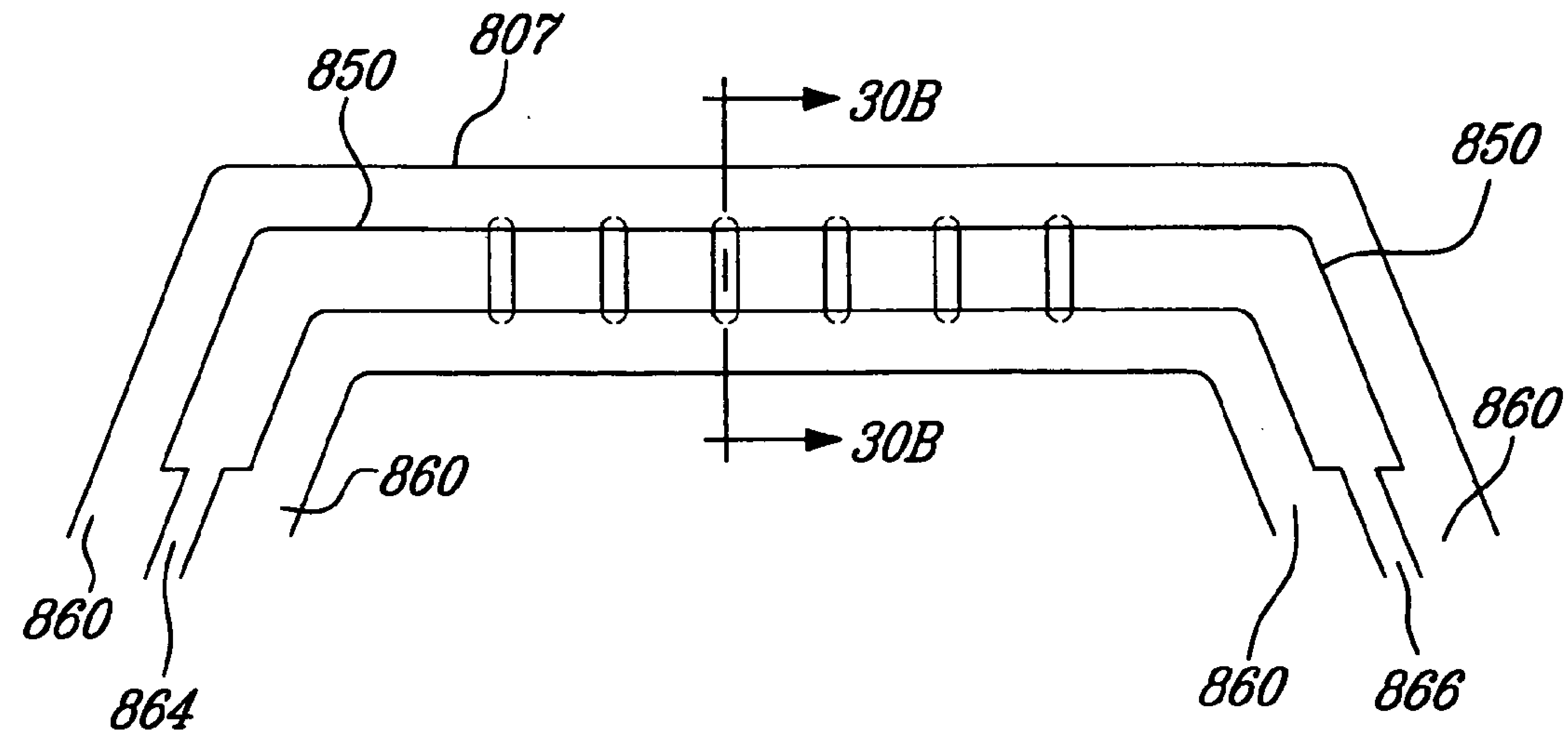


FIG. 30A

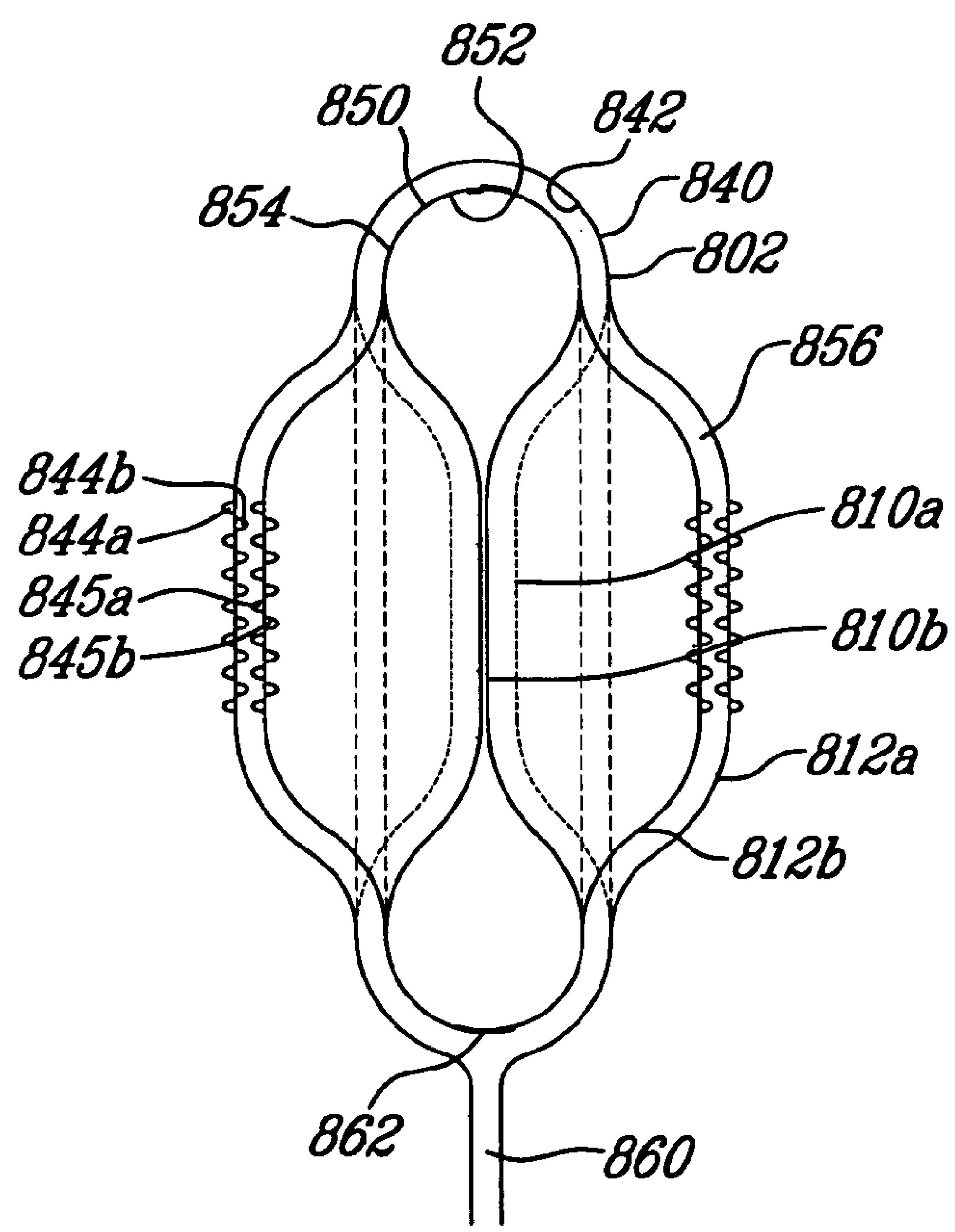


FIG. 30B

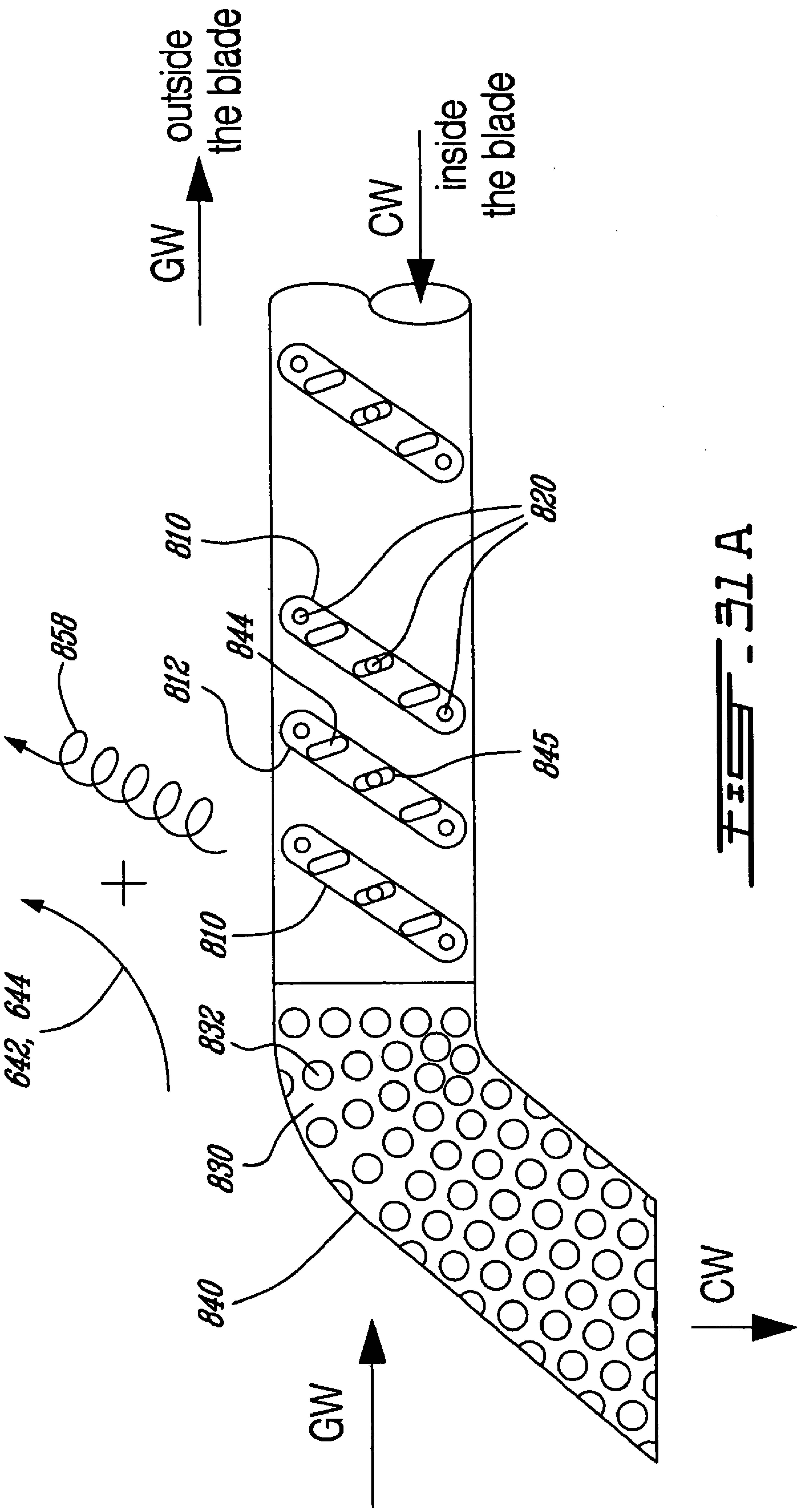

GW
outside
the blade
CW
inside
the blade
810
820
858
812
844
845
810
642, 644
832
830
840
CW
GW

