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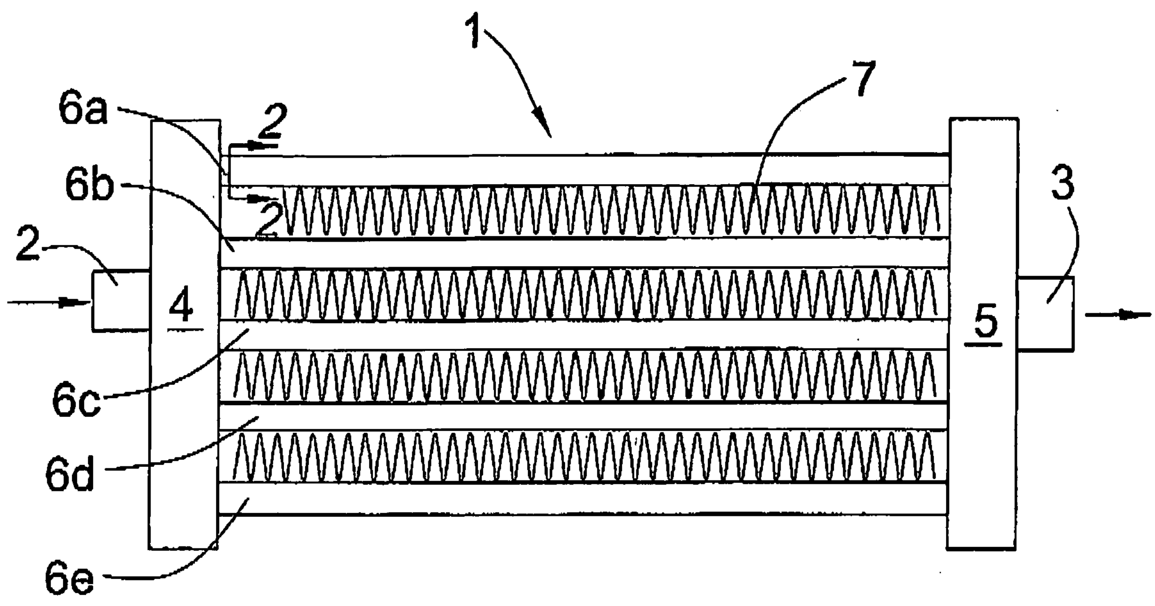
(54) **Heat exchanger**

(57) A heat exchanger comprising an inlet chamber (2), an outlet chamber (5), and a plurality of flat tubes (6a-6e) through which the fluid passes and is cooled by ambient air or coolant. The flat tubes (6a-6e) are formed by extrusion (10) and include internal fluid paths (11a-11i) to promote cooling of the fluid passing within. The fluid paths, which are formed at the same time as the tubes, may include flanges (16) to further promote the transfer of heat. Through the use of such extruded tubes with internal fluid paths, the need for a turbulator component commonly assembled into cooling tubes may be eliminated or minimized.

FIG. 1



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Description

[0001] The present invention relates to a heat exchanger in general, and the tubes used in a heat exchanger in particular. A heat exchanger including cooling tubes made according to the present invention is particularly advantageous in terms of ease of construction and manufacturing costs.

[0002] Oil-to-air coolers are widely used in motor vehicle applications to cool engine oil, transmission oil, power steering oil and hydraulic fluids. The cooler usually consists of bundles of tubes, fins and two manifolds. The oil flows inside the tubes while outside air passes through the fins. Due to the high viscosity of the oil, internal turbulators are often disposed within oil-cooling tubes to improve heat transfer. The turbulators are typically bonded to the internal walls of the oil-cooling tubes to allow heat flow from the turbulators to the tube walls.

[0003] The addition of turbulators to oil-cooling tubes, however, increases the cost and' complexity of the heat exchanger manufacturing process. Bonding turbulators with oil-cooling tubes adds a step to the process. In addition, if the turbulator-to-tube bond is not properly formed, the cooling capacity of the oil coolers will be diminished. Consequently, it is desirable to eliminate and/or simplify the construction of oil-cooling tubes, yet still have such tubes transfer heat at the same or an improved rate over known heat exchangers.

[0004] An example of a prior art approach to eliminating turbulators is set forth in U.S. Patent No. 5,036,911, the contents of which are hereby incorporated by reference. In the approach of this patent, an embossed plate replaces turbulators within the oil-cooling tubes. The plate includes uniformly spaced-apart mating projections, which, when brought together during the assembly process, create additional surface area to enhance the transfer of heat from the oil during operation of the heat exchanger. Although there is no turbulator component, the plate sizes are fixed, which makes assembly of different cooler sizes difficult. Also, there is a risk of two plates not properly bonding together, which could result in leaks and loss of heat transfer.

[0005] A need therefore exists for a more high-performance leak proof oil-coolers that do not include turbulators as a separate assembly. In addition, a need exists for a cost effective and automated means to manufacture such oil-coolers. The invention is generally directed to a heat exchanger for a motor vehicle, such as an oil-to-air heat exchanger, a charge air heat exchanger or an exhaust gas heat exchanger, which heat exchanger includes internal cooling tubes formed by extruding a suitable material, such as aluminum, steel, or stainless steel. The cooling tubes include a plurality of fluid paths, which are also extruded as part of the tube-forming process. The transverse cross-section of the fluid paths is typically rectangular. The walls of the fluid paths may be smooth or, alternatively, contain flanges, ribs or teeth to improve heat transfer.