FIG. 31A

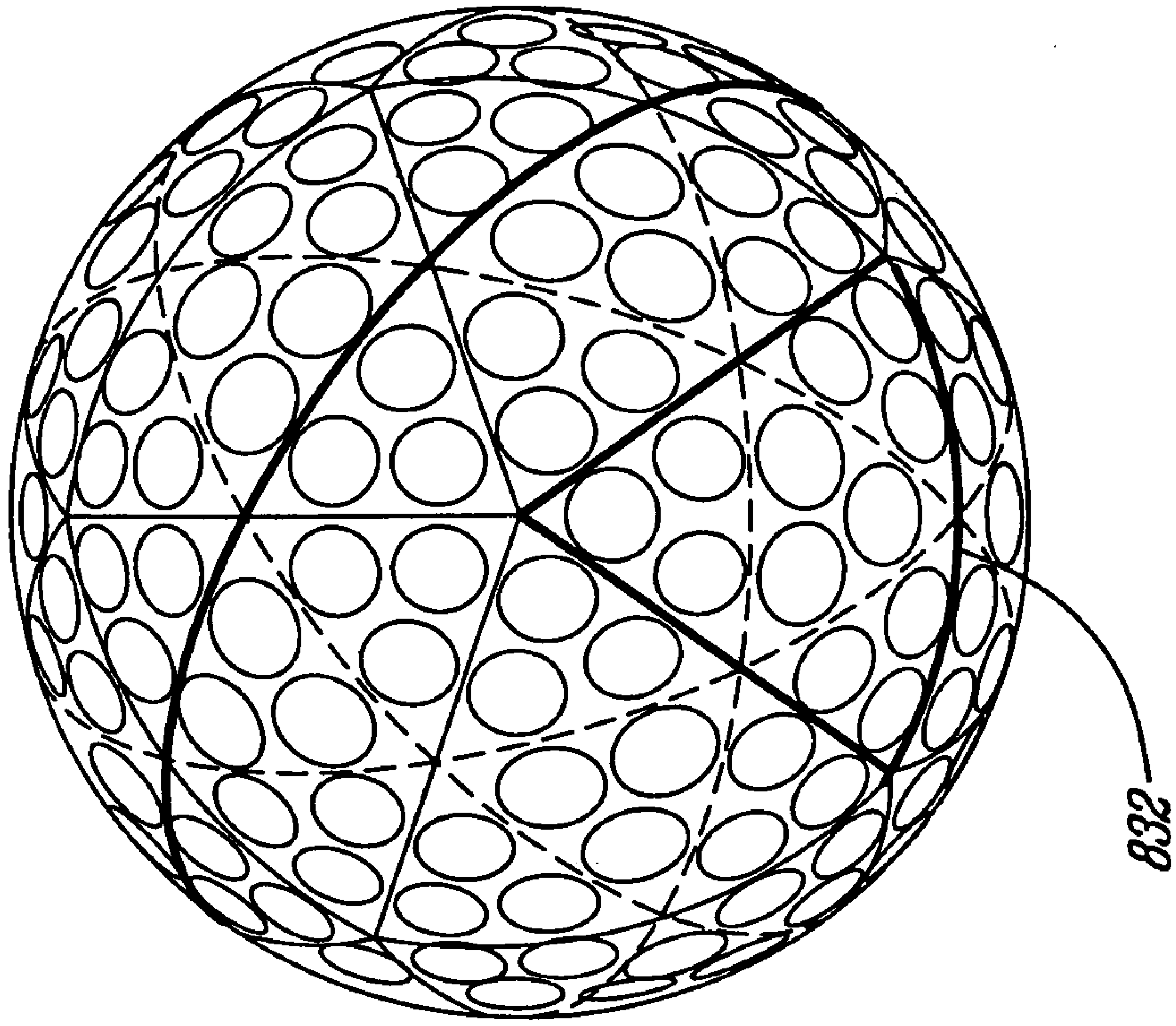


FIG. 32B

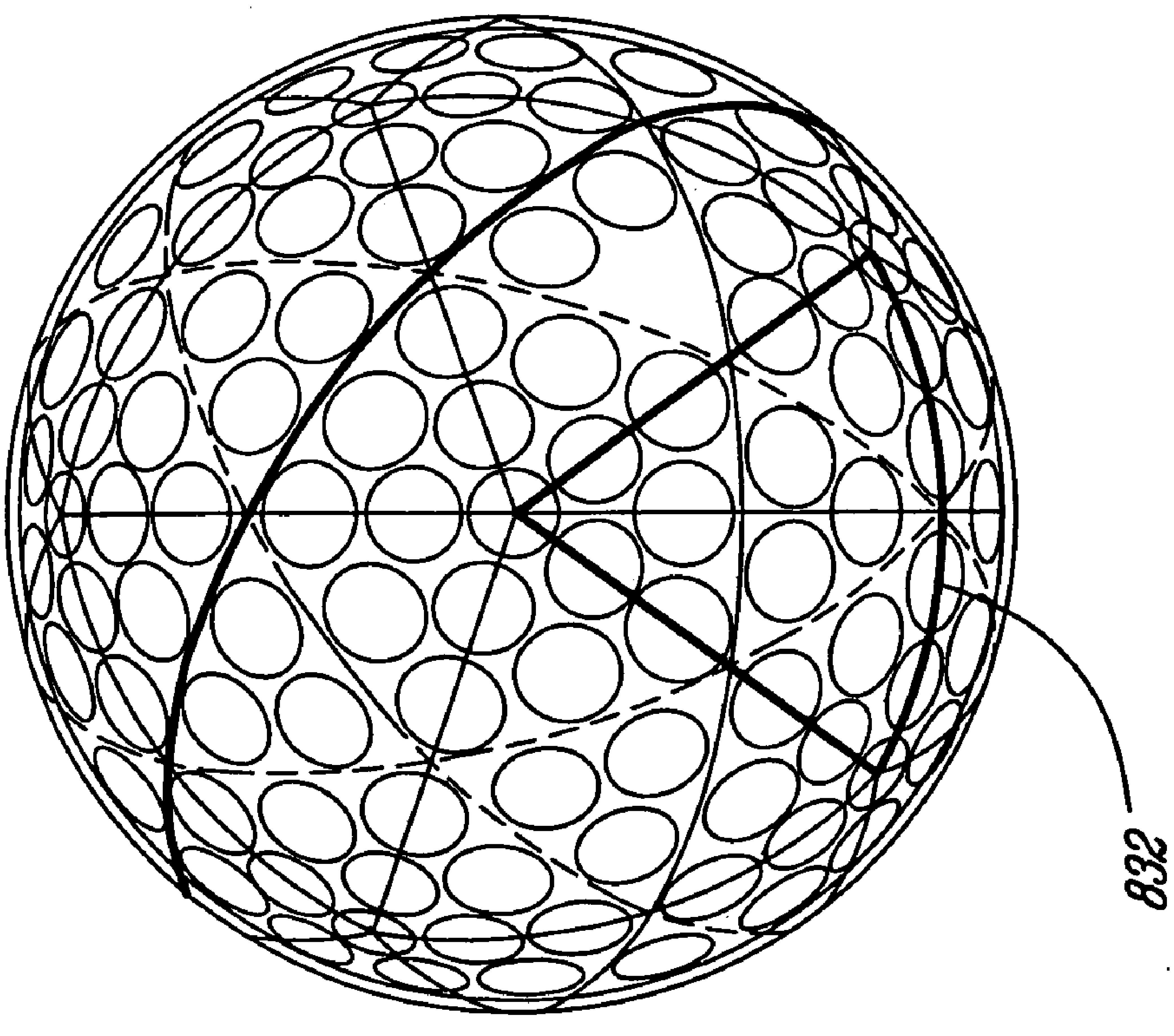


FIG. 32A

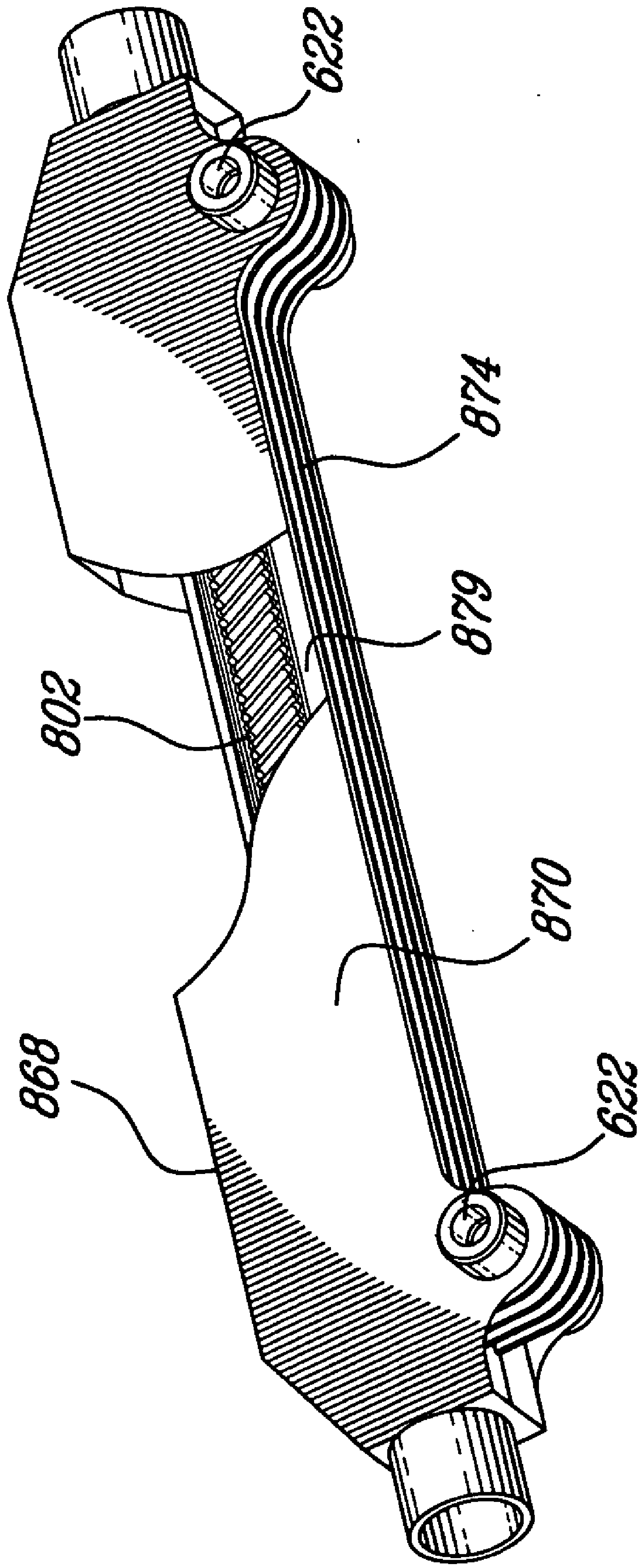


FIG-33

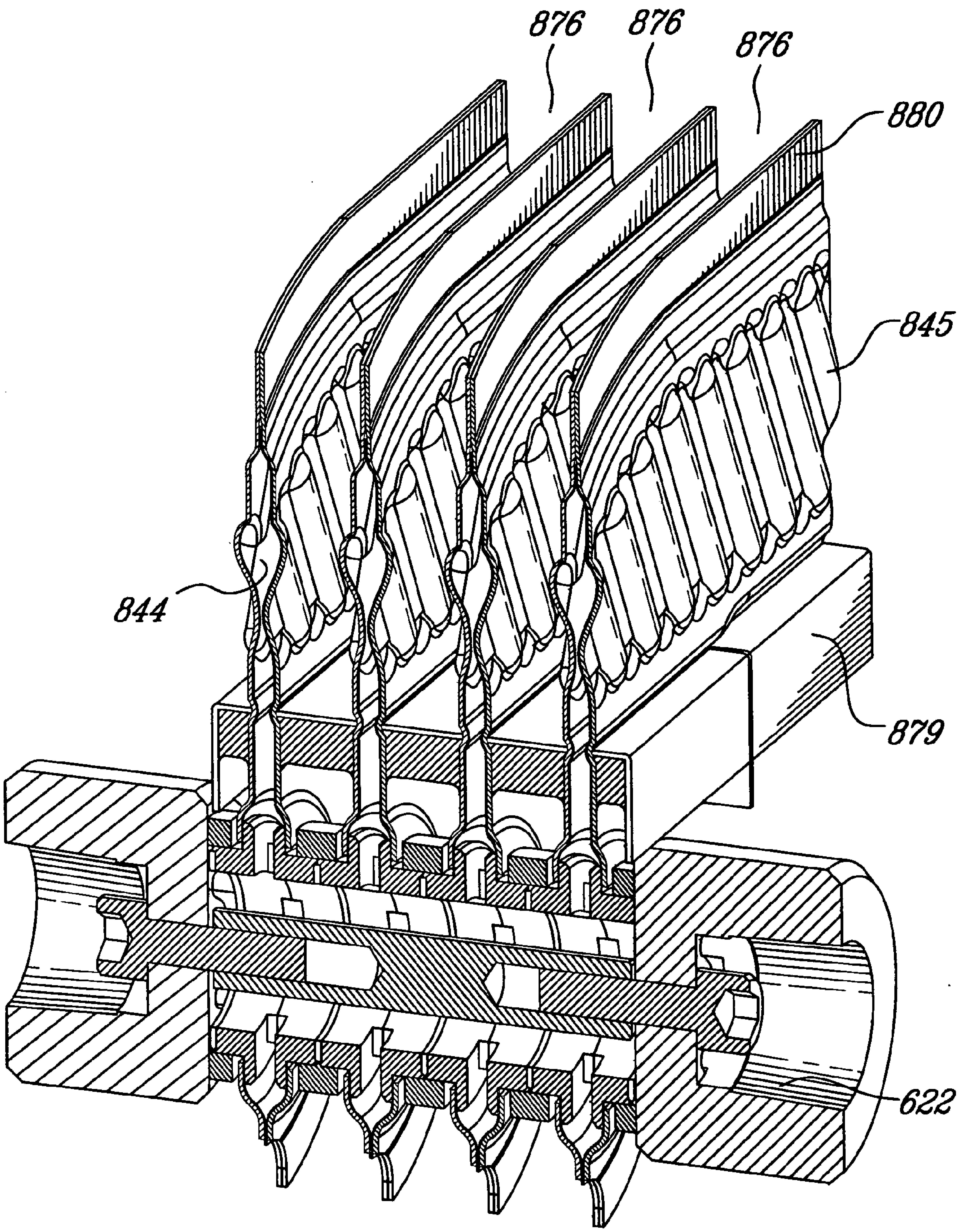


FIG. 34

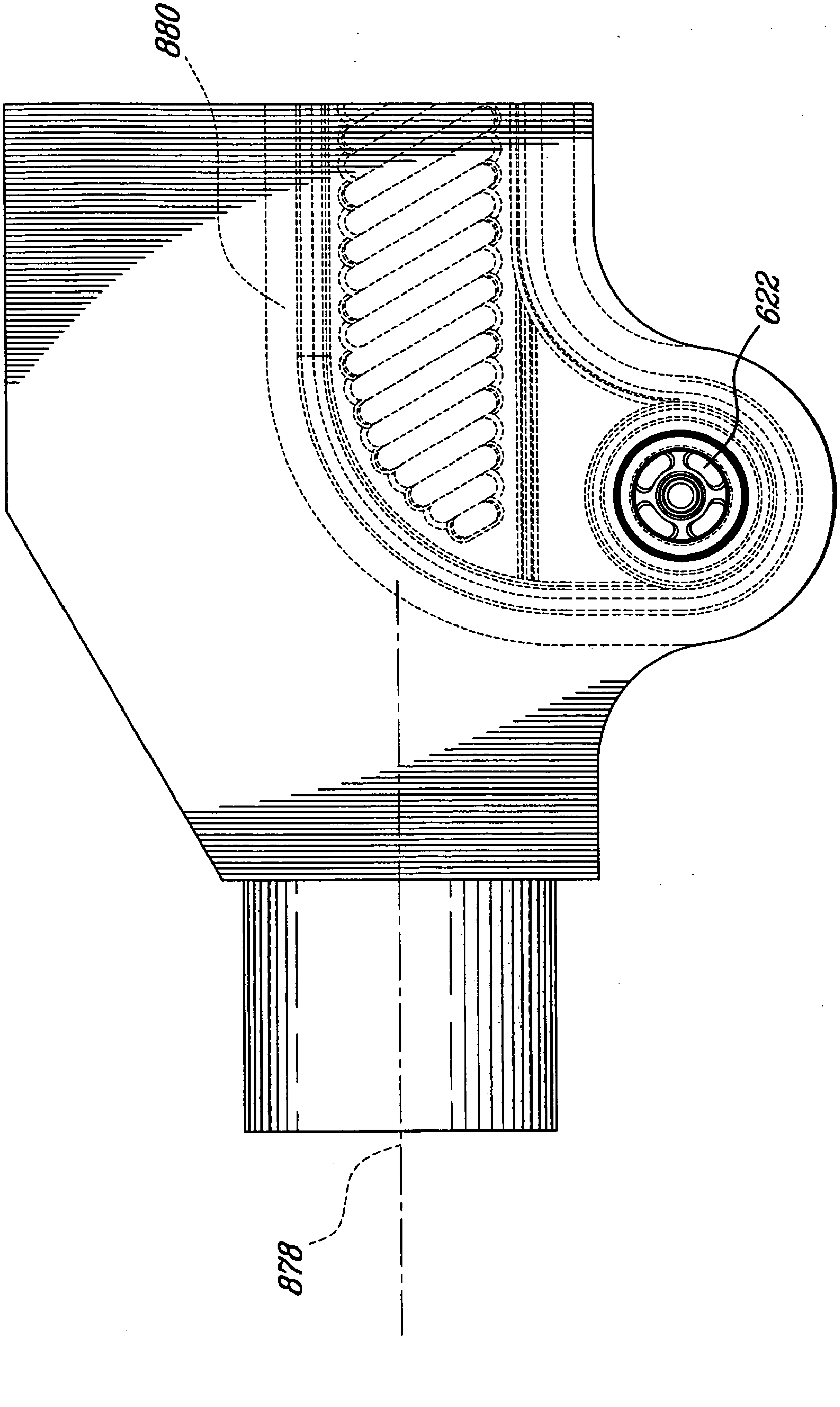


FIG-35

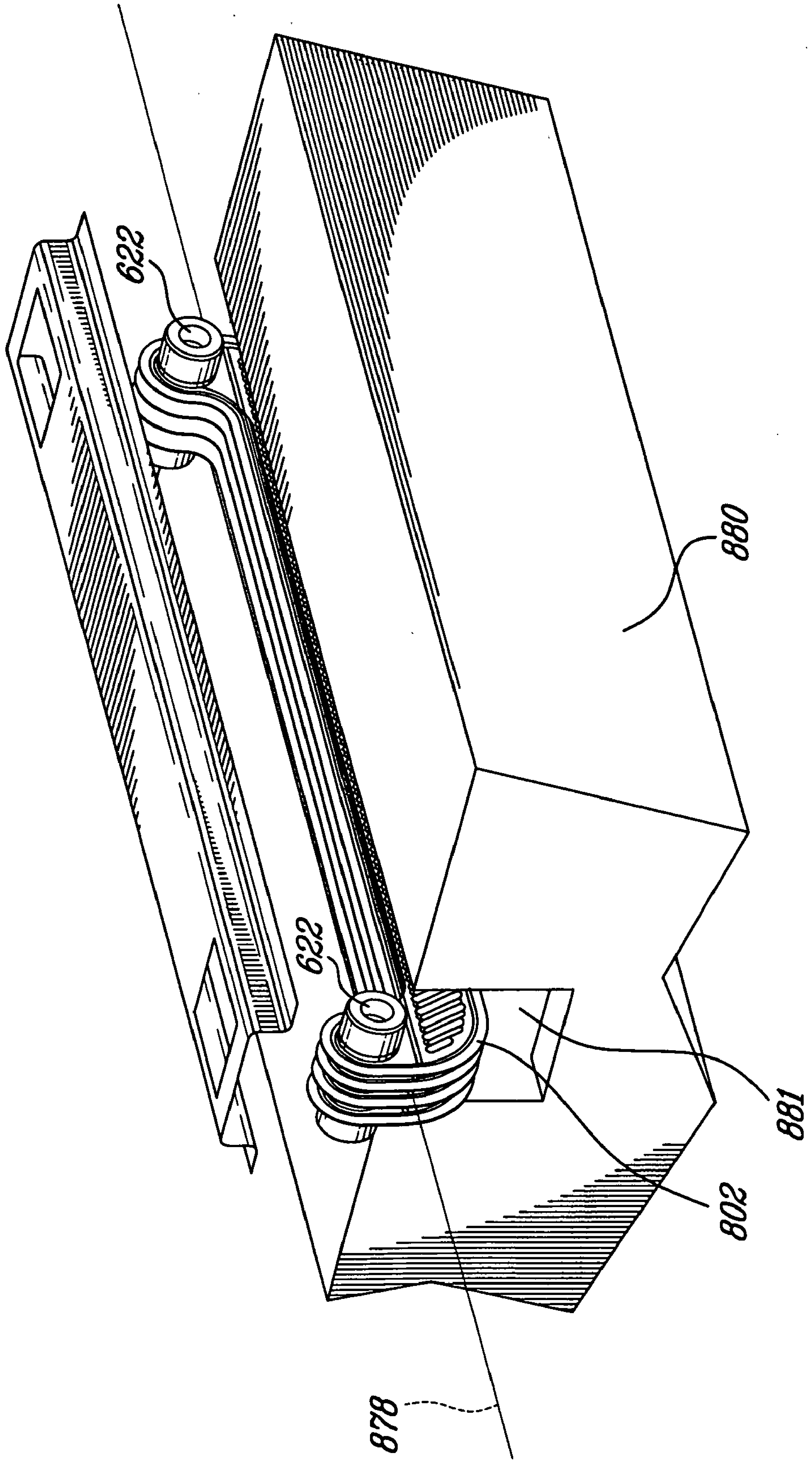


FIG. 36

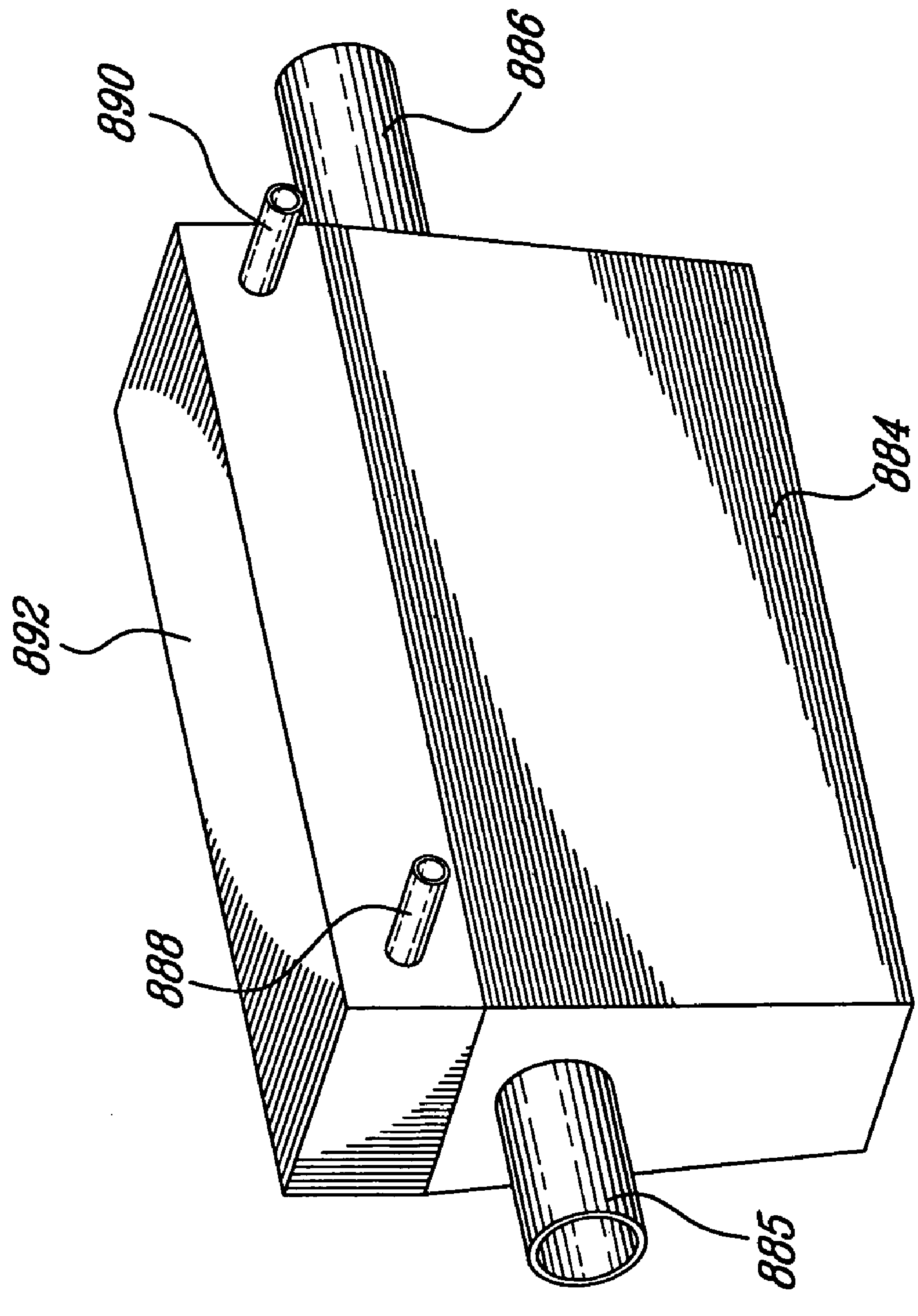


FIG. 37

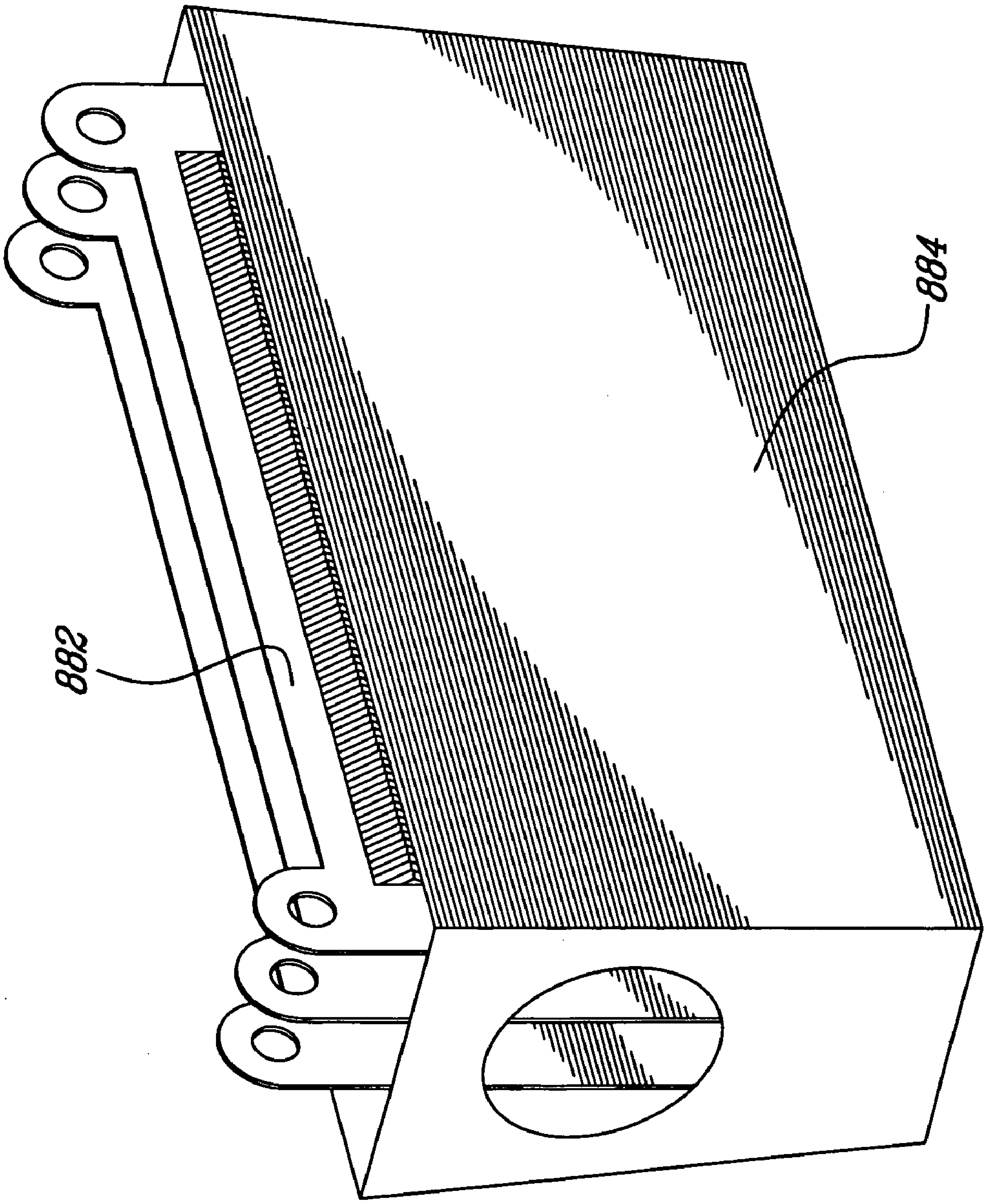


FIG-38

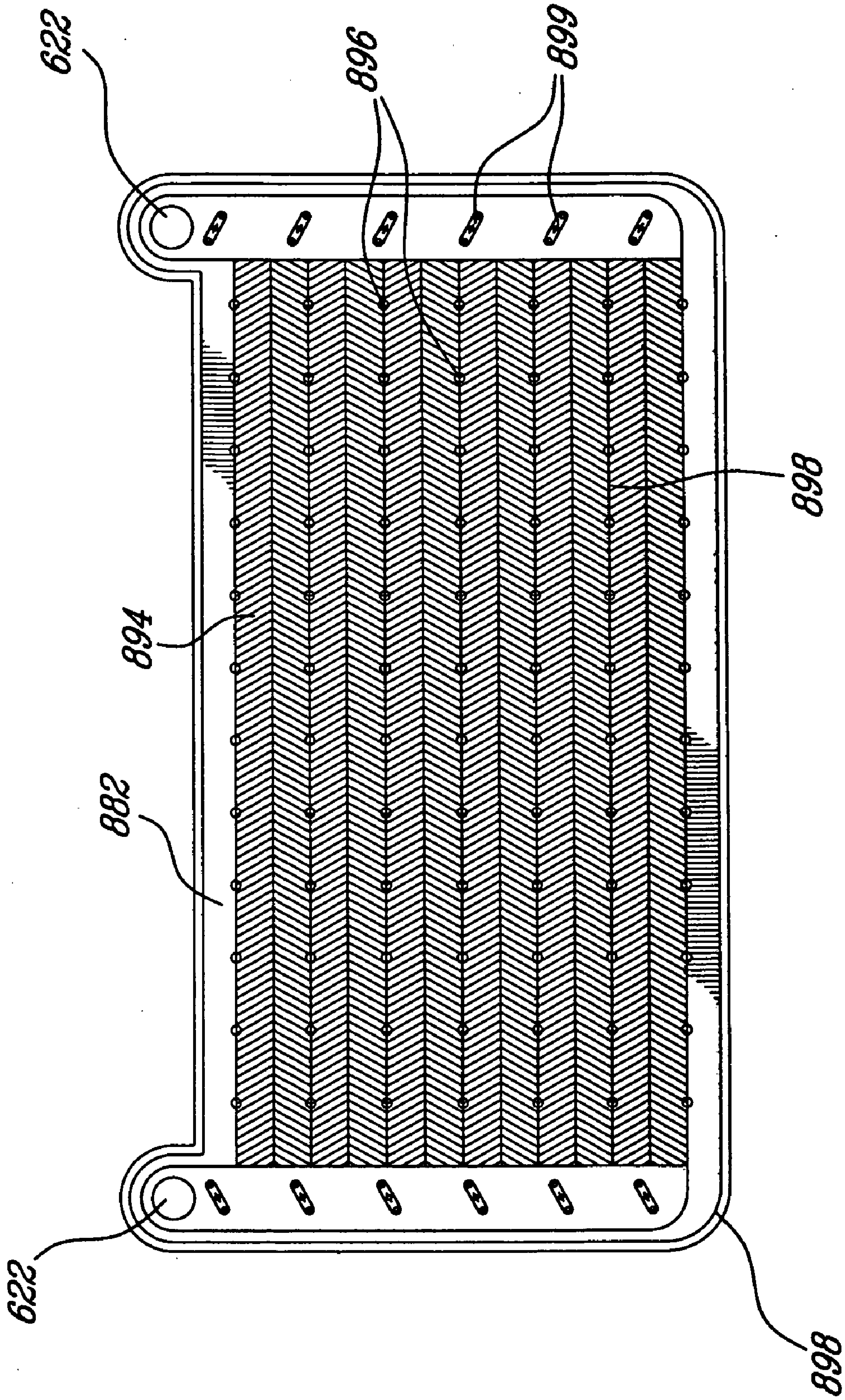


FIG - 59

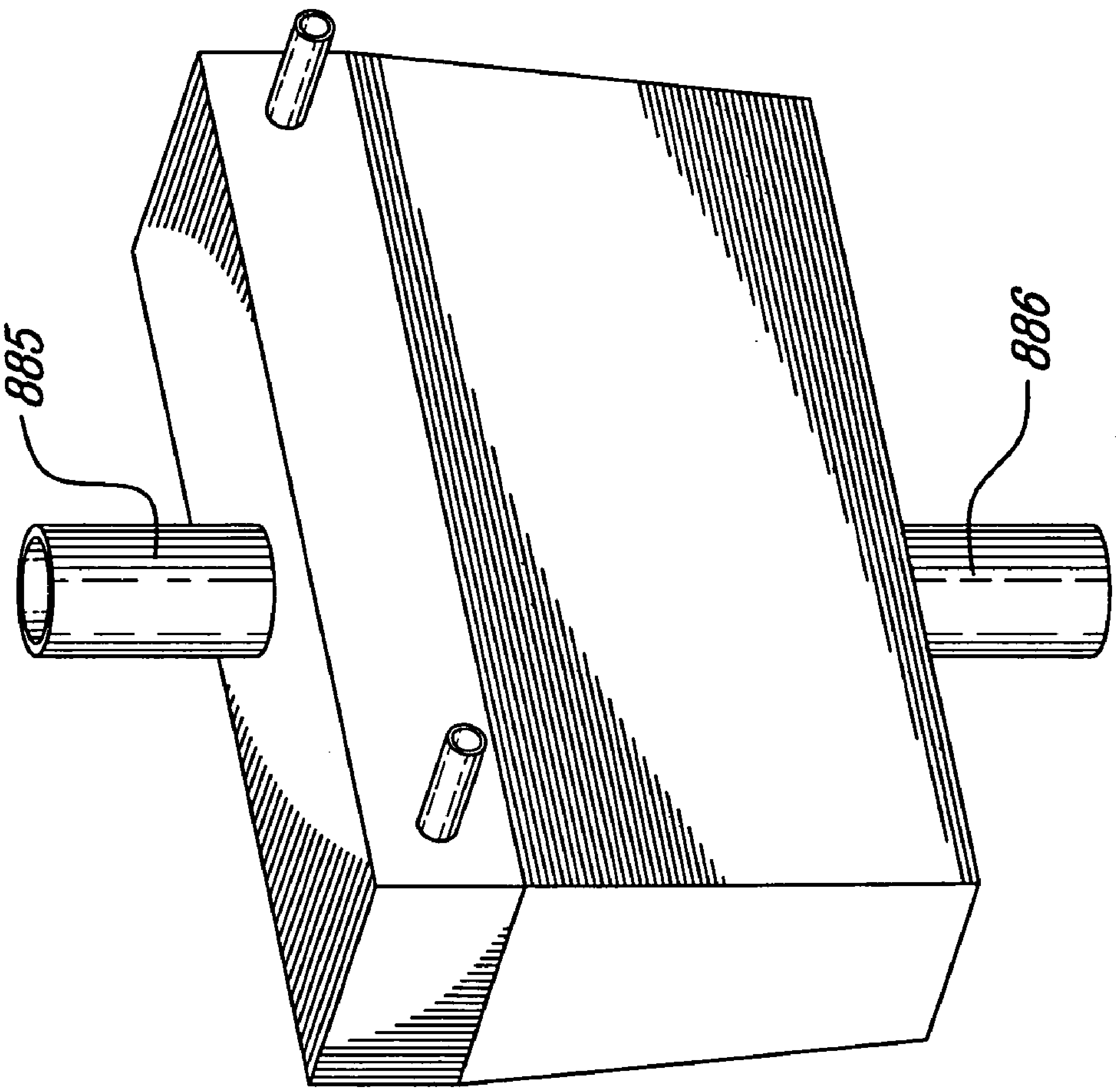


FIG-40

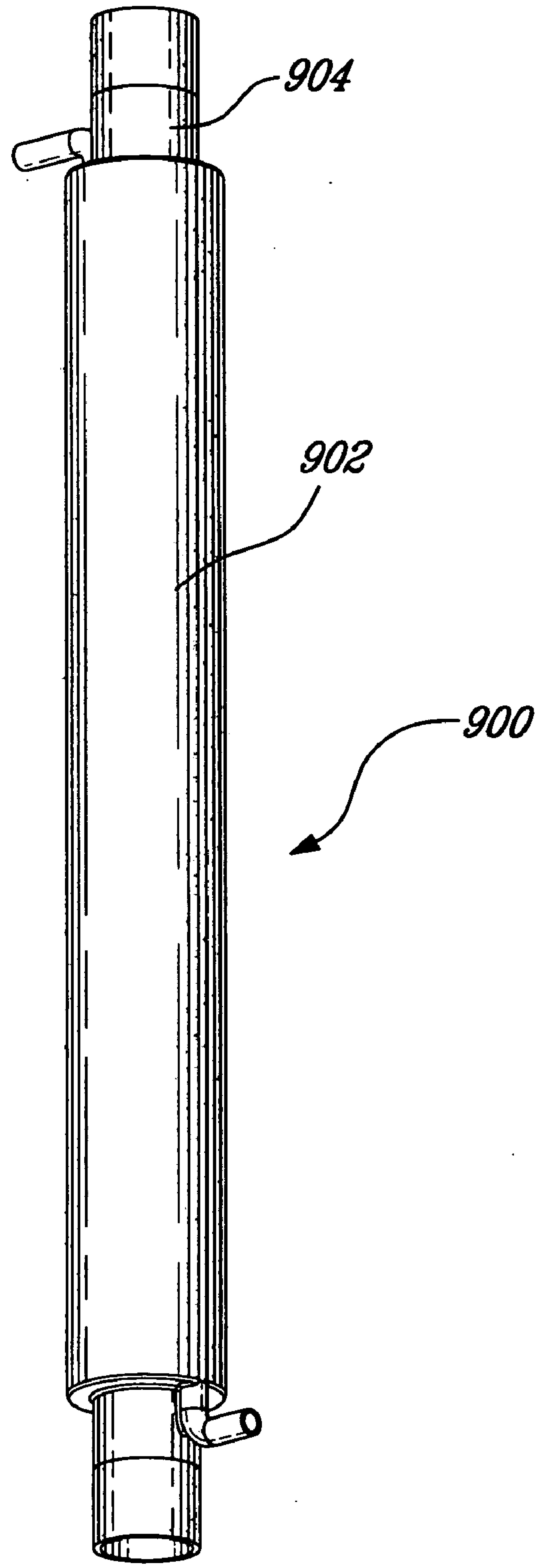


FIG. 41

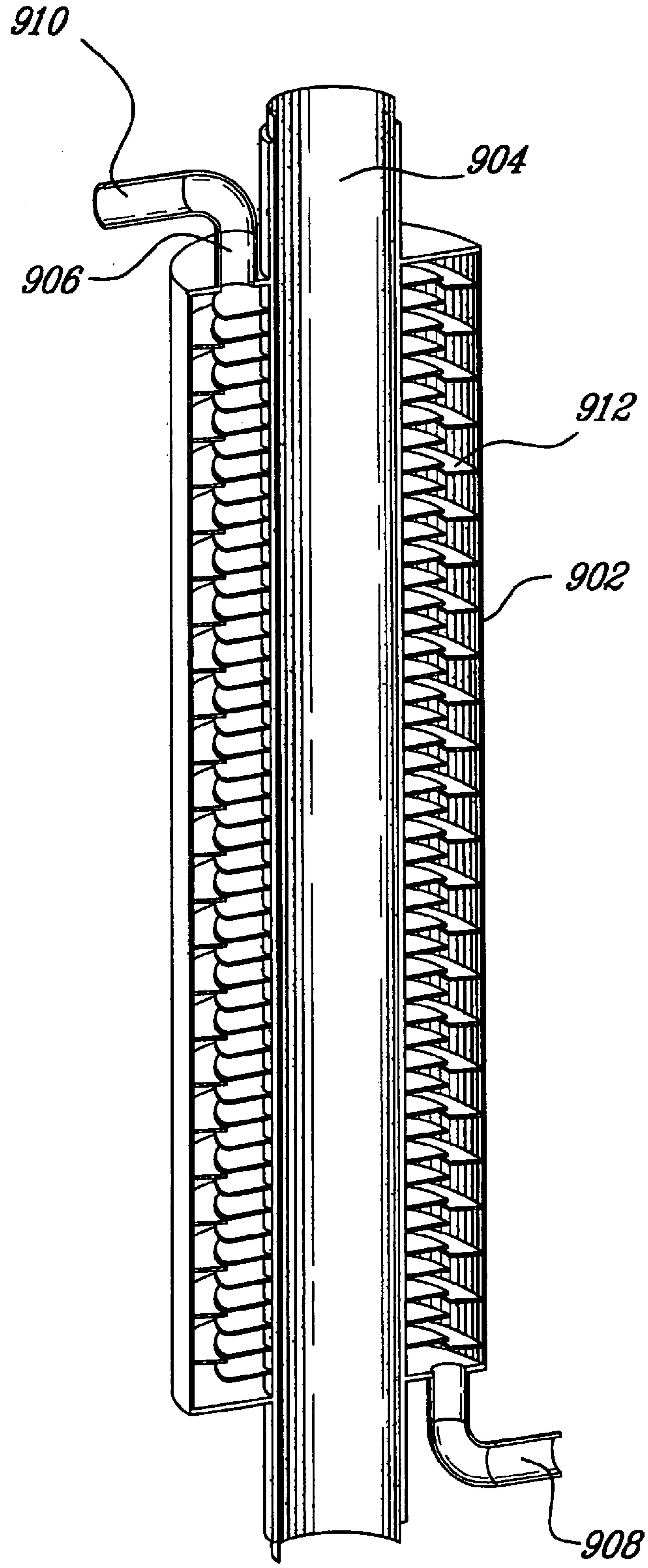


FIG. 42

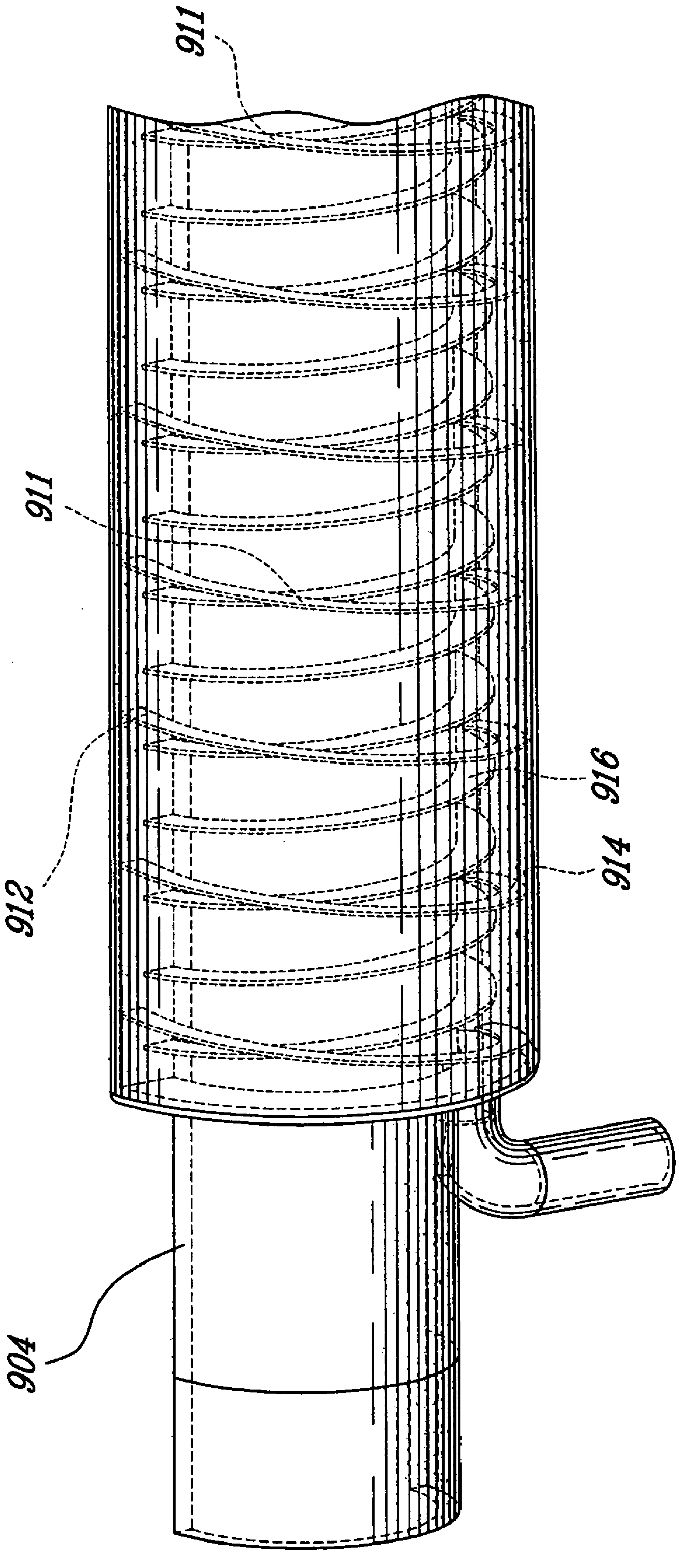


FIG. 43

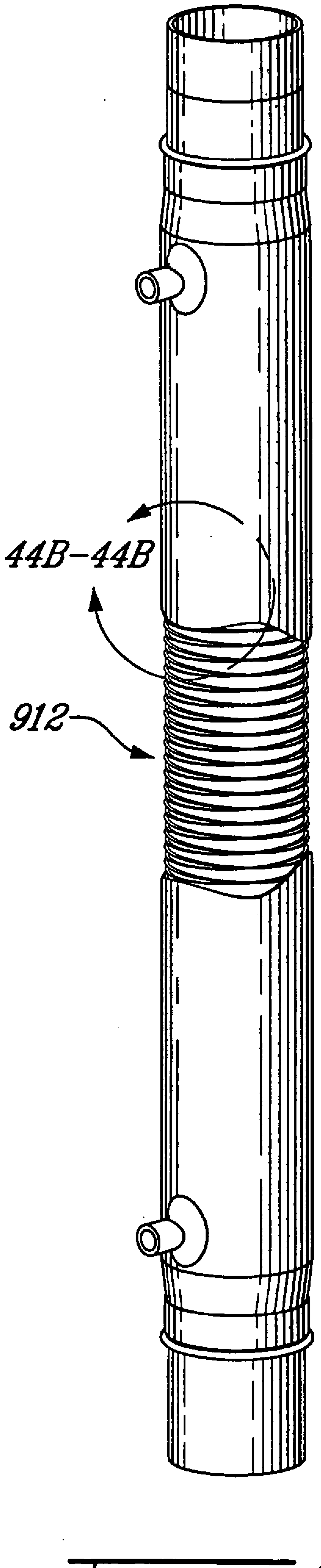


FIG. 44A

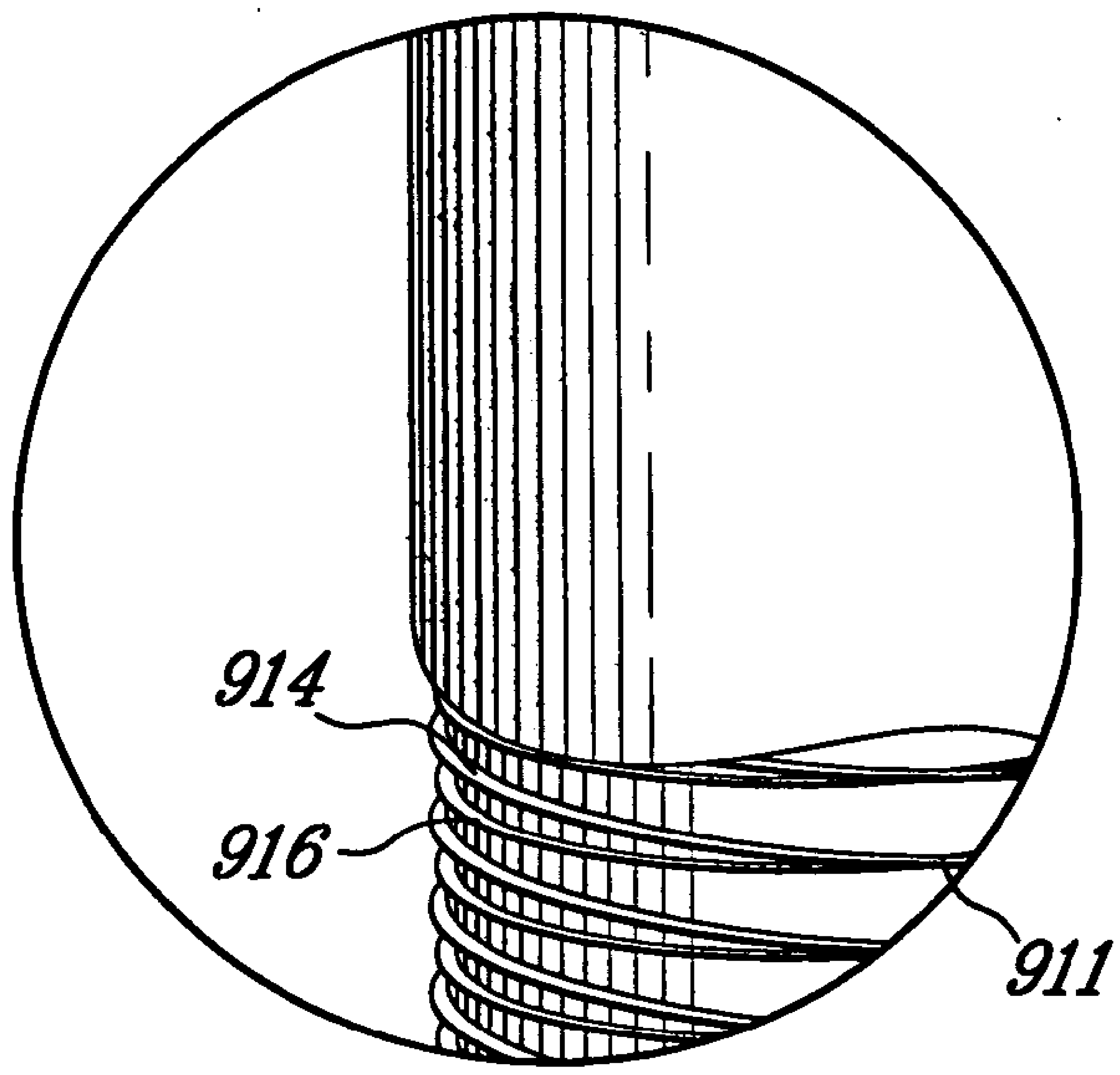


FIG. 44B

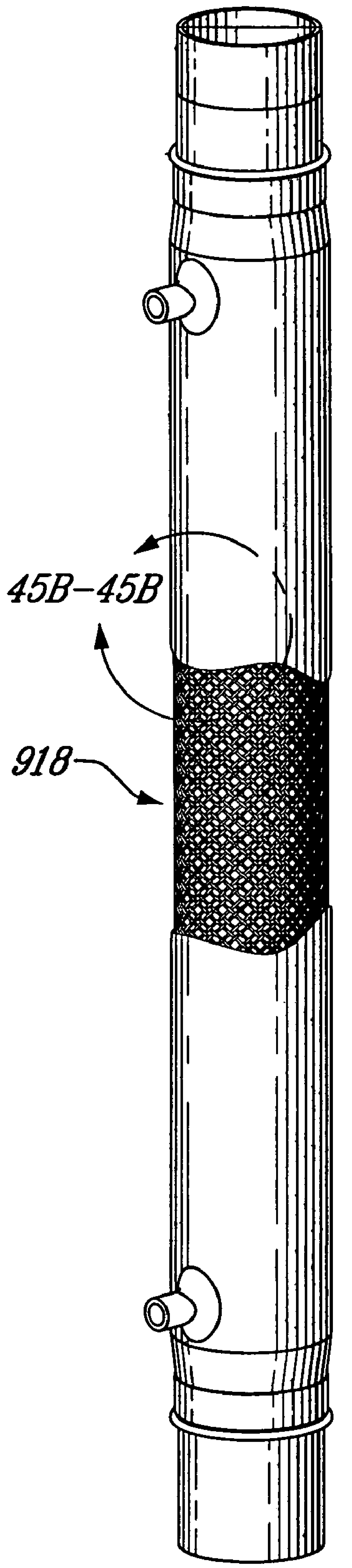


FIG. 45A

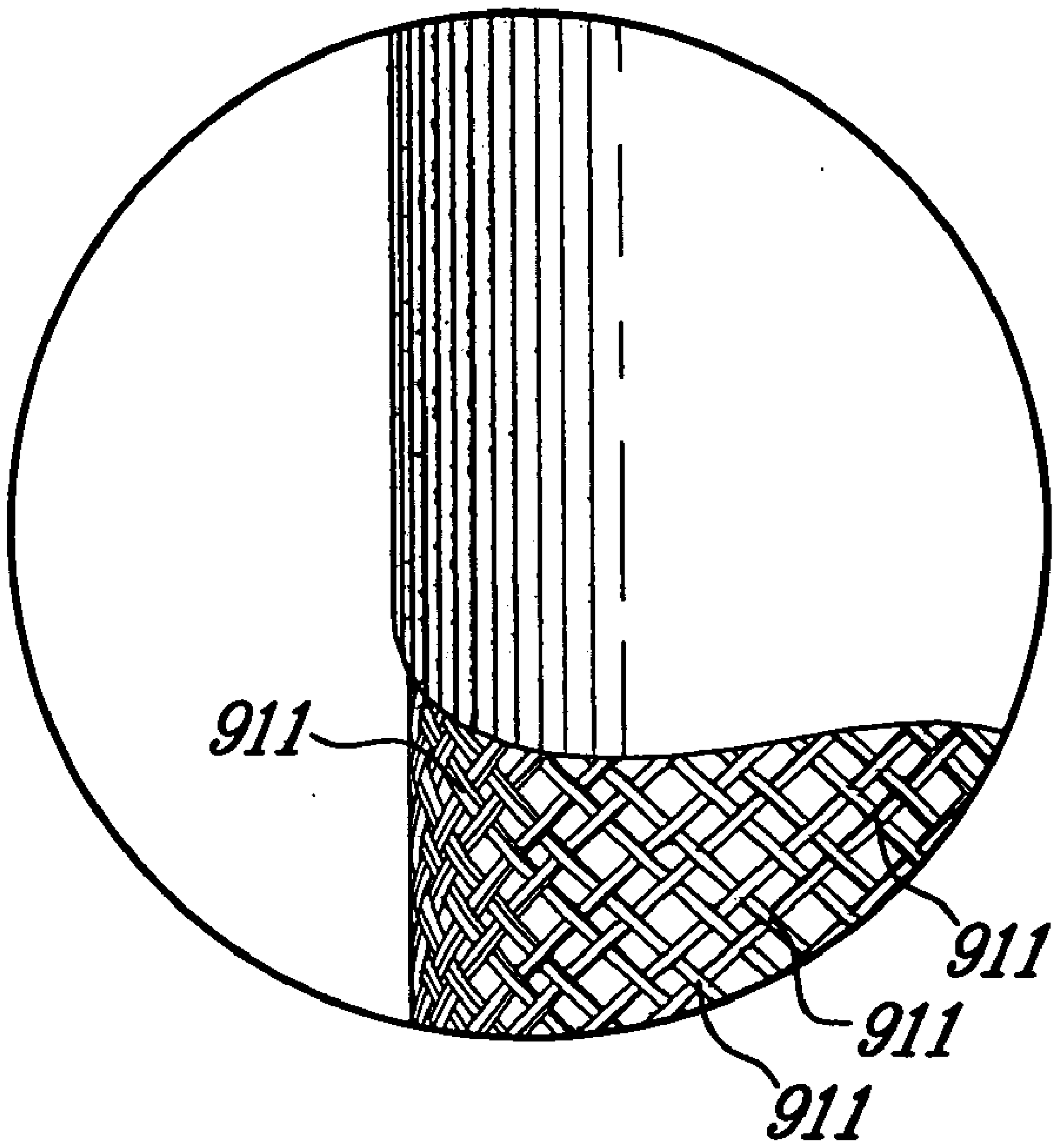


FIG. 45B

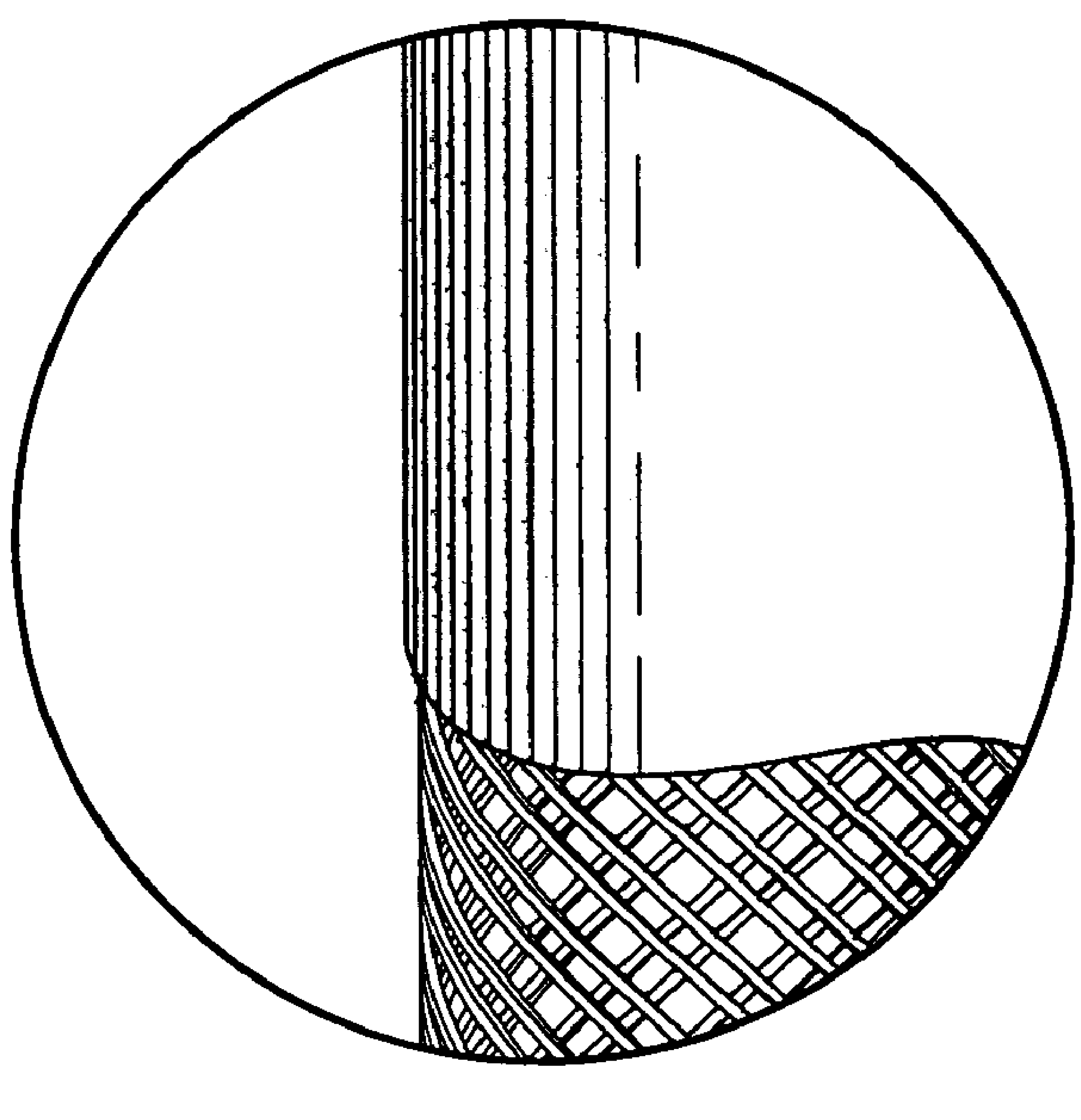


FIG. 45C

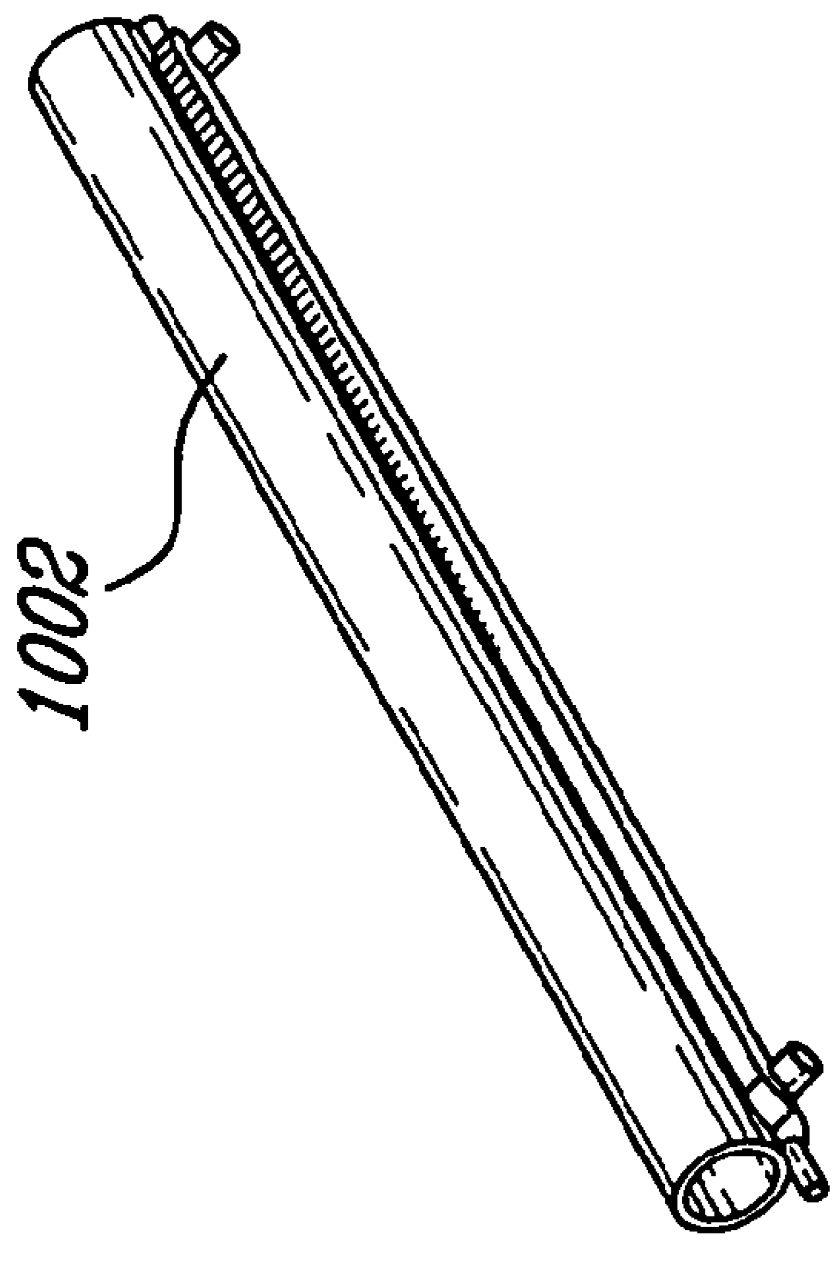


FIG. 46A

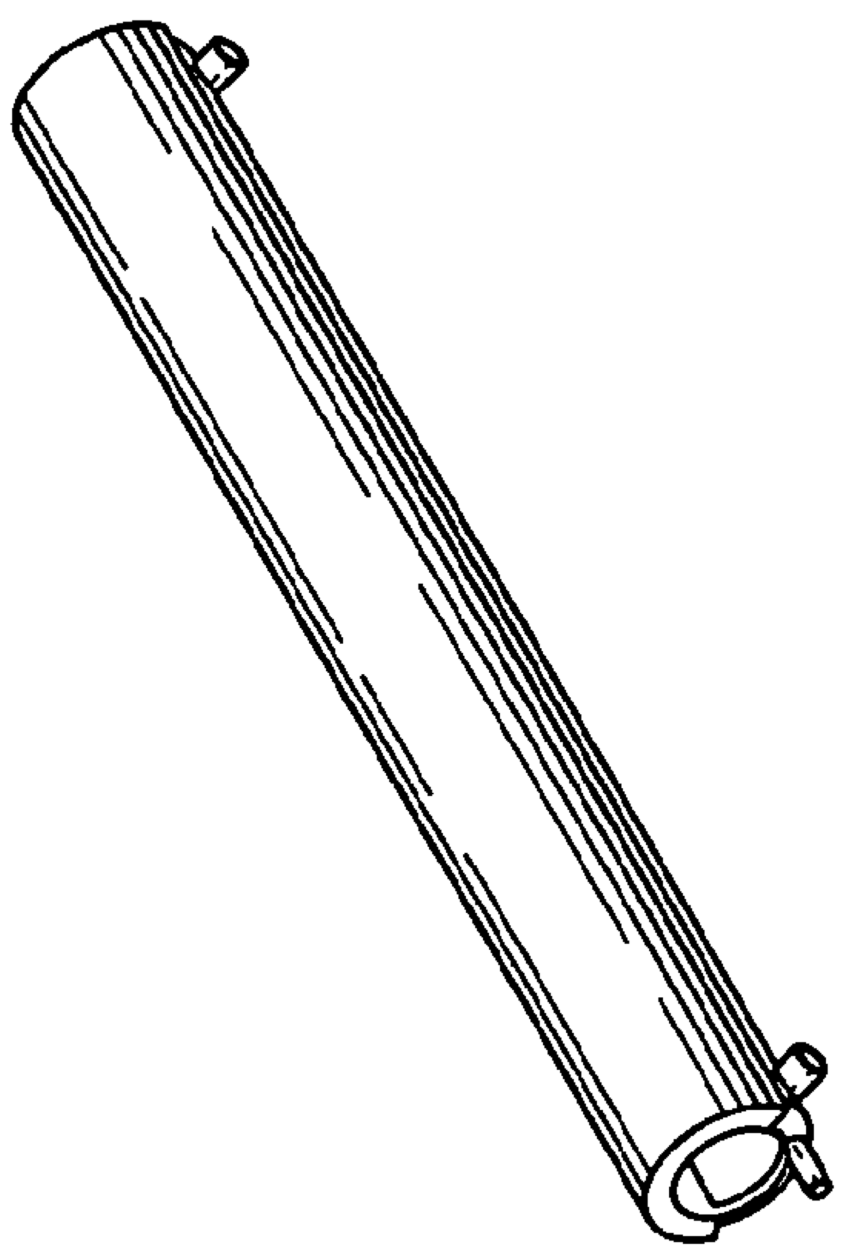


FIG. 46B

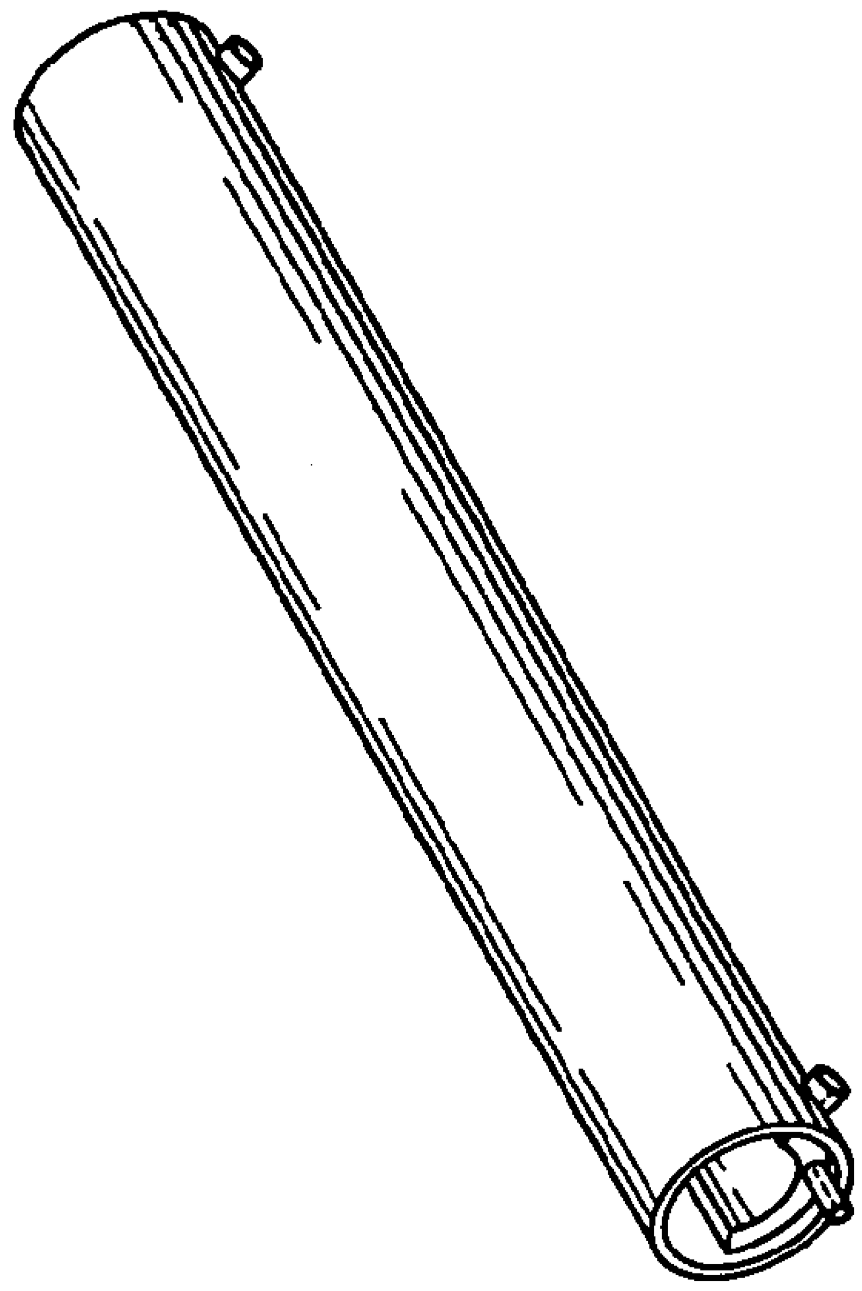


FIG. 46C

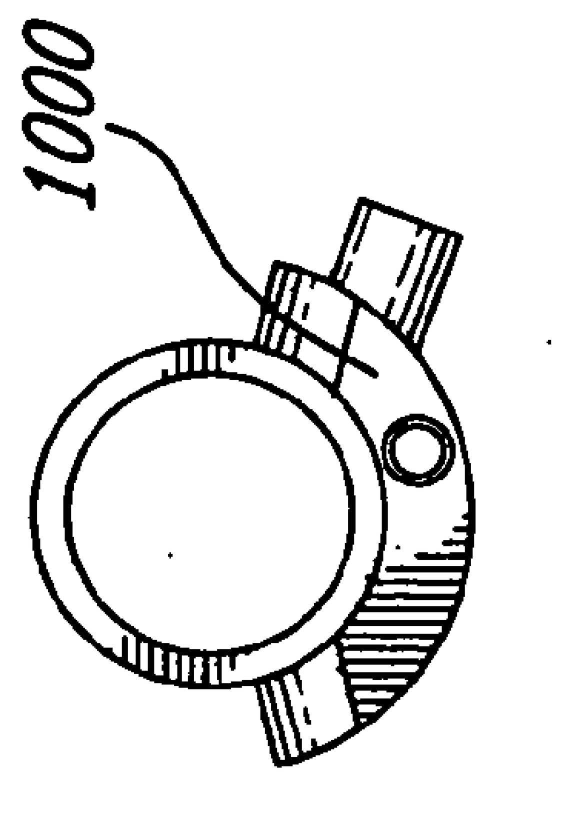


FIG. 46D

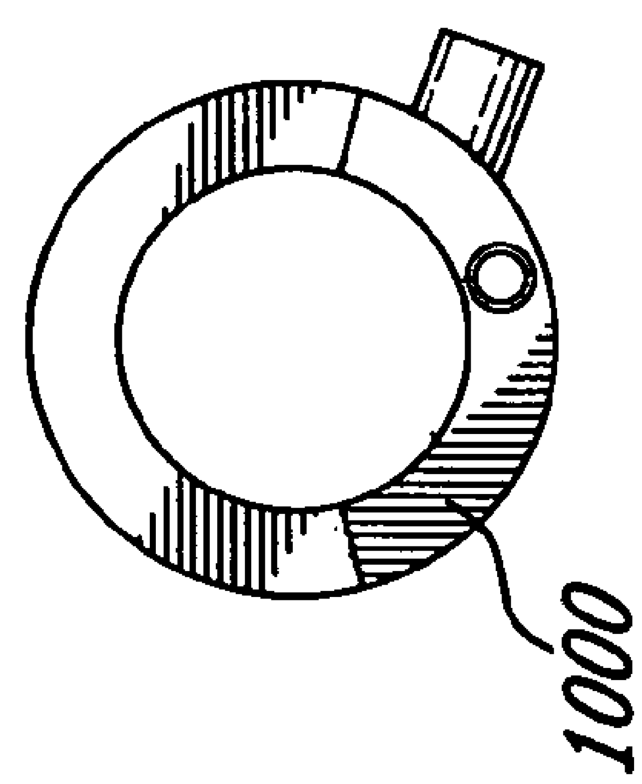


FIG. 46E

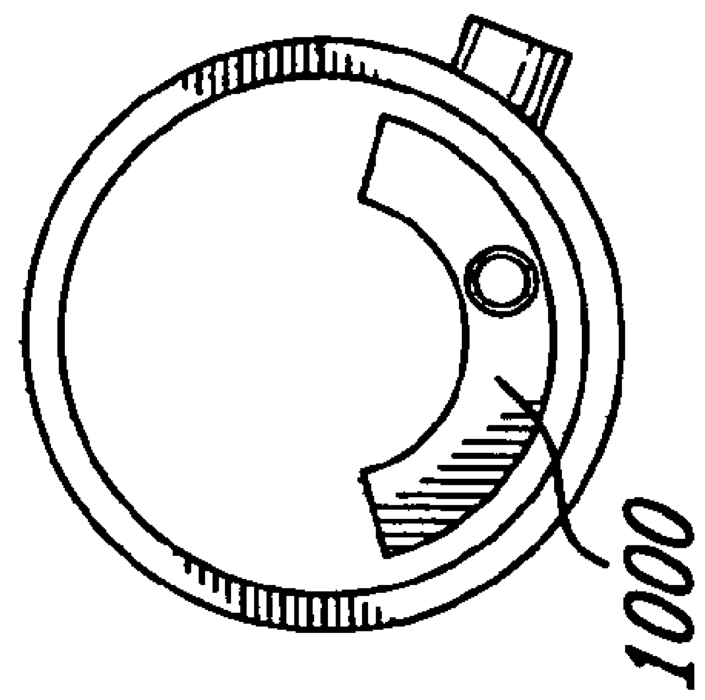


FIG. 46F

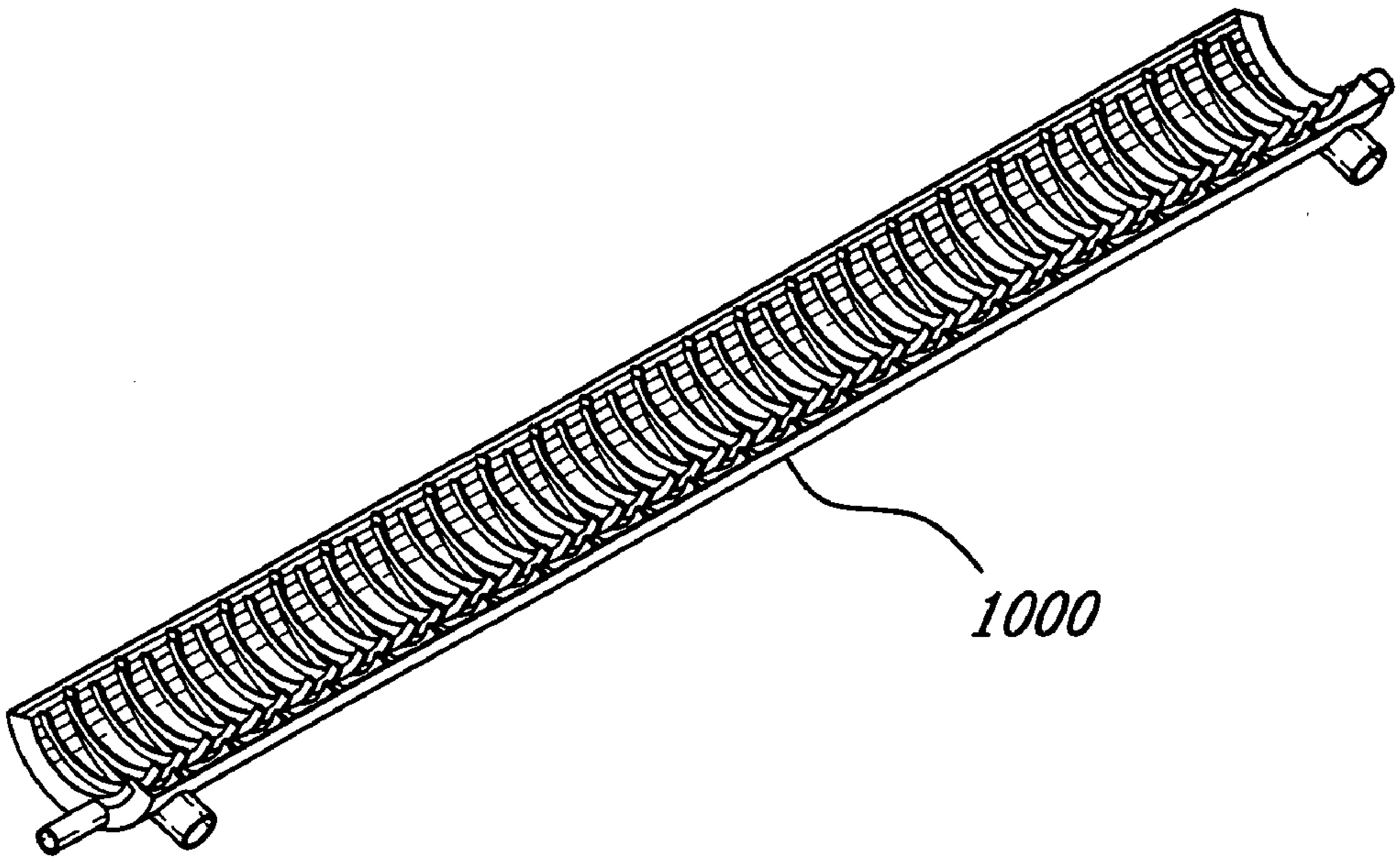


FIG. 46G

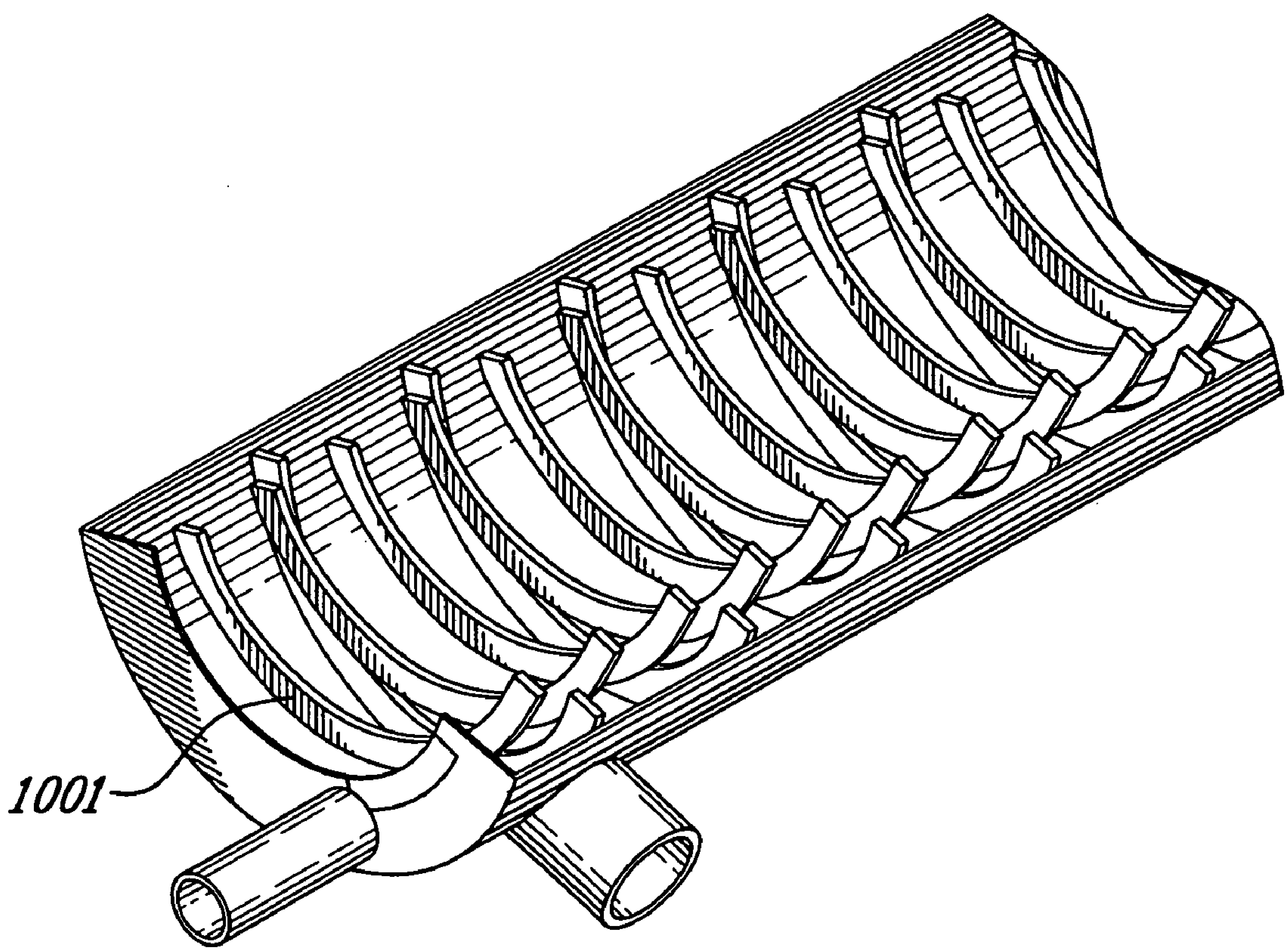


FIG. 46H

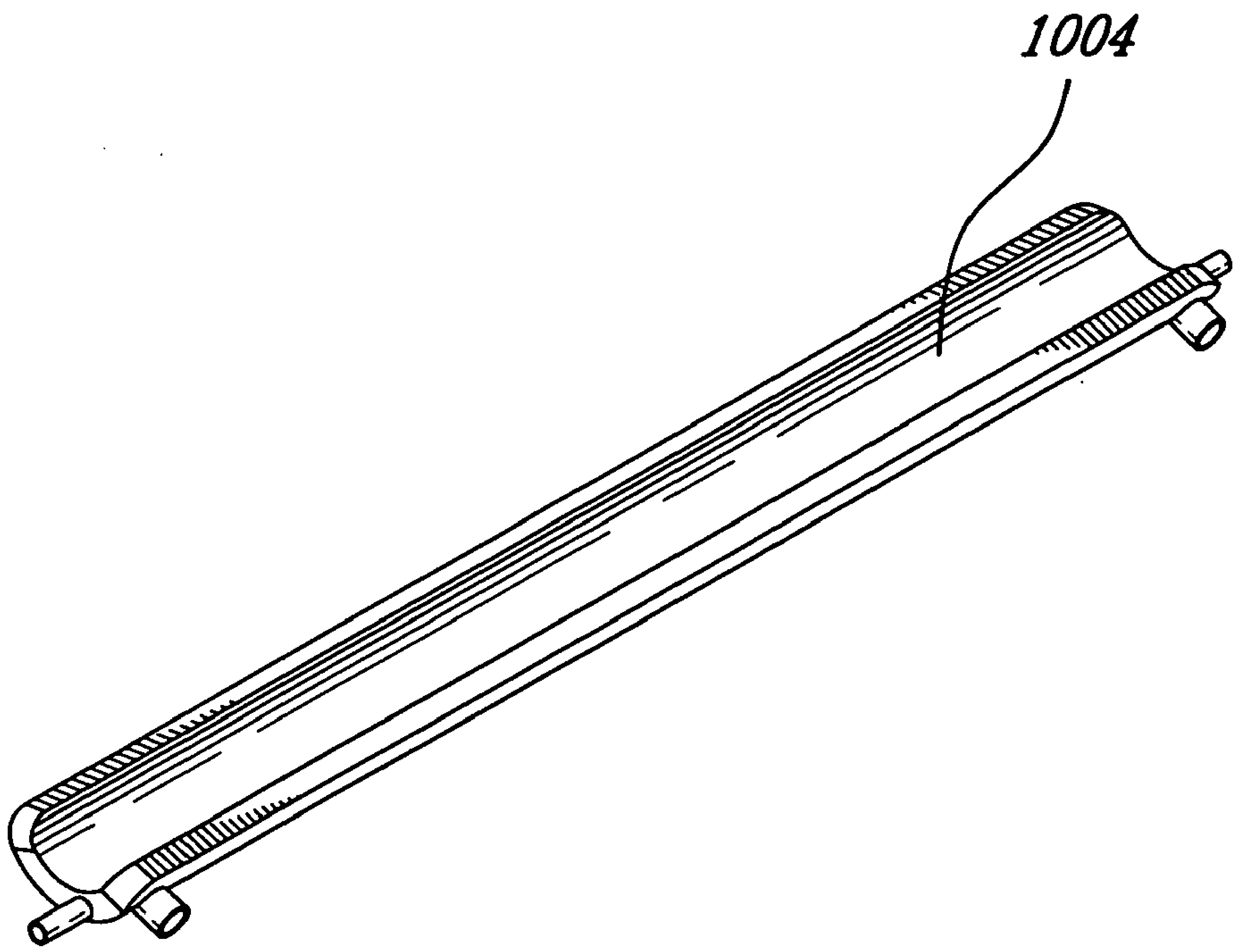


FIG. 47A

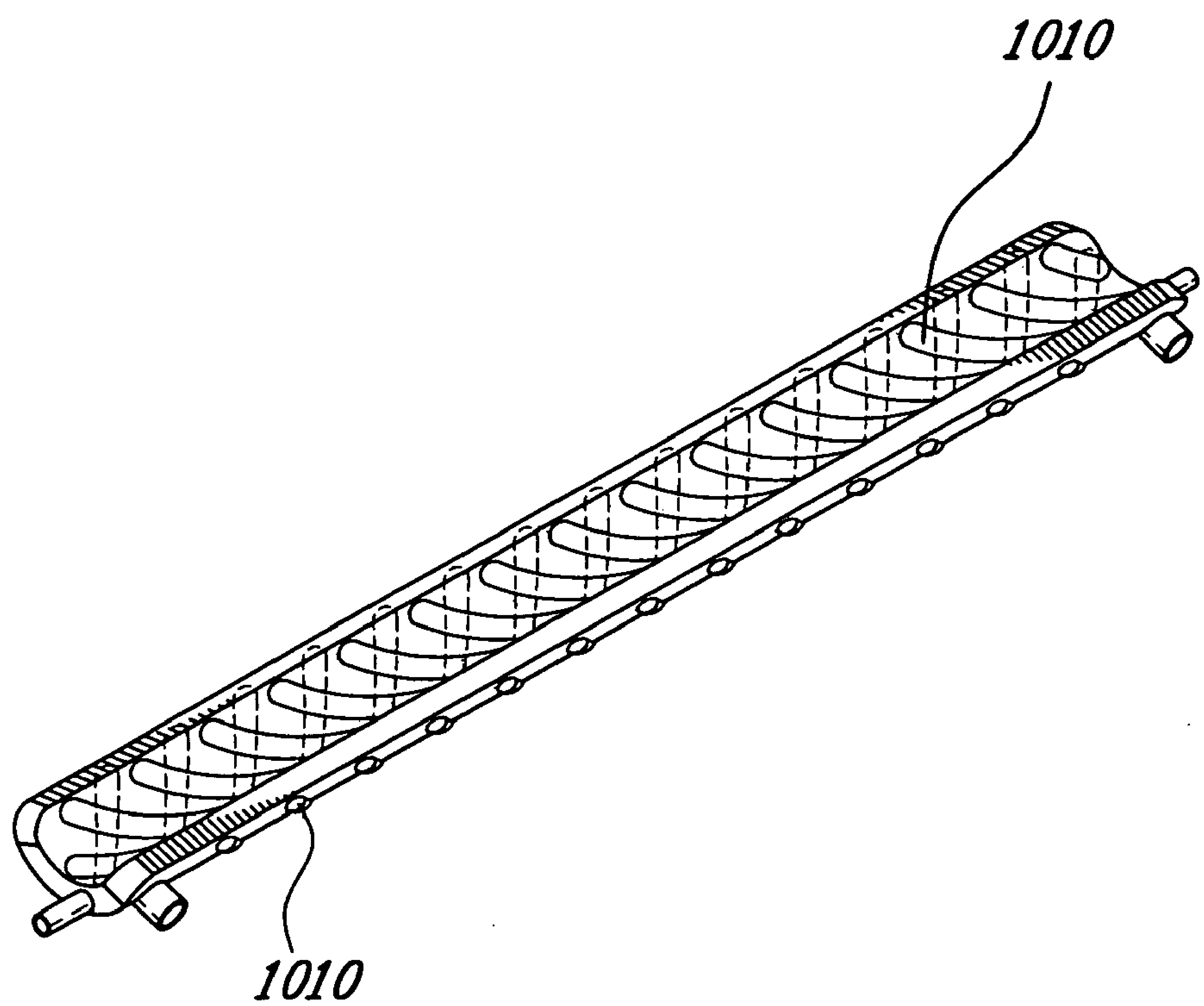


FIG. 47B

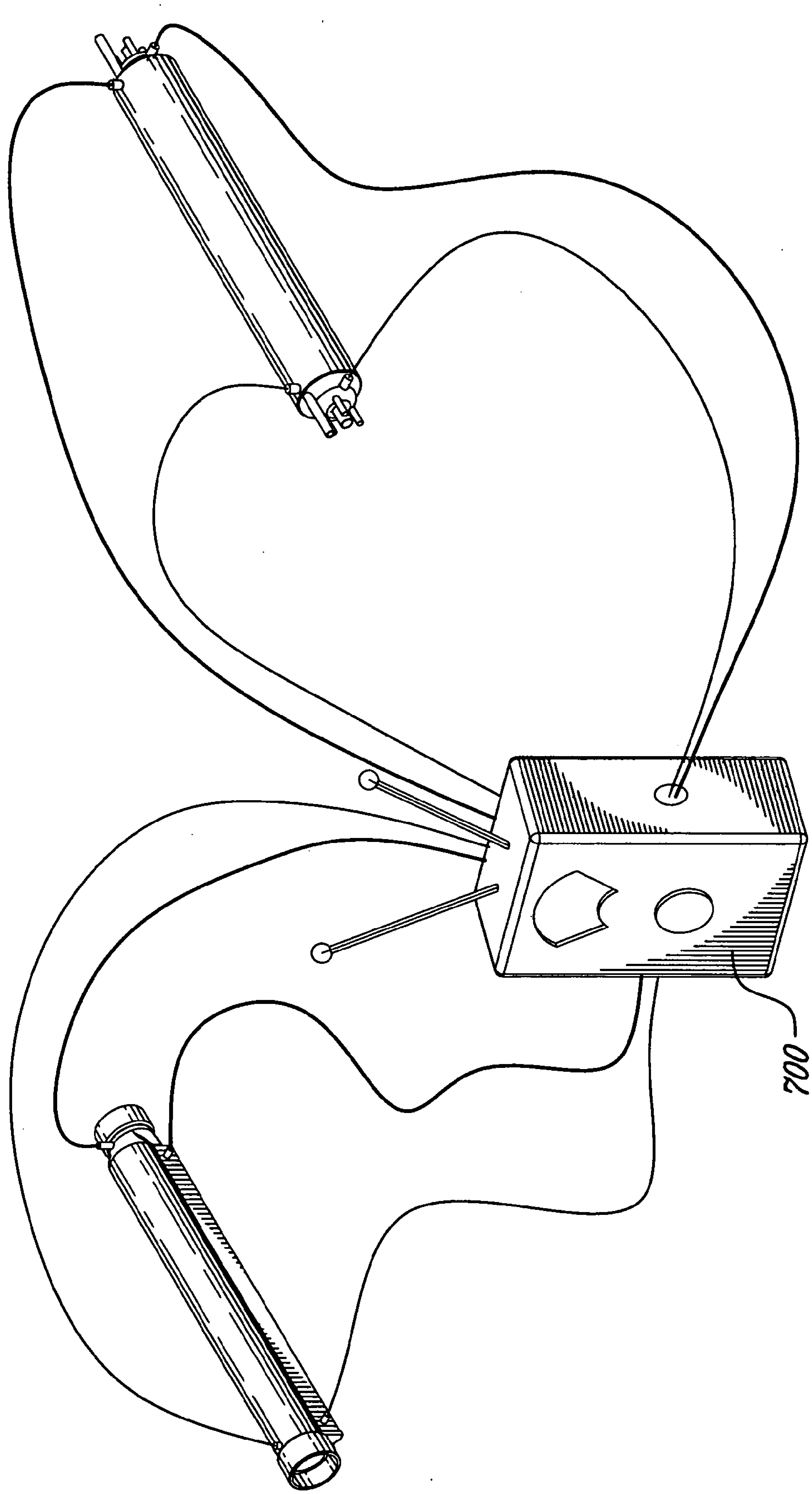


FIG-48

HEAT EXCHANGER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of the filing dates of U.S. provisional patent application Ser. No. 60/964,658, filed Aug. 14, 2007; U.S. provisional patent application Ser. No. 60/994,039, filed Sep. 17, 2007; U.S. provisional patent application Ser. No. 61/008,766, filed Dec. 21, 2007; and U.S. provisional patent application Ser. No. 61/134,666, filed Jul. 11, 2008, the disclosures of which are hereby incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention concerns heat exchangers, and more particularly to blade-type heat exchangers for recovering heat from fluids.

BACKGROUND OF THE INVENTION

[0003] Heat exchangers are well-known and widely used in a number of environments to recover thermal energy from fluids. The thermal energy, if not recovered, would be lost to the environment. Generally speaking, heat exchangers work by transferring heat from one fluid to another via a solid wall, which separates the two fluids. This straightforward principle has been used to recover heat from waste water (so called "grey water") in, for example, household shower and bath systems. A number of designs of heat exchangers that have been used with household shower/bath systems are described as follows.

[0004] U.S. Pat. No. 5,143,149 issued to Kronberg on Sep. 1, 1992 concerns a heat recovery system that includes a heat exchanger and a mixing valve. The heat exchanger appears to include a drain trap with an inner coiled tube, a baffle plate and a waste water outlet. The inner coiled tube includes a cold water inlet and a pre-heated water outlet in fluid communication with each other and is coiled around the inside wall of a cylindrical member. A waste water inlet is located in the drain trap such that waste water enters the cylinder through the inlet, contacts the baffle plate and is deflected away from a solid central portion towards a perforated outer region such that the waste water gradually moves downwardly through the cylinder until it reaches the bottom. Cold water located in the coiled tube moves in a generally upward direction opposite to the waste water as it flows downwardly over the coiled tube to heat the cold water. Heat exchange appears to take place through the walls of the coiled tube. The heated water then exits the heat exchanger via the outlet. The design is simple and relies on the counter-flow principal of heat exchange across a thermally conductive wall of the coiled pipe. While this apparatus uses the heat from waste drain water to heat cold water via a heat exchanger, it does so by direct contact of the waste water with the coiled cold water tube.

[0005] U.S. Pat. No. 4,821,793 issued to Sheffield on Apr. 18, 1989 discloses a tub and shower floor heat exchanger in which a heat exchanger cover is supported on the tub floor by a number of supports, each having an opening therein. The heat exchanger cover is disposed away from the tub floor and includes a gap between the cover and the tub floor. A heat exchange tube is connected to a cold water supply line, the heat exchange tube being arranged directly beneath the heat exchanger cover. Water flowing from a shower head strikes the tub bottom and, as waste water flows towards a drain hole, it is forced back and forth over an extended path by means of the supports which serve as a baffle system. As the waste water moves through the baffle system it moves through the openings and is maintained in a heat exchange relationship with the heat exchange tube over an extended period of time, thereby heating the cold water in the heat exchange tube, which is then fed back to a water line. Disadvantageously, a user of the tub may trip over the raised heat exchanger cover. The tub may also be difficult to clean and maintain.

[0006] U.S. Pat. No. 4,619,311 issued to Vasile et al. on Oct. 28, 1986 discloses a counter-flow heat exchanger system in which waste water exits a shower tub via an essentially vertical waste pipe. A lower portion of the waste pipe is surrounded by a jacket into which is fed cold water in a coaxial counter-flow orientation such that waste water travelling down the waste water pipe exchanges its heat with the cold water travelling up the jacket thereby heating the cold water by heat transfer across the waste water pipe wall. The heated water exits directly to the shower system or moves to a hot water heater tank.

[0007] U.S. Pat. No. 4,472,372 issued to Hunter on Feb. 8, 1983 discloses a heat exchanger that is located in a drain pipe of a shower bath. A cylindrical member is in communication with the drain hole and includes, on the interior, a coiled heat conducting conduit. The coiled conduit includes a coiled copper tube which extends the full length of the cylindrical housing and a second heat conducting coil that is disposed within the annulus of the first heat conducting coil. The coils are each fed by a common inlet conduit which feeds cold water through the coiled conduits such that waste water flowing into the cylindrical member heats the cold water flowing through the coils which then exits via a common outlet towards the mixing valve of the shower unit. A baffle in the form of a central core member is disposed within the annulus of the central coil and appears to cause the water flowing from the drain pipe to be maintained in contact with both coils so as to maximize heat transfer. The heat exchange in this design takes place by direct contact of the waste water with the cold water conduit.

[0008] U.S. Pat. No. 4,304,292 issued to Cardone et al. on Dec. 8, 1981 discloses a shower unit in which a U-shaped conduit as part of a heat exchange apparatus. A heat exchange conduit is coiled around the exterior of the U-shaped conduit. Cold water flows through the coiled conduit and is heated by the waste water flowing through the U-shaped conduit, although there is no indication as to the nature of the contact between the coils and the U-shaped conduit. It is possible that the heat exchange is occurring across the walls of the two conduits. The coiled cold water conduit may also be located internally of the U-shaped conduit. Heat exchange appears to take place by direct contact of the waste water with the coiled cold water conduit.

[0009] U.S. Pat. No. 4,300,247 issued to Berg on Nov. 17, 1981 discloses a heat exchanger integral with the base of a shower unit in which a drain hole is in communication with the heat exchanger. The heat exchanger has a pair of so-called drain water flow through compartments, which are separated by a heat conducting material from a pair of cold water flow through compartments. Cold water is fed into the compartments and, after absorbing heat from the drain water, exits via an output. The heat exchange appears to occur by direct contact of water with the surface of a supply of cold water; in this case, however, instead of being a conduit, the cold water is located in compartments. Waste water fills one side of a number of serpentine compartments up to a line and exchanges heat across the folded layers of heat conductive material into complementary cold water containing compartments. Presumably, this folded arrangement of the heat conductive material allows for a great surface area over which the heat exchange can take place. The heat exchange takes place by direct contact of waste water on the container of cold water.

[0010] U.S. Pat. No. 6,722,421 issued to MacKelvie on Apr. 20, 2004 discloses a rather complex arrangement of either vertical or horizontal heat exchangers which have built-in heat storage for continuous heat recovery from waste drain water. A vertical heat exchanger includes a drain conduit connected to a drain water source, a water reservoir surrounding the drain conduit and a cold water conduit coiled around the water reservoir. A number of nested convection chambers are located on the external wall of the drain conduit and hold a volume of water adjacent to the wall of the drain conduit. In operation, drain water in the drain conduit heats the volume of water in the chambers, which through convention flows into the reservoir thereby heating same and the cold water flowing through the coiled conduit. The horizontal version of the heat exchanger has a convention chambers that appears to "cup" the central drain conduit and operate on the same convection principle as described for the vertical design. Interestingly, simultaneous flow of cold water in the coiled conduit and waste water in the drain conduit is not necessary. There is no contact between the drain conduit and the cold water conduit.

[0011] U.S. Pat. No. 5,791,401 issued to Nobile on Aug. 11, 1998 discloses a portion of a waste water conduit which is U-shaped. The drain conduit includes a number of axially disposed consecutive solid wall ridges and depressions, which are located around the entire inner surface of the drain conduit. A cold water conduit is coiled around the waste water conduit and includes a smooth, arcuate thermal transfer surface complementary to the curvature of the cold water conduit sidewall. This design appears to operate when the void in the U-shaped portion of the waste water drain conduit is entirely filled with waste water.

[0012] U.S. Pat. No. 5,740,857 issued to Thompson et al., Apr. 21, 1998 discloses a heat recovery and storage device useful to recover heat from warm waste water in which a generally horizontal waste water conduit is surrounded by a cold water reservoir. The waste water conduit includes a number of projections made of a high thermally conductive material located on a lower external surface of the conduit and which project into the cold water reservoir so as to transfer heat to same. The upper portion of the conduit is made of a material which limits heat re-conduction. The cold water is in direct contact with the outer wall of the drain water conduit.

[0013] U.S. Pat. No. 4,256,170 issued to Crump on Mar. 17, 1981 discloses a liquid-to-liquid heat exchanger which includes a number of fins located at a lower portion of the waste water conduit. The fins are arranged to define a generally serpentine fluid pathway within a jacket of cold water, which surrounds the waste water conduit. The fins are also used to transfer heat to the cold water and induce turbulence in the cold water flow.

[0014] Thus, there is a need for an improved heat exchange apparatus, in which the fluids do not contact each other and which provides efficient thermal energy transfer across the heat exchanger walls over a short pathway, and in which debris and maintenance tooling can pass through the heat exchange apparatus.

SUMMARY OF THE INVENTION

[0015] We have designed a novel, blade-type, passive fluid-to-fluid heat exchange apparatus, which uses turbulators to induce and maintain turbulent flow to provide unexpectedly high efficiency heat recapture from waste water (also known as "grey water") commonly found in household shower and bath systems. Moreover, the blade members are self-supporting and do not require additional frames for support as is typically required in existing heat exchange designs.

[0016] Accordingly, in one aspect there is provided a heat exchange apparatus, the apparatus comprising: a hollow blade member having a first fluid inlet and a first fluid outlet and a first fluid passageway for a first fluid extending therebetween, the blade member being sized and shaped for location in a second fluid passageway for a second fluid, the blade member being configured to enhance thermal energy transfer between the fluids as they flow along their respective passageways.

[0017] Accordingly in another aspect, there is provided a blade heat exchange apparatus, the apparatus comprising: at least one blade member having a first fluid inlet and a first fluid outlet, and a first fluid passageway for a first fluid extending therebetween, the blade member having a longitudinal blade axis; a second fluid passageway for a second fluid, the second fluid passageway being sized and shaped to receive therein the blade member; the blade member has two blade walls, each blade wall having an inner and outer thermal transfer surface, the thermal transfer surfaces each having a plurality of spaced apart ridges and recesses, the ridges and recesses being substantially parallel to each other, the ridges and recesses of the first blade wall being angled in a first direction relative to the longitudinal axis, the ridges and recesses of the second blade wall being angled in a second direction relative to the longitudinal axis, the second direction being different from the first direction so as to induce cross flow in the first and second fluids as they travel along their respective passageways.

[0018] Accordingly in another aspect, there is provided a heat exchange apparatus, comprising: a central conduit having a conduit wall; an outer jacket substantially encasing the central conduit, the jacket being spaced apart from the conduit wall to define an enclosure and having a fluid inlet and a fluid outlet; a turbulator located in the enclosure, the turbulator having a first helical wire disposed in a clockwise orientation and a second helical wire disposed counterclockwise to the first helical wire so as to induce shear turbulent flow in a fluid as it flows through the enclosure and contacts the turbulator.

[0019] Accordingly in another aspect, there is provided a heat exchange apparatus, the apparatus comprising: a central conduit having a conduit wall; an outer jacket substantially encasing the central conduit, the jacket being spaced apart from the conduit wall to define an enclosure and having a fluid inlet and a fluid outlet; a mesh turbulator located in the enclosure, the mesh turbulator being configured to induce shear and turbulent flow in a fluid as it flows through the enclosure and contacts the turbulator.

[0020] Accordingly in one embodiment of the present invention there is provided a heat exchange apparatus, the apparatus comprising:

[0021] a) at least one hollow fin member having first and second thermal transfer surfaces, the first thermal transfer surface defining a first fluid passageway for a first fluid, which first fluid being flowable along the first passageway in contact with the first thermal transfer surface; and

[0022] b) a second fluid passageway for a second fluid, the second fluid passageway being located in intimate contact with the second thermal transfer surface, such that the first fluid when flowing along the first fluid passageway exchanges thermal energy with the second fluid flowing along the second fluid passageway.

[0023] Accordingly in another embodiment of the present invention there is provided a heat exchange apparatus, the apparatus comprising:

[0024] a) a channel member having first and second end portions, the channel member having a plurality of hollow fin members extending between the first and second end portions, the fin members having first and second thermal transfer surfaces, the first thermal transfer surface defining a first fluid passageway, the first end portion being connectable to a source of a first fluid, the first fluid entering the first end portion at a first temperature and flowable along the first thermal transfer surface, the first fluid exiting the second end portion at a second temperature; and

[0025] b) a second fluid passageway having an inlet and an outlet, the second fluid passageway being located in intimate contact with the second thermal transfer surface, the inlet being connectable to a source of a second fluid, the second fluid entering the inlet at a third temperature and flowable along the second fluid passageway, such that the first fluid when flowing along the first fluid passageway exchanges thermal energy with the second fluid flowing along the second fluid passageway, the second fluid exiting the outlet at a fourth temperature.

[0026] Accordingly in one embodiment of the present invention there is provided a heat exchange apparatus, the apparatus comprising:

[0027] a) a channel member having first and second thermal transfer surfaces, at least one thermal transfer surface being uneven and defining a first fluid passageway for a first fluid; and

[0028] b) a second fluid passageway for a second fluid, the second fluid passageway being located in intimate contact with the second thermal transfer surface, the flow of at least one of the fluids being disrupted such that the first fluid when flowing along the first fluid passageway exchanges thermal energy with the second fluid flowing along the second fluid passageway.

[0029] Accordingly in another embodiment of the present invention, there is provided a heat exchange apparatus, the apparatus comprising:

[0030] a) a fluid passageway having a fluid passageway sidewall of a membraneous material, the material having at least one heat conductive surface locatable in intimate contact with a portion of a conduit sidewall, the conduit having an inlet and an outlet, a first fluid entering the inlet at a first temperature and exiting the outlet at a second temperature, the fluid passageway sidewall being spreadable over an area of the conduit sidewall, the fluid passageway having a fluid passageway inlet and a fluid passageway outlet, a second fluid entering the fluid passageway inlet at a third temperature and exiting the fluid passageway outlet at a fourth temperature.

[0031] Accordingly, in another embodiment, there is provided a heat exchange apparatus, the apparatus comprising:

[0032] a) a conduit having an arcuate conduit member having first and second ends, and an arcuate heat exchanger having first and second connecting portions sealingly connectable to the respective first and second ends, the heat exchanger having first and second thermal transfer surfaces, an amount of a first fluid entering the conduit at a first temperature and being in contact with the first thermal transfer surface and exiting the conduit at a second temperature; and

[0033] b) a fluid passageway having a fluid passageway sidewall of a membraneous material, the material having at least one heat conductive surface locatable in intimate contact with the second thermal transfer surface, the fluid passageway sidewall being spreadable over an area of the second thermal transfer surface, the fluid passageway having a fluid passageway inlet and a fluid passageway outlet, a second fluid entering the fluid passageway inlet at a third temperature and exiting the fluid passageway outlet at a fourth temperature.

[0034] Accordingly in another embodiment of the present invention, there is provided a heat exchange apparatus for use with a P-Trap having an inlet and an outlet, the P-Trap having a first drain portion disposed orthogonal to the ground and connectable to a drain, a second drain portion being disposed away from the ground in a downward gradient, and a U-shaped drain portion interconnecting the first and second drain portions, the apparatus comprising:

[0035] a) a fluid passageway having a fluid passageway sidewall of a membraneous material, the material having at least one heat conductive surface locatable in intimate contact with a sidewall of first drain portion, the second drain portion and the U-shaped portion, a first fluid entering the inlet at a first temperature and exiting the outlet at a second temperature, the fluid passageway sidewall being spreadable over an area of the first drain portion, the second drain portion and the U-shaped portion sidewall, the fluid passageway having a fluid passageway inlet and a fluid passageway outlet, a second fluid entering the fluid passageway inlet at a third temperature and exiting the fluid passageway outlet at a fourth temperature.

[0036] Accordingly in another embodiment of the present invention, there is provided a drainage apparatus for use with a drain trap, the apparatus comprising:

[0037] a) a P-Trap having an inlet and an outlet, the P-Trap having a first drain portion being disposed orthogonal to the ground and connectable to the drain trap, a second drain portion being disposed away from the ground in a downward gradient and a U-shaped drain portion interconnecting the first and second drain portions;

[0038] b) the second drain portion comprising:

[0039] i) an arcuate conduit member having first and second ends, and an arcuate heat exchanger having first and second connecting portions sealingly connectable to the respective first and second ends, the heat exchanger having first and second thermal transfer surfaces, an amount of a first fluid entering the second drain portion at a first temperature and being in contact with the first thermal transfer surface and exiting the second drain portion at a second temperature; and

[0040] ii) a fluid passageway having a fluid passageway sidewall of a membraneous material, the material having at least one heat conductive surface locatable in intimate contact with the second thermal transfer surface, the fluid passageway sidewall being spreadable over an area of the second thermal transfer surface, the fluid passageway having a fluid passageway inlet and a fluid passageway outlet, a second fluid entering the fluid passageway inlet at a third temperature and exiting the fluid passageway outlet at a fourth temperature.

[0041] Accordingly in another embodiment of the present invention, there is provided a drainage apparatus for use with a drain trap, the apparatus comprising:

[0042] a) a P-Trap having a drain portion disposed orthogonal to the ground and connectable to the drain trap and a U-shaped drain portion;

[0043] b) a heat exchanger in fluid communication with the U-shaped portion, the heat exchanger having a channel member having first and second end portions, the channel member having a plurality of hollow fin members extending between the first and second end portions, the fin members having first and second thermal transfer surfaces, the first thermal transfer surface defining a first fluid passageway, a first fluid entering the first end portion from the U-shaped portion at a first temperature and flowable along the first thermal transfer surface, the first fluid exiting the second end portion at a second temperature; and

[0044] c) a second fluid passageway having an inlet and an outlet, the second fluid passageway being located in intimate contact with the second thermal transfer surface, the inlet being connectable to a source of a second fluid, the second fluid entering the inlet at a third temperature and flowable along the second fluid passageway, such that the first fluid when flowing along the first fluid passageway exchanges thermal energy with the second fluid flowing along the second fluid passageway, the second fluid exiting the outlet at a fourth temperature.

[0045] Accordingly in one embodiment of the present invention there is provided a drainage apparatus for use with a drain trap, the apparatus comprising:

[0046] a) a P-Trap having a drain portion being disposed orthogonal to the ground and connectable to the drain trap and a U-shaped drain portion;

[0047] b) a heat exchange apparatus in fluid communication with the U-shaped portion, the apparatus having a channel member having first and second thermal transfer surfaces, at least one thermal transfer surface being uneven and defining a first fluid passageway for a first fluid received from the U-shaped portion; and

[0048] c) a second fluid passageway for a second fluid, the second fluid passageway being located in intimate contact with the second thermal transfer surface, the flow of at least one of the fluids being disrupted such that the first fluid when flowing along the first fluid passageway exchanges thermal energy with the second fluid flowing along the second fluid passageway.

[0049] Accordingly, in another embodiment there is provided a heat exchange apparatus, as described in the embodiments above, for use with a drain trap of a bath tub or a shower tub in a household drainage system.

[0050] Accordingly, in another embodiment there is provided a turbulator for inducing turbulent flow in a fluid, the turbulator comprising: a hollow blade member having a fluid inlet and a fluid outlet, and a fluid passageway for the fluid extending therebetween, the fluid passageway being configured to induce turbulent flow in the fluid as it flows therealong.

[0051] Accordingly, in yet another embodiment, there is provided a heat exchange apparatus, the apparatus comprising: a plurality of turbulators for inducing turbulent flow in a first fluid, each turbulator having a hollow blade member having a fluid inlet and a fluid outlet, and a first fluid passageway for the first fluid extending therebetween, the first fluid passageway being configured to induce turbulent flow in the first fluid as it flows therealong; and a second fluid passageway for a second fluid, the second fluid passageway being sized and shaped to receive the turbulators therein and configured to induce turbulent flow in the second fluid as it flows along the second fluid passageway.

BRIEF DESCRIPTION OF THE DRAWINGS

[0052] These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings wherein:

[0053] FIGS. **1**A and **1**B illustrate a household shower/bath system showing the location of an embodiment of a heat exchange apparatus;

[0054] FIG. **2** is an exploded perspective view of an embodiment of a heat exchange apparatus;

[0055] FIG. **3**A is a perspective view of a channel member of FIG. **2**;

[0056] FIG. **3**B is a partial cross-sectional view taken along line **3***b*-**3***b*' of FIG. **3** showing two uneven thermal transfer surfaces;

[0057] FIG. **4**A is an end view of the channel member showing a single uneven thermal transfer surface;

[0058] FIG. **4**B is a detailed view of a number of peaks and troughs of the channel member of FIG. **4**A;

[0059] FIG. **5**A is a longitudinal cross section view of the heat exchange apparatus showing the location of end caps;

[0060] FIGS. **5**B and **5**C are end views showing respectively the first end cap and the second end cap located relative to the channel member;

[0061] FIG. **5**D is a cross sectional end view of the heat exchange apparatus with the end cap removed;

[0062] FIG. **6** is a perspective view of another embodiment of a capillary heat exchange apparatus with end caps removed to show a channel member;

[0063] FIGS. **7**A-**7**D are a number of cross section views of the channel member of FIG. **6** showing different locations of capillaries and double walls;

[0064] FIG. **8** is an alternative cross section view of the channel member of FIG. **6** showing the location of grey water;

[0065] FIGS. **9**A and **9**B are diagrammatic representations showing an end view comparison of a standard conduit with a heat exchange apparatus;

[0066] FIG. **10** is a detailed partially exploded perspective view of an alternative capillary embodiment of a heat exchange apparatus;

[0067] FIG. **11** is a partial cutaway view showing detail of the apparatus of FIG. **10**;

[0068] FIGS. **12**A and **12**B are respectively an end view and a perspective view of an insert showing circumferentially disposed hollow (capillary) fin members;

[0069] FIG. **13** is a longitudinal cross sectional view of an embodiment of a partial clam shell and partial blister pack heat exchange apparatus located around a grey water pipe;

[0070] FIG. **14** is a cross sectional end view of a blister pack-type heat exchange apparatus located adjacent a grey water pipe;

[0071] FIGS. **15**A and **15**B are cross sectional views showing a double wall bladder-type heat exchange apparatus and a blister pack heat exchange apparatus located around a grey water pipe;

[0072] FIG. **16** is a cross sectional end view of an embodiment of a heat exchange apparatus showing an arcuate insert and atmospheric vent;

[0073] FIGS. **17**A and **17**B illustrate a household shower/bath system showing the location of a heat exchange apparatus relative to a P-Trap;

[0074] FIGS. **18**A and **18**B illustrate a household shower/bath system showing the location of a check valve relative to the heat exchange apparatus;

[0075] FIGS. **19**A and **19**B is an end view and a perspective partial exploded view of an alternative embodiment of a heat exchange apparatus showing a one piece insert having a multiple fluid circuit;

[0076] FIG. **20**A is a perspective partial exploded view of a heat exchange apparatus showing multiple one piece inserts;

[0077] FIG. **20**B is an end view of the heat exchange apparatus of FIG. **20**A;

[0078] FIG. **21**A is a perspective exploded view of an embodiment of an alternative capillary heat exchange apparatus;

[0079] FIG. **21**B is a side view of the heat exchange apparatus of FIG. **21**A

[0080] FIG. **21**C is a cross sectional view of the channel member of FIG. **21**A showing square top hollow fin members;

[0081] FIG. **22**A is an end view of round top capillary heat exchange walls;

[0082] FIG. **22**B is diagrammatic representation of a heat exchange apparatus showing difference planes of flow for grey water;

[0083] FIG. **23** is a perspective view of an embodiment of a blade type heat exchange apparatus with blade members removed;

[0084] FIG. **24**A is a perspective view of an alternative embodiment of a blade type heat exchange apparatus showing blades having surface patterns;

[0085] FIG. **24**B is a partial cross-sectional view of blade members of FIG. **24**A showing interdigitating surface projections;

[0086] FIG. **25**A is a diagrammatic representation of a hollow blade member showing combined performance enhancement surface features in which GW is grey water and CW is cold water;

[0087] FIG. **25**B is a diagrammatic representation of the hollow blade member taken along lines **25**B showing fluid flow patterns;

[0088] FIG. **26** is a perspective, exploded view of an alternative embodiment of a blade type heat exchange showing blades having angled surface ridges;

[0089] FIG. **27** illustrates a number of club grip type corrugated heat exchanger piping;

[0090] FIG. **28**A is a side view of a blade member showing in solid lines a plurality of angled ridges on one surface and in phantom lines a plurality of angled ridges on another surface and illustrating criss cross patterns and contact points;

[0091] FIG. **28**B is a cross sectional view of the blade member taken along line **28**B showing the location of ridges and recesses of two blade surfaces;

[0092] FIG. **29** is a diagrammatic representation of a section of a blade member showing a centre spot weld, ridges, and crimped ends;

[0093] FIG. **30**A is a longitudinal cross section view of a double wall blade member showing atmospheric vents;

[0094] FIG. **30**B is a cross section view of the blade member taken along **30**B showing the double wall and surface textures;

[0095] FIG. **31**A is a diagrammatic representation of a hollow blade member showing macroscopic and microscopic textures and fluid flow patterns;

[0096] FIGS. **32**A and B is a representation of a golf ball showing alternative icosahedron dimple structure;

[0097] FIG. **33** is a perspective partial cutaway view of a blade-type heat exchanger;

[0098] FIG. **34** is a detailed view of an end portion of the blade-type heat exchanger of FIG. **33** showing the manifold and heat exchange wall details;

[0099] FIG. **35** is a detailed side view of one end of the heat exchange apparatus of FIG. **33** showing ridges and recesses of blade member surfaces;

[0100] FIG. **36** is a partially exploded view of a blade type heat exchanger showing an alternative orientation of the cold water manifolds;

[0101] FIG. **37** is a perspective view of a large scale blade-type heat exchange apparatus housing;

[0102] FIG. **38** is a perspective view of the heat exchange apparatus of FIG. **3** with the top removed to show the blade members;

[0103] FIG. **39** is a side view of a large dimensioned blade member;

[0104] FIG. **40** is a perspective view of an alternative design of a large dimension heat exchanger apparatus housing;

[0105] FIG. **41** is a side view of an alternative embodiment of a vertical heat exchange apparatus;

[0106] FIG. **42** is a longitudinal cross sectional view of the heat exchange apparatus of FIG. **41** showing the location of a double slinky turbulator;

[0107] FIG. **43** is a detailed view of a section of the double slinky wire turbulator;

[0108] FIGS. **44**A and **44**B are respectively a partial cutaway view and a detailed view of a double slinky wire turbulator;

[0109] FIGS. **45**A, **45**B and **45**C are respectively a partial cutaway view and a detailed views of a mesh turbulator;

[0110] FIGS. **46**A-**46**H illustrate a number of designs of compact heat exchanger apparatus comprising internally located wire turbulators or surface defined ribbed turbulators;

[0111] FIGS. **47**A and **47**B are perspective view of respectively a smooth turbulator and a double sided ribbed turbulator;

[0112] FIG. **48** is a diagrammatic representation of a system for controlling and for monitoring heat exchange apparatuses.

DETAILED DESCRIPTION

Definitions

[0113] Unless otherwise specified, the following definitions apply:

[0114] The singular forms "a", "an" and "the" include corresponding plural references unless the context clearly dictates otherwise.

[0115] As used herein, the term "comprising" is intended to mean that the list of elements following the word "comprising" are required or mandatory but that other elements are optional and may or may not be present.

[0116] As used herein, the term "consisting of" is intended to mean including and limited to whatever follows the phrase "consisting of". Thus the phrase "consisting of" indicates that the listed elements are required or mandatory and that no other elements may be present.

[0117] As used herein, the term "turbulator" when referring to either a surface or to an insert having a surface that acts as a turbulator, is intended to mean that the surface has a plurality of projections extending away therefrom. Surface turbulators and inserted turbulators are used to increase convenction rates and heat transfer coefficients at heat exchange surfaces in fluid passageways in order to provide high performance in compact heat exchange assemblies, and to orientate fluids into a pre-defined direction often resulting in chaotic paths. Examples of types of turbulators include, but are not limited to, corrugations, peaks and troughs, nubbins, raised chevrons having a gap between, fish scales, raised zigzag moldings, meshes, criss cross oriented wires, porous materials, and the like. Turbulators may comprise uniform or non-uniform surface profiles, textures, open cell structures, and shapes. Porosity and fluid passageway geometry allow control of fluid flow via solid or semi-solid mechanical structures and may be constructed from laminate composites, molded parts, and even mesh of plastics, ceramics, metals or other materials.

[0118] As used herein the term "fluid" is intended to mean gas or liquid. Examples of liquids suitable for use with the heat exchangers described herein include, but are not limited to, water, hydraulic fluid, petroleum, glycol, oil and the like. Examples of gases include, for example, combustion engine exhaust gases and steam.

[0119] The invention features a novel heat exchange apparatus in which hollow fin members or hollow blade members with or without surface patterns can be used to promote efficient thermal energy transfer between fluids across thermal energy transfer surfaces. The flow of fluids can be passive, i.e. by gravity or can flow under the influence of pressure, either above or below atmospheric pressure. The heat exchange apparatuses described herein are also self-draining. Moreover due to their design, the blade members can be located directly in a grey water pathway with or without the use of pre-filtration to remove particulate debris. In one example, the efficiency of heat recapture is 40-60% when compared to 25% heat recapture efficiency of conventional systems. To achieve this, in one example, we use a channel with plurality of hollow blades to move, by gravity, grey water along a pathway such that it exchanges its heat (typically about 40° C.) to a source of cold water flowing through another passageway located in intimate contact with the channel. In other examples, higher fluid temperatures (>100° C.) can also exchange their thermal energy to cold water so as to generate steam. The heat exchange takes place across a thin (typically from about 1/1000 inch to about 1/5 inch thickness) double wall arrangement. Furthermore, thermal energy transfer occurs along a significantly shorter pathway between thermal transfer surfaces when compared to thermal transfer across solid fins. The cold water is heated to produce warmed water, which may then be stored in a storage tank or communicated to a mixing valve in a shower or bath system. Advantageously, the heat exchanger apparatus is constructed from inexpensive materials and when installed is essentially maintenance-free. The grey water conduits (pipes) used are standard 1.5 to 4 inch and are universally retrofittable into existing plumbing systems with the minimum of disruption to the household. The apparatus may also be connectable to active heat exchange apparatus such as, for example, a Peltier Module. The various designs of heat exchange apparatus will now be described in detail.

[0120] Referring now to FIGS. **1**A and **1**B, an embodiment of a modular heat exchange apparatus is shown generally at **10** in use with a household shower and bath system **12**. The household shower and bath system **12** includes a water heater **14**, a hot water line **16**, a cold water line **18**, a warm water line **20**, a mixing valve **22**, a shower head **24** and a drain trap **26**. The hot and warm water lines **16**, **20** are each connected to the mixing valve **22**, the temperature of the water exiting the shower head **24** being controlled by the user operating the mixing valve **22**. The cold water line **18** is connected to the heat exchange apparatus **10** and feeds cold water **25** (a second fluid) into the apparatus **10**. The warm water line **20** is connected to the heat exchange apparatus **10** and the mixing valve **22**. The drain trap **26** receives drain water **28** (so called "grey water") (a first fluid) from the shower/bath tub and communicates the drain water to the heat exchange apparatus **10**. After flowing through the heat exchange apparatus **10**, the grey water **28** exits the household shower system **12** to a main drain (not shown). It should be noted that although an example of a household shower/bath system is illustrated, the heat exchange apparatus described may also be used for other applications that require heat exchange between two fluids. Furthermore, it is to be noted that any of the heat exchangers described hereinbelow can also be connected to the system **12**.

[0121] Referring now to FIG. **2**, the heat exchange apparatus **10** is described in more detail. Broadly speaking, the heat exchange apparatus **10** comprises a channel member **30** which has a first end portion **32** and a second end portion **34**, and which defines a first fluid passageway **36** for the first fluid **28**. The channel member **30** includes a first thermal transfer surface **38** and a second thermal transfer surface **40**. At least one of the thermal transfer surfaces is uneven. In the example illustrated, both the thermal transfer surfaces **38**, **40** are uneven. In the example shown, the first thermal transfer surface **38** is corrugated and defines a plurality of fin-like peaks (or blades) **42** and troughs **44** that extend longitudinally along the channel member **30** between the first and second end portions **32**, **34**. Although the peaks **42** and troughs **44** are disposed substantially parallel to each other, it is to be understood that the peaks **42** and troughs **44** can be arranged in any manner. The first end portion **32** is connectable to a source of the grey water **28**, which enters the first end portion **32** at a first temperature T**1** and flows along the surface **38**, exiting the second end portion **34** at a second temperature T**2**. A second fluid passageway **46**, typically a cold water conduit, has a second fluid inlet **48** and a second fluid in outlet **50**, and is located in intimate contact with the second thermal transfer surface **40** of the channel member **30**. The second fluid inlet **48** is connectable to a source of the second fluid (not shown), which enters the inlet **48** at a third temperature T**3** and flows along the second fluid passageway **46**. The grey water **28** exchanges thermal energy with the cold water such that it exits the outlet **50** at a fourth temperature T**4** as warmed water. The temperature of the warmed water T**4** is greater than the temperature T**3** of the cold water entering the inlet **48**. The warmed water feeds into the warm water line **20** and may be mixed with hot water in the mixing valve **22**.

[0122] The first and second fluids flow in a contra-flow manner through the heat exchange apparatus **10**. It is also possible to have the fluids flow in a parallel flow manner. The first temperature T1 of the first fluid **28** entering the first fluid passageway **36** can be greater than or less than the second temperature T2 of the first fluid **28** as it exits the first fluid passageway **36**. Similarly, the third temperature T3 of the second fluid **25** can be greater than or less than the fourth temperature T4 of the second fluid **25** as it exits the second passageway **46**. In the examples illustrated herein, the first temperature T1 of the first fluid **28** entering the first fluid passageway **36** is greater than the second temperature T2 of the first fluid **28** as it exits the first fluid passageway **36**. The third temperature T3 of the second fluid **25** is less than the fourth temperature T4 of the second fluid **25** as it exits the second fluid passageway **46**. By way of example, T1 is typically 40° C. for grey water (the first fluid), T2 is typically 30° C. for grey water exiting the heat exchanger **10**, T3 is typically 10° C. for cold water (the second fluid), and T4 is typically 24° C. for warmed water entering the warm water line **22** from the heat exchanger **10**. To measure the efficiency of the heat exchange apparatus, the following equation is used:

$$\text{Effectiveness} = \frac{T_{cold\ out} - T_{cold\ in}}{T_{grey\ in} - T_{cold\ in}}$$

[0123] where T denotes temperature in ° C.

[0124] At least one of the fluids flows through its respective passageway under pressure, the other fluid flowing through its respective passageway at atmospheric pressure. Typically, the second fluid (the cold water) flows under pressure at approximately 50 psi along the second fluid passageway **46**.

[0125] Still referring to FIG. **2**, the heat exchange apparatus **10** further comprises an arcuate piece **52**, a first end cap **54** and a second end cap **56**. A support member **58** interconnects the arcuate piece **52**, the end caps **54**, **56**, and provides a housing for the channel member **30** and the second fluid passageway **46**. The channel member **30** may optionally include a mesh filter **60** which lies snug against the channel member **30**. The mesh filter **60** significantly reduces the amount of debris, such as hair, soap scum and other particulates, which would otherwise clog the channel member **30**.

[0126] Referring now to FIGS. 3A and 3B, the channel member **30** is generally elongate and, when viewed in cross-section, is H-shaped. The channel member **30** includes two sidewalls **62**, **64** which form a boundary on either side of the channel member **30**. It is to be understood that although the channel member **30** in this example illustrated is H-shaped, any cross sectional shape is possible. When connected to the drain trap **26**, the channel member **30** is disposed away from a horizontal plane towards the ground at an angle of about 1° such that when the grey water from the shower drain enters the channel member **30** at the first end portion **32** it flows passively and by gravity along the first fluid passageway towards the second end portion **34**. Two adjacent peaks **42*a*** and **42*b*** define one trough **44*a*** located therebetween. A fluid convection promoter **68** (or turbulator) is located at a trough base **70** and projects into the trough **44*a***. The convection promoter **68** is located on the first thermal transfer surface **38** and increases thermal exchange, across the surface **38**. Located between an end peak **42*c*** and each side wall **62**, **64** is another convection promoter **68**. The convection promoters **68** can be in the form of a microscopic peak, although other promoters known to those skilled in the art can be used. The second thermal transfer surface **40** may optionally include a plurality of fin-like projections (or blades) **66**, which extend away from the surface **40**, as best illustrated in FIG. **3**B. In one example, the projections **66** may be also be corrugations similar in shape to the corrugations on the first thermal transfer surface **38**. The cold water conduit (the second fluid passageway) lies snugly and in intimate contact with the projections **66** so as to provide highly efficient heat transfer from the first fluid passageway **36** to the second fluid passageway **46**.

[0127] Referring now to FIGS. **4**A and **4**B, the second thermal transfer surface **40** is smooth. In this case, the second fluid passageway **46** is located adjacent the second thermal transfer surface **40** and includes a plurality of turbulators **72** located in the second fluid passageway **46**. The turbulators **72** in due turbulence and establish shear forces in the second fluid as it flows through the second fluid passageway **46**. A number of turbulators designed for round pipe insertion are known to those skilled in the art.

[0128] As best illustrated in FIG. **4**B, as the grey water flows along the first fluid passageway **36** a rotational flow pattern is established, as indicated by the arrows, between adjacent peaks. This convective rotational flow pattern provides enhanced transfer of thermal energy from the grey water to the heat conductive peaks **42** and troughs **44** of the first thermal transfer surface **38** to the second fluid passageway **46** located adjacent thereto. Delaminators (turbulators) can also be used to induce fluid rotation, or laminar flow disrupters (turbulators) may be used to enhance thermal energy transfers and also to manage fluid flow. Advantageously, turbulators also manage debris and reduce its accumulation in the first and second fluid passageways.

[0129] As best illustrated in FIGS. **2** and **5**A through **5**D, the first end cap **54** is connected to the first end portion **32** of the channel member **30**, whereas the second end cap **56** is connected to the second end portion **34**. In order to aid flow of the grey water along the first fluid passageway **36** by gravity and to reduce "pooling" of water in the apparatus, the second end cap **56** is disposed at an angle away from a longitudinal axis **74** of the channel member **30**. The location of the second end cap **56** with respect to the first end cap **54** creates a deviation away from the axis **74**. While this may be acceptable to some local plumbing regulations, it may be prohibited in others. In order to circumvent this problem, the first end cap **54** can be connected to the lower first end portion of the channel member **30** with the same deviation from the longitudinal axis of the channel member **30** such that the grey water would flow along the channel member at a typical angle of 1° away from the horizontal.

[0130] Referring now to FIG. **6**, an alternative example of a heat exchange apparatus **76** is illustrated which comprises a non-H shaped channel member **78**, the first and second end caps **54**, **56**, the cold water inlet **48** and the warmed water outlet **50**. The channel member **78** includes a plurality of capillary hollow fin members **79** which define wave-like peaks **80** and troughs **82** extending along the channel member **78** between the first and second end portions **32**, **34**.

[0131] As best illustrated in FIGS. **7**A through **7**D, the hollow fin members **79** include a first thermal transfer surface **84** located on an upper portion of a first wall **86** (adjacent the grey water), the first thermal transfer surface **84** defining the first fluid passageway **28** for the first fluid, and a second wall **88** located in intimate contact with the first wall **86**. A second thermal transfer surface **90** is located on a lower portion of the second wall **88**. The grey water flows along the first fluid passageway **28** in contact with the first thermal transfer surface **84**. A second fluid passageway **92** is in intimate contact with the second thermal transfer surface **90**. The second fluid passageway **92** is a capillary which carries the second fluid. The walls **86**, **88** are generally constructed from thin sheet thermally conductive material such as, for example, aluminium, gold, copper or alloys thereof. Additionally, the second wall **88** is sandwiched between the capillary fluid passageway **92** and can allow venting to the atmosphere via an interstitial gap between the first and second walls **86**, **88** in the event that the integrity of the walls **86**, **88** are compromised. It should be noted that although a double wall arrangement is illustrated, a single wall arrangement is also contemplated, such that the capillary lies in intimate contact with the second thermal transfer surface of the single wall. The channel member **78** is mounted on a support **94** that includes a number of complementary posts **96** which extend into the space between adjacent peaks. As described above for the heat exchange apparatus **10**, the grey water flows along the first fluid passageway it exchanges thermal energy with the cold water flowing along the second fluid passageway. However, in this case the hollow design of the fin members **79** allows heat exchange across a thin (typically from about 1/1000 inch to about 1/5 inch thickness) wall arrangement, such that thermal energy transfer occurs along a significantly shorter pathway between the thermal transfer surfaces when compared to thermal transfer across solid fins as described above. The thin walls of the heat exchanger **76** improve performance. Various stiffeners such as, for example, surface adhesion, interlocking geometries, external supports, fasteners, internal ribs and chambers, as well as turbulators or combinations thereof, are used to allow the use of thin walls. Water hammer protection (not shown) can be built into the soft zones of the support **94** or the posts **96**. Additionally, turbulators (surface or insertable) may be used with either of the first and second fluid passageways.

[0132] As best illustrated in FIG. **8**, instead of having a capillary fluid passageway **92** for the second fluid, the second fluid may flow against the lower portion of the second wall **88** with the addition of turbulators **98** to provide forced convection by shearing of the second fluid at it travels in intimate contact with the second thermal transfer surface. It is also possible to have similar turbulators **98** on the first thermal transfer surface, but this may compromise the flow of the grey water. An additional advantage of having turbulators **98** replacing posts **96** is increased strengthening of the channel member. Owing to the thinness of the walls of the hollow fin members, strengthening members such as the turbulators **98** may be necessary to maintain the structural integrity of the channel member. Grey water flowing along the channel member **78** fills the troughs **82** to near the top of the peaks **80**. Thermal energy is transferred across the first thermal transfer surface **84** to the second thermal transfer surface **90** via the first and second walls **86**, **88** and to the cold water flowing in the second fluid passageway **92**.

[0133] Referring now to FIGS. **9**A and **9**B, typically, grey water exiting the drain trap **26** of the shower or bath tub enters a cylindrical 2-inch drain pipe **70** and defines a surface areas of approximately 0.85 in^2 at a flow rate of approximately 10 L/minute. A volume of the grey water in the pipe **70** normally never contacts the sidewall of the pipe **70** and if thermal energy is to be recaptured by heat exchange across the sidewall, its transfer will be largely inefficient. Advantageously, using the channel members **30** and **78** described above, the grey water **8** flows along the first fluid passageway **36** at the same flow rate as with the pipe **70**, but does so over the length of the channels by contacting the heat conductive peaks **42** and troughs **44**. Thus, the distribution of the 0.85 in^2 area into multiple smaller area sections maximizes the heat transfer from the grey water by maximizing heat exchange contact area surfaces.

[0134] Referring now to FIGS. **10**, **11**, **12**A and **12**B, in which an alternative embodiment of a heat exchange apparatus is illustrated generally at **100**. The apparatus **100** comprises a circumferentially disposed channel member **102**, two end manifolds **104**, **106**, optional turbulators **108**, and an outer sleeve **109**. The channel member **102** includes a plurality of hollow fin members **110** and a capillary cold water passageway **112**, which lies in intimate contact with the second thermal transfer surface. A cold water inlet **114** feeds cold water into the capillary **112** and warmed water exits the capillary at an outlet **116**. Grey water flows into the apparatus **100** via the manifold **104** and flows over the first thermal transfer surface of the channel member **102**. The turbulators **108** not only disrupt the flow of the grey water and create forced convention, but they also maintain the structural integrity of the hollow fin members **110**. The turbulators can be surface turbulators or insertable turbulators. Water hammer protection (not shown) can be built into the soft zones of the turbulators **108**. A one-piece capillary insert **111**, as illustrated in FIGS. **12**A and **12**B, may be inserted into the outer sleeve **109**. The one-piece insert **111** includes the channel member **102** as described above. The turbulators **108** can also be inserted into the insert **111** to further enhance thermal transfer as well as enhance the structural integrity of the apparatus. The centrally disposed turbulator **108** can be used in a configuration where the shaft of the element **108** is used to fasten and tighten the manifolds **104**, **106**.

[0135] Referring now to FIG. **13**, an alternative embodiment of a heat exchange apparatus of the present invention is shown generally at **200**. Broadly speaking, the heat exchange apparatus **200** comprises a cold water fluid passageway **202**, which has an optional fluid passageway sidewall **204** in double wall configurations that is made of a membraneous material, which is pliable, yet resilient. The material can be made from pliable sheet material, such as, for example, but not limited to, gold, copper, or aluminium. The material includes at least one heat conductive surface **206** which is located in intimate contact with a portion of a sidewall **208** of a grey water conduit **210**. The conduit **210** has an inlet **212** and an outlet **214**. The grey water enters the inlet **212** at a first temperature T**1** and exits the outlet **214** at a second temperature T**2**. In this embodiment, the fluid passageway sidewall **204** is spreadable over an area of the conduit sidewall **208**. The membrane may be a single sheet of pliable material or it may be part of a bladder that is made of the same pliable material. The fluid passageway **202** may be defined by the use of an inwardly directed force from an external shell **218** that is located adjacent the sidewall **204**. In the example illustrated, the shell **218** surrounds the conduit **210** and the sidewall **204**. It is also contemplated that only a half shell located adjacent a lower portion of the conduit could be used. The shell **218** includes a plurality of inwardly directed projections **220**, which when pressed against the membrane or bladder defines the fluid passageway **202**, and act as turbulators. The fluid passageway includes a fluid passageway inlet **221** and a fluid passageway outlet **223**. The second fluid (cold water) enters the fluid passageway inlet **221** at a third temperature and exits the fluid passageway outlet **223** at a fourth temperature. Examples of shells include, but are not limited to, clam-shells or blister packs. The pre-defined designs of the projections **220** can be used to imprint a complementary design onto the membrane or bladder thereby define a fluid passageway having an identical design as the clamshell or blister pack. In single wall configurations, the bladder or the blister packs are omitted, and the passageway **202** is defined directly by the shell **218**.

[0136] Referring to FIG. **14**, an example of a blister pack type of shell **222** is shown located adjacent a heat conductive sidewall **224** of a grey water conduit **225**. The blister pack **222** includes a thermal transfer surface **226** which lies in intimate contact with the conduit **225**. Although the example illustrated shows a grey water conduits it is to be understood that this is an optional feature and that the grey water may flow in direct contact with the thermal transfer surface **226**. A plurality of spaces **228** between adjacent blisters **230** serves as the second fluid passageway for cold water to flow therealong. One or more of the spaces **228** may also comprise turbulators. The blister pack and clam shells can be positioned so that metallic surfaces in contact with the grey water conduit effectively extend with fin-like patterns into the cold water passageway.

[0137] Referring now to FIGS. **15**A and **15**B, the heat exchange apparatus **200** and the blister pack **222** can be located around a grey water conduit. In the examples illustrated, the conduit includes inwardly projecting square-shaped fins **232** and an outer shell **234**, which provides support for the components of the heat exchange apparatus. In one example, the bladder **204** lies snug against the outer wall of the conduit. In another example, the blister pack **222** lies in intimate contact with the sidewall **224**. The blister pack **222** also defines the second fluid passageway. A drain hole **236** is located in the shell **234** to provide venting of the first and second fluid passageways away from the apparatus should either of the blister pack or the bladder rupture.

[0138] Referring now to FIG. **16**, an embodiment of a heat exchange apparatus is shown generally illustrated at **300** in cross sectional view. This heat exchange apparatus **300** comprises a conduit **302** with an arcuate conduit member **304** and a fluid passageway **306**. The conduit **302** has first and second ends **308**, **310**, and an arcuate heat exchange plate **312**. The arcuate heat exchange plate **312** has first and second connecting portions **313**, **314** that are sealingly connected to the respective first and second ends **308**, **310** of the conduit **302**. The heat exchange plate **312** has first and second thermal transfer surfaces **316**, **318**. An amount of grey water enters the conduit **302** at a first temperature and contacts the first thermal transfer surface **316** and exits the conduit **302** at a second temperature. Generally speaking, this embodiment is useful for grey water that covers the arcuate heat exchange plate **312** and reaches a depth of several millimeters in the conduit **302**. A fluid passageway **320** similar to the one described for the heat exchange apparatus **200** above can be used with this embodiment. In this example, the fluid passageway **320** is in the form of a bladder and is located in intimate contact with the second thermal transfer surface **318** of the heat exchange plate **312**. A cap **322**, which is comparable to the shell described above, may be located snug against the bladder so as to form the fluid passageway **320**. A drain hole **324** is located in the cap **322** to drain water away to atmosphere in case the integrity of the bladder or the conduit **302** is compromised. The ability to vent cold or grey water is a requirement for certain plumbing standards to prevent mixing of cold water with waste drain water.

[0139] Referring now to FIGS. **17**A, **17**B, **18**A and **18**B, a household shower system is shown generally at **400** and includes a P-Trap **402**. P-Traps are know to those skilled in the art. The heat exchange apparatus **300** as described above, would be ideally suited for use with any part of the P-Trap such that the heat conductive surface of the heat exchange apparatus could be located in intimate contact with a sidewall of the P-trap **402**. Furthermore, any part of the P-trap could be modified to include the heat exchange apparatus **300**, as described above. In this case, the grey water exiting the P-Trap would contact and flow along and against the heat exchanger plate **312**. Similarly, the heat exchange apparatus **10** and **76** could be used in place of downstream portions of the P-trap. The heat exchangers as described above and below may optionally include a check valve **403**. The check valve **403** is of the type known to those skilled in the art. In the event of either a plumbing system failure or maintenance, simultaneous to a grey water channel wall failure of the heat exchanger, the check valve **403** will replace or supplement the double wall membrane of the heat exchanger to protect the water supply circuit of the building where the installation is located.

[0140] As best illustrated in FIGS. **19**A, **19**B, **20**A, **20**B and **21**, an alternative embodiment of a heat exchange apparatus is illustrated generally at **500**. The heat exchange apparatus **500** comprises a one piece insert **502** similar to the one piece insert **111** described above. In this embodiment, however, the insert **502** includes a multiple circuit **504** with a circumferentially disposed channel member **506** located inside a shell **508**. The shell **508** is larger than the radius of the insert **502** and defines a void **510**. The void **510** may be filled with an insulating media such as air or some other suitable insulating material. The void **510** may also contain a fluid to which the insert **502** can exchange thermal energy. The channel member **506** includes hollow capillary fin members **512**, each adjacent fin member **512** having located therebetween a post **514**. The insert **502** may include longitudinally disposed perforations **516**, which expose the fin members **512** to fluid circulating within the shell **508**. The shell **508** protects and structurally reinforces the fin members **512** either by mechanical contact or by additional components such as turbulator **526** located between the insert **502** and the shell **508**. Two end caps **520** are located at either end of the insert **502** and seal the insert **502**, the fin members **512** and the void **510** in the shell **508**. Tubing **522** and **524** carry the grey water and cold water via manifolds (not shown) into and out of the heat exchange apparatus **500**. It is to be noted that either of the tubes **522** and **524** can be individually connected in series or in parallel into one of the multiple circuits **504** as well as in contra flow or parallel directions so as to obtain the desired contra flow or parallel flow thermal performance characteristics of the heat exchange apparatus **500**. Additional turbulators **526**, as described above, are located between the insert **502** and the shell **508**. The turbulators **526** create turbulence in all fluid passing through the void **510** and promote heat exchange on the fin members **512** through the perforations **516**. Furthermore, the turbulators **526** also provide additional stiffening to the heat exchange apparatus **500**.

[0141] As best illustrated in FIGS. **20**A and **20**B, a plurality of inserts **502** may be grouped together into a larger heat exchange apparatus **528**. This heat exchange apparatus **528** is typically used when high volume, high flow and high performance is required such as for example in industrial applications. Typically, for these applications rapid heating and cooling is necessary for technical reasons, whether in grey water, pharmaceutical processes, steam generation applications, food sterilization, or cleaning applications such as in farming. Using the apparatus **528**, rapid and precise heat transfer from one fluid to another is achieved. The apparatus **528** can be assembled with bundles of the inserts **502**, which are enclosed in sealed and pressurized vessels **530**. The vessels **530** include the multiple inserts **502** as well as multiple turbulators **526**. Fluid enters the void **510** via inlets **532** and exits via outlets **534**. The combination of series and parallel connections of the grey water and cold water inlets and outlets of the fluid circuits provides improved heat exchange performance in a variety of circuit combinations and connections.

[0142] Built-in options may be included within any of the heat exchange apparatuses described herein in order to increase overall system performance and durability. These options include thin wall elements; laminar flow disruptor elements; check valve systems; one or more external level indicators; anti scaling capabilities such as, for example, mechanical devices and passage configurations to reduce scaling, anti-scaling coatings, vibration, chemical, and electrical means; anti corrosion means such as, for example, electrical, chemical, anodic, cathodic, and coatings; and water hammer protection such as, for example, shock absorbers, flexible or relatively soft and elastic cold water circuit components. Additional features may include use of an insulating shell on the systems and subsystems. System leaks and malfunctions can be detected in a variety of ways using, for example, relative flow measurement and/or pressure transducers and gauges located at strategic points in the heat exchange apparatus. Extrudable capillary fin geometry, as well as flow disruptors and other structural elements can be made of glass or Pyrex. The heat exchangers may be self draining in both horizontal and vertical positions. Individual heat exchanger modules or cylinders or heat exchanger bundles can be positioned at the top or at the bottom of larger vessels, such as with the vessels **530** described above, depending on heat exchange requirements in a given application. If electric power is required for monitoring or control equipment, power sources such as batteries, thermoelectric, or micro-turbines can be advantageously used in combination or alone.

[0143] Referring to FIGS. **21**A, **21**B, **21**C and **22**A, an alternative design of a heat exchange apparatus is shown generally at **600**. The apparatus **600** can be used in shower applications and can advantageously be packaged into an enclosure of modest dimensions, and easily inserted as a component of existing or new plumbing systems, with or without a check valve (not shown). The apparatus **600** comprises a tray **602**, a grey water area cover **604** and a channel member **606**. Two end plates **608** each include a grey water opening **610** are located at the ends of the channel member **606**. The channel member **606** includes an angled entry portion **612** and an angled exit portion **614**. The angled portions **612** and **614** are angled inwardly away from the end plates **608**. Cold water is communicated into and out of the apparatus via cold water connectors **616** and flows along a cold water passageway **618**. As it is generally the case with the other Heat Exchanger embodiments described above, grey water area cover **604** may optionally include internal auger guiderails (not shown) to allow the passage of a plumber's drain observation and cleaning tools inserted into either of the two grey water openings **610**, without interfering with the flow of grey water along the channel member **606**. The tray **602** includes cavities **620** and entry and exit manifolds **622**. Cold water turbulators (not shown) may be located in the cavities **620** and inside the cold water passageways **618** between the cold water entry and exit manifolds **622**. The tray **602** and the cover **604** may be combined into a single piece if desired. The turbulators increase the thermal performance of the system by creating turbulent flow within the cold water passageways **618**. As best illustrated in FIG. **21**C, when viewed in cross section, the channel member **606** comprises a heat exchange wall **624** of minimal thickness. The heat exchange wall **624** defines a plurality of troughs **626**, along which the grey water travels, and a corresponding plurality of square topped peaks **628**. Located adjacent the heat exchange wall **624** is the cold water passageway **618**. The heat exchange wall **624** corresponds to the distance traveled by the heat from each of the troughs **626** to each of the cold water passageways **618**. This capillary configuration provides exceptional heat exchange performance between the troughs **626** and the cold water passageway **618**. The very small thickness of the capillary heat exchange wall **624**, combined with very large heat exchange surfaces can be achieved using specific geometries and high strength materials such as, for example, stainless steel, copper, gold, and the like, to form hollow fin members, leading to higher thermal performance than those obtained when solid material are used. It is well known in the art that thermal performance in relatively low temperature cases, such as with the heat exchange apparatuses described herein, thermal energy transfer performance depends on the following factors: heat exchange area, physical material properties (heat transfer rate), material thickness, flow turbulence (convection) in each fluid, and thermal gradient present between the two fluids. The heat exchange apparatus **600** advantageously uses a corrugated foil to form the thin heat exchange wall surface **624** with a large surface area. A stiffening surface **630** is attached to the lower end of the troughs **626** at fastening locations **632** using fastening means such as, for example, brazing, seam welding or spot welding. This allows the location of the channel member **606** into a vessel that can be pressurized at will, while maximizing heat exchange surfaces of the fin members.

[0144] Referring now to FIG. **22**B, the grey water passageway can enter the heat exchange apparatus at two distinct levels, as indicated by arrows **1** and **2** with respect to grey water channel planes **627**, **629**. Arrow **2** above the higher plane **629** advantageously promotes debris passage in the grey water channel, albeit at the expense of drainage system slope disruption when installed in existing drainage systems such as during renovations. Also, the exit of the apparatus can be done in two different configurations with respect to the plane **627**, the exit being either coplanar with the grey water channel or below, as illustrated by arrows **3** and **4**.

Blade-Type Heat Exchange Apparatus

[0145] It is to be noted that in the heat exchange apparatuses **10**, **76**, **100**, **200**, **300**, **500**, and **600** described above, the grey water was described as the "first fluid" and the cold water was described as the "second fluid". In the following embodiments, for ease of description of the heat exchangers, the cold water is now referred to as the "first fluid" and the grey water is now referred to as the "second fluid"

[0146] As best illustrated in FIG. **23**, we have now designed a so-called blade-type heat exchange apparatus, which comprises one or more hollow blade members **638**, each blade member having a first fluid (cold water) inlet **639** and a first fluid outlet **641** and a first fluid passageway **643** for a first fluid extending therebetween. The hollow blade members **638** are sized and shaped to be located in a second fluid passageway **645** for a second fluid (grey water). The blade members **638** are configured to enhance thermal energy transfer between the fluids as they flow along their respective passageways. The blade members **638** can be each manufactured from suitably formed thin sheet material, and spot or seam welded, or brazed and individually assembled. A plurality of hollow blade members **638** can be arranged substantially parallel to each other and assembled as a heat exchange apparatus in which the blade members **638** are connected together using fasteners **640**. Each blade member **638** can be removed, tested for quality and re-assembled in the heat exchange apparatus. Also included is a cold water manifold **622** having a plurality of slots **623**. The blade members **638** can also be assembled using mechanical components such as O-rings and gaskets, or they can be fastened by more permanent means, such as welding or brazing. In the latter case, the heat exchange apparatus can be made exclusively from welded or brazed thin sheet material, using well known high volume manufacturing techniques and quality control procedures in order to provide a high quality heat transfer and a durable system. Vents to the atmosphere may also be included in the assembly such as via an opening (not shown) adjacent to the manifolds **622**.

[0147] Referring now to FIGS. **24**A and **24**B, the hollow blade member **638** includes a plurality of projections **649** located either on an inner wall surface **641***a* or on an outer wall surface **645** or on both surfaces of the blade member **638**. The projections **649** can be located on a portion of the aforesaid surfaces or, as illustrated, can be located along the entire length of the outer surface **645** of the blade member **638**. The projections **649** can be any shape such as ridges, chevrons, pads, discrete nubbins and the like. Furthermore, the projections **649** may themselves comprise well defined surface roughness and additionally include microscopic projections extending therefrom. The projections **649** can be embossed on the surfaces **641***a* or **645**, or they may be added to a smooth surface of the blade member. Surface texture (roughness) increases the frictional forces acting between the fluid and the surface leading to higher turbulence. For household and industrial applications, the cold water passageway **643** of each blade member **638** typically operates under pressures of approximately 500-100 psi for a duration of about thirty years, therefore it is desirable to reinforce the blade members **638** to increase their lifespan. The projections **649** provide increased burst resistance to the passageways **643** by reinforcing and stiffening the blade members **638**. Furthermore, the reinforcement that the projections **649** provide allows the use of very thin walls, hence providing improved thermal exchange performance. Moreover, the projections **649** can be used to align the cold water passageways among themselves within the assembly, and with an outer shell **647**. Advantageously, the projections **649** control the fluid flow and enhance the thermal energy transfer between the grey water and the cold water by promoting and sustaining turbulent flow in the grey water or the cold water, or both, as they travel along their respective passageways. Additionally, the projections **649** enhance the thermal energy transfer between the grey water and the cold water by disrupting laminar flow and causing shear in the grey water, the cold water or both. The projections **649** can be incorporated to increase thermal performance, by modifying and controlling the flow of either or both fluids by a suitable configuration, while determining, aligning, and maintaining the geometry of the individual heat exchange blade members as well as the geometry of their assembly. Additionally, the projections **649** may be extended from the blades **638** into the top of the grey water passageway (not shown) to help guide the passage of plumbing tools traversing the heat exchanger during maintenance, repair, or inspection activity. Also, alignment and sealing mechanisms and devices either directly or indirectly involved with the thermal energy exchange of the heat exchange apparatus, may be used and are constructed of metallic or non-metallic materials. Various fastening systems such as welding, brazing, adhesion, cohesion, mechanical fasteners and seals and the like can be used to position, assemble and attach turbulator sub-system components into the heat exchange apparatus. An additional advantage of the projections **649** is that they provide cold water anti scaling action and grey water anti clogging action created through suitable cold water and grey water water speed and water direction management geometries, which in turn increases the useful life of the blade members and decrease maintenance needs.

[0148] As best illustrated in FIGS. **25**A and **25**B, the location of the projections **649** along the surfaces of the blade members **638** causes induction of flow patterns as shown by arrows **642**. The projections **649**, in this case, ridges, are orientated in such as manner that when cold water passes through the blade member **638** it is de-laminated as well as rotated as shown by the arrows **642** so as to generally induce shear and turbulent flow in the cold water passageway **643**. Similarly, in a contraflow configuration, rotation is also induced in the grey water channel by the same shaped projections **649**, as illustrated by arrows **644**, which enhances turbulent flow in the grey water. The ridges **649** can be stamped into or out of the flat surface of the blade **638** or they can be added as sub-systems as described above.

[0149] Referring now to FIG. **26**, an embodiment of a high pressure blade type heat exchange apparatus **800** is shown which comprises a bundle **801** of hollow blade members **802** formed and stamped from stainless steel sheet and welded and connected through a manifold to form the apparatus, which is then assembled inside a low pressure, atmospheric drain system envelope **803** through which grey water **804** flows by gravity. Each blade member **802** is made from a stainless steel sheet that is formed to obtain a hollow "flat" tubular shaped passageway where the general shape is other than cylindrical. Each blade member **802** includes a plurality of angled ridges **805** or other tubulators located on at least a portion of a blade surface, and/or as an alternative turbulators may be inserted inside the blade or positioned outside the blade as a discrete mechanical component.

[0150] Referring now to FIGS. **27**, **28**A and **28**B, it is possible to increase the performance of the blade type heat exchange apparatus described herein by using blade members, which are based on cylindrical, corrugated heat exchanger piping (also known as "club grips"). As illustrated, a number of designs of "club grips" are known in the art and have wall exchanger surface dimensions that are maximized by the surface patterns. The patterns provide internal and external helical or "threaded screw motion" of the fluids resulting in fluid rotation. However, club grips lack the ability to maximize fluid shear and fluid turbulence. As best illustrated in FIGS. **28**A and **28**B, our blade design is based on a flattened club grip and provides inwardly disposed projections **810**, which project into the cold water passageway **806**, and outwardly disposed projections **812**, which project outward, typically by stamping during the manufacturing process, from flat walls **814**, and which provides unexpectedly high chaotic blade passageway geometry, leading to high levels of shear and turbulence generated in the displaced fluids. Seam welds **816** are located along the length of the blade member **802**. Additional indentation shapes such as sharp bends and corrugations are also permissible, as are additional components (not shown) that can be welded onto either one or both sides of the originally flat and smooth heat exchanger walls (or by a combination of both) in order to delaminate and agitate the flow (i.e. induce shear and turbulence) of cold water flowing in the cold water passageway **806**, as well as grey water flowing outside the blade member **802** and in contact with the outer surface of the blade member **802**. It is to be noted that the chaotic helical cross flow motion of fluids is obtained in the pressurized fluid, such as the cold water flowing in the cold water passageway and also in the atmospheric fluid, such as the grey water flowing externally of the blade member **802**. It is to be noted that the helical "club grips", typically made from copper tubing, and other similar style "round" tubing may also be employed in the high pressure apparatus **800**, whether straight or with 90 degrees bent ends, in place of the "corrugated flat wall" stainless steel hollow blade members. Additionally, turbulators can be inserted into the blade members **802**.

[0151] It is known that greater thermal transfer performance and ease of manufacturing are obtained by using a thin formed sheet material in the manufacturing process of the heat exchanger components. Using thin wall stainless steel composite sheets of approximately 0.015" to 0.035" thicknesses in heat exchanger apparatuses provides low resistance to burst due to possible excessive high internal cold water pressure, such as those commonly used in household or industrial plumbing systems.

[0152] Referring now to FIGS. **28**B and **29**, an example of a stiffened geometrical heat exchange blade member, which includes fasteners **820** to maintain the structural integrity of the blade member. It is therefore useful to use geometries of wall stiffening corrugation as well as fasteners **820** where they can self reinforce the structure of the pressurized cold water passageway. The fasteners **820** may be rivets, adhesives, or seam welds **816**, as described above, as well as spot welds. In order to maximize thermal energy transfer as well as structural parameters, the internal projections **810** and the external projections **812** with respect to the originally flat blade surfaces **814** and multiple blades located together may intimately contact each other for added in a fastened confirmation structural stability. The blade members **802** can be manufactured by stamping, bending and crimping an originally flat metal sheet. This can be advantageous when compared to using relatively slow linear welding to produce the seam weld **816**. It is possible to use a combination of high speed edge crimping methods and tools to produce crimped areas **824** in the sheet **814**. Methods and tools, such as those used to produce canned goods in the food industry can be used, with the use of optional adhesives or sealants to ensure seal intergrity where required. One such particularly useful technique, when long and straight seams are fabricated, is named "Swage Roll", in which the assembly of two sheets of metal is done by using compression wheels that shape and form a sealed seam between the two sheet metal surfaces. Progressive dies are also used for even faster forming and sealing assembly of such parts.

Double Wall Construction

[0153] Cross-connection of plumbing devices is ruled by strict, but variable, local regulations, where grey water and fresh cold water are present within the same heat exchanger apparatus. Universally, a double wall design is preferred over any other protection means to prevent fresh water contamination by grey water in the event of system failure, such as if the heat exchanger wall is ruptured or pierced.

[0154] Referring now to FIGS. **30**A and **30**B, for single walled construction of a hollow blade member, that is, one without a lining such as a bladder, the external wall surfaces **840** and the internal wall surfaces **842** are the thermal transfer surfaces of the blade member and provide two work surfaces. For the double wall blade construction, four heat exchange "work" surfaces are available. In the double wall construction, as illustrated, the internal wall (bladder) **850** includes an inner thermal transfer surface **852** and an outer thermal transfer surface **854**, and the outer wall includes the internal wall surface **842** and the external wall surface **840**. An inter-surface space **856** is a void located between surfaces **842** and **854**. The space **856** creates the separation between the blade surfaces in the double wall configuration, and allows atmospheric venting via a vent **860**. The bladder **850** optionally includes a sealed wall overlap portion **862** located adjacent the vent **860**. The overlap portion **862** is sealed using a weld or adhesive. The bladder **850** further includes a cold water inlet **864** and a warmed water outlet **866**. The bladder **850** is constructed of a relatively flexible, possibly pre-crushed and later pressure expanded, micro-corrugated, folded, ribbed or patterned material, with a typical wall thickness of between 0.001 inch to 0.015 inch. A metallic material is preferred, but other wall compositions are contemplated. As best illustrated in FIG. **30**B, the double wall configuration includes macroscopic peaks (or ridges) **812** and a macroscopic recesses **810**. Microscopic textures **844***a* and **844***b* are located on respectively the external and internal surfaces **840** and **842**, and microscopic textures **845***a* and **845***b* are located respectively on the external and internal surfaces **854** and **852**. The microscopic textures provide additional surface turbulence to the fluids in motion.

[0155] The shell **802** of the blade assembly is essentially the same as in the single wall construction described above except for the fact that a plurality of atmospheric venting ports **860** are present in order to immediately evacuate any fluid penetrating into the defined inter-surface zone space **856**. Leaking fluid immediately evacuates to the atmosphere either by gravity or by water pressure, whichever is greater, and depending on the origin of the leak. Leaking fluid evacuation is, however, increased by the textures described above. The inner pressure of the cold water compresses the bladder **850** with great force against the pressure bearing surface of the external shell **802** to provide acceptable heat transfer rates between the grey water and cold water. A suitable thermal paste or porous filler material may be optionally used to fill the inter-surface zone space **856** to further enhance the thermal transfer rate.

[0156] Blade surface dimensions and shapes, areas and thicknesses, wall and surface compositions and the nature of the material used to construct the blades, as well as surface treatment, macroscopic and microscopic surface shape and texture, all determine the blade's ability to transfer heat and become non-adhesive, or self-cleaning. Additionally, non adhesion of dirt, soap, scum, hair and debris to all heat exchanger walls and surface features, can be controlled by fluid flow management by fluid velocity and surface turbulence control, as well as chemical anti-fouling and surfaces geometrical self-cleaning properties.

[0157] Referring again to FIGS. **25**A, **25**B, **30**A, **30**B and **31**A, blade wall surface geometry controls and generates both deep (macroscopic) and surface (microscopic) directional turbulence mechanisms in given fluid dynamic conditions, resulting in combined and mutually reinforced convection patterns **642**, **644**, and **858**, which enhance fluid-to-fluid heat transfer rate and performance. The increased heat transfer rate is obtained by the sum of a surface (or microscopic) fluid velocity caused by microscopic fluid surface textures **844***a*, **844***b*, **845***a* and **845***b*, which act as turbulators, on the heat exchanger walls as well as those turbulences created macroscopically as shown by the convention patterns **642**, **644**. The microscopic textures **844***a*, **844***b*, **845***a* and **845***b* are used to further delaminate the fluids circulating within the larger internal and external projections (ribs or ridges) **810**, **812**. A variety of microscopic and macroscopic shapes and textures are contemplated and may be combined to achieve maximum turbulence. Within the space **856**, the textures **844***a*, **844***b*, **845***a* and **845***b* are used to increase atmospheric venting efficiency, by providing an easier path to eventual leaks to the atmospheric vents **860**.

[0158] Referring again to FIG. **30**B, **31**A and now FIGS. **32**A and **32**B, different patterns and strategies can be used or combined on different sections of the blades as well as individual fins, as described above, to maximize heat transfer rates for the whole blade assembly. In one example, a "golf ball icosahedron" surface pattern **832** in a specific location, such as on the nose of the external surface **840** of the blade, can be used to greatly reduce the accumulation of material, such as hair, at this particularly critical location.

Blade Member Design Variations

[0159] It should be noted that the wall materials, shapes, thicknesses, widths and heights, surface textures and cross sections of the blade members and of their inner components do not need to be symmetrical, fixed or constant in any manner with respect to given geometrical axes of the assembly. For example, it is possible to use a blade with a large "front-end" and a slimmer "tail-end", in order to precisely control heat transfer surface dimensions and corresponding heat transfer rates between two fluids in cross-flow configurations. Variations where the effective cross section and the height and width of a blade or inter-blade spacing varies according to a mathematical function along the length of the blade or blade bundle assemblies are also contemplated to further enhance performance.

[0160] One of the advantages of the blade assembly is that whole assembly or even an individual blade can be removed for cleaning, inspection and maintenance and replaced if necessary. Moreover, the grey water can flow unfiltered along its passageway. Specialized cleaning tools such as wire brushes or enzyme or bacteria based solutions, as well as chemical cleaners, or combinations thereof can be periodically applied via the floor drain of the shower in order to dissolve any dirt accumulated over time on the heat exchanger grey water walls within the drainage system in order to maintain optimal said grey water flow characteristics and thermal transfer rates of the system, without affecting the environment or the drainage components in any significant matter. A strainer located at the grey water floor drain will also advantageously reduce debris entering the drain.

[0161] Referring now to FIGS. **33**, **34**, and **35**, a plurality of blade members **802** are illustrated for use in a blade-type heat exchanger **868**. The blade members **802** are located in a housing **870** in which a lower portion **874** of the housing **870** is optionally open to allow atmospheric venting in double wall configurations. The of the manifolds **622** are located substantially lower than the lower plane **627** of the grey water passageway and are also optionally open to allow atmospheric venting. The blade members **802** are located substantially parallel to each other with gaps **876** between each blade **802** which define a grey water passageway **847**. In the embodiment shown, each blade member **802** has first and second walls **853** and **855**, each with an inner thermal transfer surface **849** and an outer thermal transfer surface **851**. Each wall **853**, **855** includes a plurality of ridges and recesses **844**, **845** located thereon. As illustrated, the ridges and recesses **844**, **845** are disposed diagonally relative to a longitudinal axis **878** of the blade member **802** in one direction along the first wall **853** and disposed in opposite directions along the second wall **855** relative to the first wall. This arrangement of ridges and recessed defines a "criss-cross" pattern, when viewed from the side in which a central cross area **857** is a location where opposing ridge of opposing inner thermal transfer surfaces make contact. Although not illustrated, it is to be understood that similar ridges and recesses may also be located in the grey water passageway. This alternating pattern of ridges and recesses induces high levels of shear within the fluids leading to rapidly developing turbulent flow conditions in both the cold water and the grey water by causing cross flow near or at the central cross area **857**, and on the planes located in the centre of the fluid passageways.

[0162] When the ridges and recesses **844**, **845** are disposed diagonally, the relative "criss cross" configuration of the ridges on the walls of the blade members causes high levels of fluid shear, turbulence and cross flow within both the grey water and the cold water. However, it is to be understood that the ridges and recesses may be orientated at any angle relative to the longitudinal axis of the blade member, and may also interdigitate, or contact with each other at the central cross area, or they may be spaced apart from each other. In the example shown, the manifolds **622** for receiving the cold water are disposed generally orthogonal to the longitudinal axis **878** of the blade members and downwardly away from the longitudinal axis, as best shown in FIG. **33**. In this example, the housing **870** together with the plurality of blade members **802** can be located in a tray **879** through which the grey water is flowing or the blade members **802** can be manufactured as a unitary body with the tray located near the lower portion of the blade members **802**. The grey water passageway **847** dimensions will depend largely on the nature of the debris that is expected to be found in the grey water as it flows along the passageway **847** as well as on the fluid characteristics, such as volume, velocity and viscosity, expected in normal operating conditions also in order to optimize heat exchanger performance. A screen (not shown) can be used over the entrance to the grey water passageway **847** to prevent debris from entering the grey water passageway **847**. The screen can be located before the P-trap in a household shower/bath system. Moreover, the shape and location of each blade member **802** can be changed to allow passage of a variety of debris types and fluid hydrodynamic characteristics. Thus, the grey water flowing along its passageway **847** contacts the outer thermal surfaces of the plurality of blade members **802** such that turbulence is induced in the grey water, while simultaneously, turbulent cold water moving along the cold water passageway contacts the inner thermal surface thereby allowing for efficient thermal energy transfer across the walls of the blade members **802**.

[0163] Ridges can be evenly spaced and shaped (depth and 3D forms) or follow a pattern defined mathematically along the blade walls, to increase blade surfaces and generate turbulent flow for various grey water and cold water flow conditions, thereby maximizing heat transfer. Fluid shear inducing ridges may be located at the bottom of the grey water passageway **847**. Additionally, scale-type/shaped ridges can be used to create turbulent flow at the bottom of the grey water passageway **847**, with a reduced risk for clogging. The same scales structure may be useful for location on the periphery of vertical heat exchange embodiment, as described below.

[0164] In the example illustrated in FIG. **36**, a bottom tray **880** is designed to receive a plurality of the blade members **802** in a pre-defined grey water passageway **881**. In the example illustrated, the manifolds **622** are disposed upwardly away from the longitudinal axis **878** of the blade members **802**. This design aids the location of the blade members **802** into the tray **880**. This design is particularly well suited large laundry facilities such as those used in hospitals where a large of volume grey water is generated and flows in open channels when discarded at high temperatures. The heat exchangers of this design can be easily retrofitted into the existing plumbing and easily maintained and cleaned by lifting the blade member assemblies from the grey water passageway.

[0165] As best illustrated in FIGS. **373** to **40**, the scale of the design may be increased substantially to include a plurality of blade members **882** of larger dimensions, namely in increased height dimensions leading to a further theoretical increase in convective heat transfer performance. A housing **884** is designed to accommodate the larger blade members **882** and includes inlet and outlet grey water pipes **885**, **886** and inlet and outlet cold water pipes **888**, **890**. The housing **884** includes a removable upper portion **892**, which allows for easy access to the blade members **882**. Referring now to FIG. **39**, the larger dimension blade member **882** include a plurality of ridges and recesses **894**, which cover substantially the entire surface areas of each inner and outer sidewall of each blade member. For ease of illustration, only one outer sidewall is shown in FIG. **46**. As above, the criss-cross pattern of ridges (ribs) causes shear and turbulence in the flow of both the grey water and the cold water traveling along the internal and external portions of the blade. The pattern of ridges may include other previously mentioned shapes and may comprise combinations of them. The orientation of the grey water flow may be orthogonal to the flow if the cold water as is illustrated by the location of the grey water inlet and outlet pipes **885**, **886** in FIG. **40**. Additionally, a plurality of spot weld points **896** and/or seam welds **898** are located to fasten and seal each sidewall of the blade members together. If a double wall design is used, the welds can pass through the opening in the bladder, which is sealed around the punctured holes to maintain integrity of the double wall. Additional features of the larger blades **882** include a plurality of flow management disrupters **899** located along the edges of the blades **882**.

[0166] In the previously described examples of the blade-like heat exchange apparatus, the manifolds are disposed downwardly away from the longitudinal axis **878** of the blades to facilitate maintenance. This design is for use in household shower arrangements in which water typically drains at 10 litres/hour. For commercial applications, however, the manifolds may be disposed upwardly away from the longitudinal axis **878** of the blades. In larger applications, the larger blades are rigidified by welds and can also provide a double wall arrangement. The bladder is punctured and sealed around each structural weld. Moreover, if required, a section of the blade can be enlarged by adding additional sections of blade thereto. The additional blade sections can be embossed with flow disrupters. Alternatively, one can use a turbulator insert to induce flow turbulence inside the blades.

[0167] Referring now to FIGS. **41**, **42**, **43**, **44**A and **44**B, another example of a heat exchange apparatus is shown generally at **900** and is particularly useful, but not limited to applications when used in a vertical orientation, that is, the apparatus is disposed generally orthogonal to the ground. In this design, a housing **902** is generally tube-like and includes a central grey water conduit **904**, around which is disposed a cold water passageway **906** having an inlet **908** and an outlet **910**. The cold water passageway **906** includes a double "slinky" turbulator **912** which is modeled on the wire "slinky" children's toy, which efficiently generates shear forces within the fluid when the slinkies are arranged in a clockwise and counter clockwise configuration producing a criss cross pattern such as the one illustrated. Also, slinkies are highly flexible and will allow the heat exchange apparatus to be used in locations that require bending of the grey water and cold water passageways. One wire of the slinky **914** is coiled around the grey water passageway in clockwise orientation and the other wire **916** of the slinky is coiled in a counter clockwise orientation relative to the longitudinal axis of the grey water conduit **904**. As in a hollow blade **802**, **638** or **882** the "double helical" criss cross arrangement of the two slinky wires creates a turbulator and promotes high turbulence in the cold water flowing downwardly or upwardly such that the cold water is constantly sheared all within a single cavity located around the grey water passageway, such as that described for within the blade member **802**. Additionally, where each of the slinky wires **914**, **916** crosses each other, a cross area **911** is formed which is similar to the central cross area **857** described above for the ridges **844**. Cold water when following the path defined by the slinky wire **914** travels in one direction, and simultaneously when follows the path defined by the slinky wire **916** travels in an orthogonal direction, very high shear and turbulence is induced within the cold water passageway **906**. Since this highly turbulated cold water is trapped in the cavity between the housing **902** and the grey water conduit **904**, highly efficient heat exchange occurs between the optionally smooth thermal transfer surfaces of the conduit **904**. Again, the shearing effects is similar to the one that is caused by the criss cross surfaces of the design as described above. This heat exchange design advantageously allows the design of compact and pressure self supporting heat exchange apparatuses, which can be used either with the single wall configuration as described or with a bladder to provide the double wall capability. For increased heat exchange performance, a turbulator **108** can be located inside the grey water passageway **904**.

[0168] Referring now to FIGS. **45**A to **45**C, a mesh type turbulator **918** is shown in the heat exchanger. The mesh type turbulator **918** includes a plurality of criss crosses **911**, which are defined by a first plurality of clockwise helically orientated wires and a plurality of other helical wires disposed counterclockwise to the first plurality of wires. Although not illustrated, the mesh may also include a plurality of orthogonally orientated wires. The turbulator mesh can comprise of a variety or a combination of shear inducing short path turbulent flow inducing surfaces such as, but not limited to, perforation open cell porous medica, molded, composite, stacked, slit, interdigitated, semi-rigid and symmetrical, textured elements. As described above, turbulators may be inserted in the grey water passageway or also in the cold water passageway.

[0169] An alternative to the double helical wire criss cross turbulator is a double slinky wire criss cross turbulator which consists of an insertion of a single clockwise slinky wire into a counter-clockwise patterned corrugated tube (club grip) or even into an axial internal finned tube or any other criss cross generating wire pattern.

Compact Heat Exchangers

[0170] As best illustrated in FIGS. **46**A to **46**H, and **47**A and B and **51**, a compact heat exchange apparatus **1000** is a generally arcuate blade, where criss cross turbulator **1001** is located in a cold water passageway or could be imprinted on the surface of the blade as described above for the other embodiments. The criss cross turbulator **1001** includes a series of helically and diagonally disposed ribs **1006** and **1006**.

[0171] The suitably dimensioned blade can be located inside a tubular pipe **1002** for heat exchange of calibrated or known volumes of grey water and cold water. The heat exchange apparatus **1000** can also be located externally of the tubular pipe **1002**. In another example, the tubular pipe **1002** may be manufactured such that the arcuate heat exchange apparatus is integral with the pipe sidewall.

[0172] The arcuate blade heat exchanger apparatus **1000** can be used singly for applications in which a small volume of grey water is traveling along the pipe **1002** and located adjacent the area of the pipe where heat is to be exchanged. The arcuate design of the heat exchange apparatus means that multiple arcuate heat exchange apparatuses can be used to fully or partially encase the pipe **1002**. Two or three or more arcuate blade heat exchange apparatuses **1000** can be used to fully encase the pipe **1002**. Also, if the arcuate blades are located inside the pipe, the arcuate blades are typically constructed from metal with the turbulators **1001** located on one or both sides of the blade. If located outside the pipe, the blade is manufactured with metal on one side and the turbulators **1001** on one or both sides or inserted. Metal surfaces on both sides of the arcuate blade along with turbulators is a favoured construction for the blades.

[0173] Sections of the compact designs are particularly useful for drain pipe heat exchange applications where drains are installed in a position other than vertical relative to the ground, and where one side of the pipe carries the energy to be exchanged.

[0174] Although in the examples described above, hollow, planar blades and hollow arcuate blades have been described, it is to be understood that the blades can be of any three-dimensional shape, such as cylindrical, conical, triangular, disk-like, and the like. Moreover, we also contemplate that planar hollow blades having surface projections and recesses can be formed into a tube, the tube being optionally open along the longitudinal axis in order to be attached and clamped onto a central grey water drain.

[0175] Referring now to FIG. **46**, a control system **700** may be used to monitor or to control the function of any of the heat exchange apparatuses described herein. This is particularly useful if the heat exchange apparatus is to be imbedded in a wall or behind an inaccessible structure. Moreover, if multiple heat exchangers are being used throughout a building, the ability to monitor the functions such as the performance or the energy transfer of the individual heat exchangers is advantageous. Thus, the system **700** may include a unidirectional or a bi-directional data transmission and communication, data acquisition function. The physiochemical properties of the fluids flowing in the heat exchangers can be monitored by the control system **700** and any changes to such can be monitored and a user alerted if any deleterious changes occur. This is particularly useful in heat exchangers that are used in the food, pharmaceutical, farming and water treatment industries. The control system **700** is constructed and programmed, and can be a wireless system, as well as conventional wire assisted system or alternatively, a combination of both and individually embedded or externally integrated to one or more heat exchanger systems. The system **700** can be manually operated, or computer controlled using telemetric applications involving well-known standard process operation parameters measurement, analysis and data acquisition at strategic locations such as, but not limited to entry and exit points. Additional parameters that can be measured and monitored include fluid viscosities, fluid temperatures, fluid pH, fluid hardness, fluid ppm data, fluid mineral and chemical content, fluid lighting and imaging, fluid chromatography, fluid collection and sampling, fluid aeration, fluid velocity and flow rate, fluid pressure, fluid turbulence, heat exchanger sub-systems and overall system integrity and malfunction detection, heat exchanger system overall performance, heat exchanger instantaneous workload as well as efficiency computations. Additionally, rather than measuring within the fluid or acting upon the fluid, measurements and monitoring can be carried out within the system and sub-system components such as the heat exchanger walls, discrete system components, nozzles, sensors, actuators, fluid passageways, interstitial wall components, additional sub-systems. Fluid physical properties can be monitored, data acquisition can be made, and modifications to the heat exchange system operation can also be made. Such modifications include, but are not limited to, activation of sensors and actuators, as well as passive component temperatures, vacuum levels, pressure levels, vibration, moisture as well as other process related operating parameters related to the integrity and the performance of the heat exchanger system and other sub-systems. Manually operated, or computer controlled process control applications can include the operation and actuation of valves and sensors in order to modify working parameters of the heat exchanger system as well as actively or passively modifying the fluid physical properties. Also, the system **700** can maintain or optimize the operation of individual or remotely located heat exchange apparatuses in a larger heat exchange circuit by varying the individual workload or maintenance requirements over time, or by modifying the fluids for a subsequent process in terms of physical or chemical property requirement.

[0176] In addition to monitoring the heat exchange apparatuses, it is possible to use the system **700** to monitor and compute tariffs and fees based on heat exchanger workload and efficiency or other measurable physical workloads performed by the systems over time. Energy savings provided by the heat exchanger and peripheral systems can be evaluated, charged and billed to the user.

OTHER EMBODIMENTS

[0177] From the foregoing description, it will be apparent to one of ordinary skill in the art that variations and modifications may be made to the invention described herein to adapt it to various usages and conditions. Such embodiments are also within the scope of the present invention.

1. A heat exchange apparatus, the apparatus comprising:
a hollow blade member having a first fluid inlet and a first fluid outlet and a first fluid passageway for a first fluid extending therebetween, the blade member being sized and shaped for location in a second fluid passageway for a second fluid, the blade member being configured to enhance thermal energy transfer between the fluids as they flow along their respective passageways.

2. The apparatus, according to claim **1**, in which the enhancement of thermal energy transfer is caused by turbulent flow.

3. The apparatus, according to claim **1**, in which the enhancement of thermal transfer is caused by reduction of laminar flow.

4. The apparatus, according to claim **1**, in which the enhancement of thermal transfer is caused by shear within the first and second fluids.

5. The apparatus, according to claim **1**, in which the blade member has an inner and an outer thermal transfer surface, the inner thermal transfer surface having a plurality of spaced apart inner surface projections to induce thermal energy transfer in the first fluid, the outer thermal transfer surface being located to contact the second fluid flowing along the second fluid passageway.

6. The apparatus, according to claim **5**, in which the inner thermal transfer surface further includes a plurality of spaced apart inner surface recesses.

7. The apparatus, according to claim **5**, in which the outer thermal surface has a plurality of spaced apart outer surface projections located to induce thermal energy transfer in the second fluid as it flows along the second fluid passageway in contact with the outer thermal transfer surface.

8. The apparatus, according to claim **5**, in which the outer thermal transfer surface further includes a plurality of spaced apart outer surface recesses.

9. The apparatus, according to claim **5**, in which the inner and outer thermal transfer surfaces each have a plurality of spaced apart projections and recesses, the projections and recesses being disposed substantially parallel to each other.

10. The apparatus, according to claim **1**, in which the blade member has a longitudinal blade axis and two blade walls, each blade wall having an inner and an outer thermal transfer surface, each thermal transfer surface having a plurality of ridges and recesses disposed substantially parallel to each other.

11. The apparatus, according to claim **10**, in which the outer thermal transfer surfaces are located to contact the second fluid flowing along the second fluid passageway.

12. The apparatus, according to claim **10**, in which the ridges and recesses of the first blade wall being angled in a first direction relative to the longitudinal axis, the ridges and recesses of the second blade wall being angled in a second direction relative to the longitudinal axis, the second direction being different from the first direction so as to induce cross flow in the first and second fluids as they travel along their respective passageways.

13. The apparatus, according to claim **10**, in which the ridges located on opposing inner thermal transfer surfaces contact each other to induce cross flow in the first fluid as it travels along the first fluid passageway.

14. The apparatus, according to claim **10**, in which the ridges located on opposing inner thermal transfer surfaces are spaced apart from each other to induce cross flow in the first fluid as it travels along the first fluid passageway.

15. The apparatus, according to claim **10**, in which the ridges located on opposing inner thermal transfer surfaces are interdigitated to induce cross flow in the first fluid as it travels along the first fluid passageway.

16. The apparatus, according to claim **10**, in which the ridges located on opposing inner thermal transfer surfaces contact each other to induce turbulence in the first fluid as it travels along the first fluid passageway.

17. The apparatus, according to claim **10**, in which the ridges located on opposing inner thermal transfer surfaces are spaced apart from each other to induce turbulence in the first fluid as it travels along the first fluid passageway.

18. The apparatus, according to claim **10**, in which the ridges located on opposing inner thermal transfer surfaces are interdigitated to induce turbulence in the first fluid as it travels along the first fluid passageway.

19. The apparatus, according to claim **1**, in which the second fluid passageway is configured to induce thermal energy-transfer between the fluids.

20. The apparatus, according to claim **1**, in which the first and second fluids flow in a contraflow direction.

21. The apparatus, according to claim **1**, in which the first and second fluids flow in a parallel flow configuration.

22. The apparatus, according to claim **1**, in which the first and second fluids flow in a cross flow configuration.

23. The apparatus, according to claim **1**, in which each blade wall has a sealable blade edge to allow the blade member to be pressurized.

24. The apparatus, according to claim **23**, in which the blade member is pressurized to above atmospheric pressure or to below atmospheric pressure.

25. The apparatus, according to claim **1**, in which the blade member has a longitudinal blade axis, the first fluid inlet and the first fluid outlet being disposed orthogonal relative to the longitudinal blade axis.

26. The apparatus, according to claim **1**, in which the blade member has a longitudinal axis, the second fluid passageway has a second fluid inlet and a second fluid outlet, the second fluid inlet and the second fluid outlet being disposed coaxial to the longitudinal axis.

27. The apparatus, according to claim **26**, in which the second fluid inlet and the second fluid outlet are disposed orthogonal to the longitudinal axis of the blade member.

28. The apparatus, according to claim **1**, in which the blade member is double-walled.

29. The apparatus, according to claim **28**, in which the double wall is a lining located in intimate contact with an inner thermal transfer surface of the blade member.

30. The apparatus, according to claim **29**, in which the lining is spaced apart from the inner thermal transfer surface, a thermal transfer filler being located between the lining and the inner thermal transfer surface.

31. The apparatus, according to claim **29**, in which the lining is a bladder.

32. The apparatus, according to claim **31**, in which the bladder is made from a membraneous heat conductive material.

33. The apparatus, according to claim **1**, in which the blade member is ventable to the atmosphere.

34. The apparatus, according to claim **1**, in which the blade member further comprises a lining located in intimate contact with an inner thermal transfer surface of the blade member, the lining defining a double wall, the blade member being configured to allow the first fluid to drain away from the first passageway or the second fluid from the second fluid passageway, if either of the passageways breaks.

35. The apparatus, according to claim **1**, in which the first or second fluids flow by gravity.

36. The apparatus, according to claim **1**, in which a turbulator is located in the first fluid passageway.

37. The apparatus, according to claim **1**, in which a turbulator is located in the second fluid passageway.

38. The apparatus, according to claim **1**, in which the second fluid passageway is pressurized to above atmospheric pressure or below atmospheric pressure.

39. The apparatus, according to claim **1**, in which the first fluid is cold water and the second fluid is grey water.

40. A blade heat exchange apparatus, the apparatus comprising:

at least one blade member having a first fluid inlet and a first fluid outlet, and a first fluid passageway for a first fluid extending therebetween, the blade member having a longitudinal blade axis;

a second fluid passageway for a second fluid, the second fluid passageway being sized and shaped to receive therein the blade member;

the blade member has two blade walls, each blade wall having an inner and outer thermal transfer surface, the thermal transfer surfaces each having a plurality of spaced apart ridges and recesses, the ridges and recesses being substantially parallel to each other, the ridges and recesses of the first blade wall being angled in a first direction relative to the longitudinal axis, the ridges and recesses of the second blade wall being angled in a second direction relative to the longitudinal axis, the second direction being different from the first direction so as to induce cross flow in the first and second fluids as they travel along their respective passageways.

41. The heat exchange apparatus, according to claim **40**, the ridges located on the inner thermal transfer surfaces of the blade walls contact each other, are spaced apart from each other, or are interdigitated.

42. The heat exchange apparatus, according to claim **40**, in which the second fluid passageway is a channel located in a tray.

43. The heat exchange apparatus, according to claim **40**, in which a plurality of blade members are mounted substantially parallel to each other.

44. The heat exchange apparatus, according to claim **40**, in which a plurality of the blade members are stacked on top of each other and define a plate.

45. The heat exchange apparatus, according to claim **40**, in which a plurality of the plates are mounted in a housing, the housing having a first fluid inlet and a first fluid outlet.

46. The heat exchange apparatus, according to claim **40**, in which the blade member is double walled.

47. The heat exchange apparatus, according to claim **40**, in which the blade member is ventable to the atmosphere.

48. The heat exchange apparatus, according to claim **40**, is located downstream of a drain trap.

49. The heat exchange apparatus, according to claim **40**, in which the first fluid passageway includes a turbulator.

50. The heat exchange apparatus, according to claim **40**, in which the second fluid passageway includes a turbulator.

51. A heat exchange apparatus, comprising:

a central conduit having a conduit wall;

an outer jacket substantially encasing the central conduit, the jacket being spaced apart from the conduit wall to define an enclosure and having a fluid inlet and a fluid outlet;

a turbulator located in the enclosure, the turbulator having a first helical wire disposed in a clockwise orientation and a second helical wire disposed counterclockwise to the first helical wire so as to induce turbulent flow in a fluid as it contacts the turbulator.

52. The heat exchange apparatus, according to claim **51**, in which the first and second helical wires cross each other and induce cross flow in the fluid as it contacts the helical wires.

53. The heat exchange apparatus, according to claim **51**, in which grey water flows along the central conduit.

54. The heat exchange apparatus, according to claim **51**, in which cold water contacts the turbulator.

55. The heat exchange apparatus, according to claim **54**, in which the cold water flows by gravity.

56. A heat exchange apparatus, the apparatus comprising:

a central conduit having a conduit wall;

an outer jacket substantially encasing the central conduit, the jacket being spaced apart from the conduit wall to define an enclosure and having a fluid inlet and a fluid outlet;

a mesh turbulator located in the enclosure, the mesh turbulator being configured to induce turbulent flow in a fluid as it contacts the turbulator.

57. The apparatus, according to claim **56**, in which the mesh turbulator includes a first plurality of helical wires disposed in a clockwise orientation and a second plurality of helical wire disposed counterclockwise to the first plurality of helical wire.

58. The apparatus, according to claim **56**, in which the mesh turbulator includes a plurality of orthogonally disposed wires.

59. The apparatus, according to claim **56**, in which the central conduit and the enclosure further include turbulators.

60. A heat exchange apparatus, the apparatus comprising:

at least one hollow fin member having first and second thermal transfer surfaces, the first thermal transfer surface defining a first fluid passageway for a first fluid, which first fluid being flowable along the first passageway in contact with the first thermal transfer surface; and

a second fluid passageway for a second fluid, the second fluid passageway being located in intimate contact with the second thermal transfer-surface, such that the first fluid when flowing along the first fluid passageway exchanges thermal energy with the second fluid flowing along the second fluid passageway.

61. The apparatus, according to claim **60**, in which the fin members are disposed substantially parallel to each other.

62. The apparatus, according to claim **60**, further including a turbulator disposed on the first thermal surface to induce turbulent flow in the first fluid

63. The apparatus, according to claim **60**, further including a turbulator disposed on the second thermal surface to induce turbulanet flow in the second fluid.

64. The apparatus, according to claim **60**, in which the fin members are configured as an H-shaped channel member having first and second end portions, the first end portion being connectable to a source of a first fluid, the first fluid entering the first end portion at a first temperature and flowable along the first thermal transfer surface, the first fluid exiting the second end portion at a second temperature and a second fluid passageway having an inlet and an outlet, the second fluid passageway being located in intimate contact with the second thermal transfer surface, the inlet being connectable to a source of a second fluid, the second fluid entering the inlet at a third temperature and flowable along the second fluid passageway, such that the first fluid when flowing along the first fluid passageway exchanges thermal energy with the second fluid flowing along the second fluid passageway, the second fluid exiting the outlet at a fourth temperature.

65. The heat exchange apparatus, according to claim **60**, in which the fin members are circumferentially disposed about a conduit.

66. A heat exchange apparatus, the apparatus comprising:

a conduit having an arcuate conduit member having first and second ends, and an arcuate heat exchanger having first and second connecting portions sealingly connectable to the respective first and second ends, the heat exchange having first and second thermal transfer surfaces, an amount of a first fluid entering the conduit at a first temperature and being in contact with the first thermal transfer surface and exiting the conduit at a second temperature; and

a fluid passageway having a fluid passageway sidewall of a membraneous material, the material having at least one heat conductive surface locatable in intimate contact with the second thermal transfer surface, the fluid passageway sidewall being spreadable over an area of the second thermal transfer surface, the fluid passageway having a fluid passageway inlet and a fluid passageway outlet, a second fluid entering the fluid passageway inlet at a third temperature and exiting the fluid passageway outlet at a fourth temperature.

67. The apparatus, according to claim **1**, in which the blade member is self-supporting.

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