[0006] All of the fluid paths within a particular tube may be identical. As an alternative, a tube may contain a plurality of fluid paths, certain of which differ in cross-section from others. The one-piece extruded cooling tubes are assembled into a heat exchanger, either with other similarly extruded tubes or with cooling tubes of a more conventional design.

[0007] Further objects, features and advantages of the invention, will become apparent from the detailed description of the preferred embodiments that follows, when considered in conjunction with the attached figures of drawing.

[0008] Exemplary embodiments of the invention are given below with reference to the drawing, in which:

FIG. 1 is a drawing that schematically illustrates a heat exchanger;

FIG. 2 is a transverse cross-sectional view of a prior art tube taken along the line *2-2* in Fig. 1;

FIG. 3 is a transverse cross-sectional view of an extruded tube according to one embodiment of the invention;

FIG. 4 is a transverse cross-sectional view of an extruded tube according to another embodiment of the invention;

FIG. 5 is a transverse cross-sectional view of yet another possible variant of a tube made according to the invention;

FIG. 6 is a drawing that schematically illustrates a heat exchanger that includes a combination of different types of cooling tubes; and

FIG. 7 is a drawing that schematically illustrates a heat exchanger that includes two separate coolant loops.

[0009] A heat exchanger, such as that schematically illustrated in FIG. 1, typically includes an inlet manifold **2,** an outlet manifold **5,** a plurality of flat cooling tubes **6a-6e** disposed between the inlet and the outlet, and air-cooled fins **7** disposed between the rows of the cooling tubes. Although the type of heat exchanger illustrated in FIG. 1 is a direct heat exchanger, i.e., air is forced or drawn across fluid containing tubes, the invention may be used with other types of heat exchangers known to persons of skill in the art. The invention may be applied, for example, to indirect heat exchangers in which cooling tubes are cooled by a liquid coolant, such as water, that is separately cooled by yet another air exchanger.

[0010] During operation of a motor vehicle, a pump forces fluid from the inlet **2** of heat exchanger **1,** through the plurality of cooling tubes 6a-6e, and into the heat exchanger outlet **3.** Outside air (or coolant) is forced or drawn across fins **7,** which are in contact with cooling tubes **6a-6e.** Heat from the fluid passing through the exchanger is transferred to the air passing across fins **7** and, ultimately, out and away from the motor vehicle. The arrows near inlet **2** and outlet **3** illustrate the direction of fluid flow within heat exchanger **1.**

[0011] FIG. 2 illustrates a transverse cross-section of a common prior art oil-cooling tube **6a** taken along section *2-2* of FIG. 1. In this prior art structure, tube **6a** includes a turbulator **8,** which promotes heat transfer within the tube for the relatively low viscosity oil. The turbulator is a separate component that must be properly bonded to the tube **6a.** The ends of tube **6a** are assembled to the inlet and outlet manifolds in a manner known to persons of skill in the art.

[0012] The cooling tubes of one embodiment of the invention differs from the prior art as illustrated in the transverse cross-section of FIG. 3. A flat cooling tube 10 is formed through an extrusion process and includes a plurality of fluid-flow paths **11a-11i**, which are also formed during extrusion of the tube. Each flow path typically has a rectangular cross-section as illustrated, but persons of skill in the art will appreciate other shapes that may be used, such as rounded or oval shapes. The separate flow paths within each tube eliminate the need for a turbulator component, thereby resulting in a one-piece tube that is simple to manufacture and assemble into a heat exchanger. A one-piece tube also reduces the risk of fluid leaking from the tube due to an improper assembly. In addition, cooling tubes formed through extrusion may be cut to an appropriate length for a variety of sizes of heat exchangers, thereby allowing maximum flexibility during the manufacturing and assembly processes.

[0013] Tubes, such as cooling tube 10, are assembled to the inlet and outlet manifolds of a heat exchanger in a manner known to persons of skill in the art. For example, tube **10** may be assembled to an inlet and outlet manifold through a Nocolock controlled-atmosphere brazing process. Tube **10** is preferably formed from metal. In highly preferred embodiments, tube **10** may be extruded from any suitable metal, such as aluminum, steel or stainless steel.

[0014] Tube **10** includes a major axis, indicated by the "H" dimension, and a minor axis, indicated by the "W" dimension. It has been empirically determined that the preferred range of the external cross-sectional area for an extruded one-piece oil cooler tube, which is calculated as the product of H and W, should be between 45 and 160 mm^2 for automotive applications. If the cross-sectional area is above 160 mm^2, the heat transfer per volume of oil flow will not be sufficient. If the cross-sectional area is below 45 mm^2, the internal oil pressure drop will be too high, which, in turn, will result in insufficient oil flow. In addition, it has been determined that the preferred hydraulic diameter of the tube, which is defined as four times the internal area of the tube divided by wetted perimeter, should be between 1.2 mm to 3.5 mm.

[0015] FIG. 4 illustrates an alternative embodiment of the invention. The extruded tube **12** still includes a plurality of extruded fluid paths **13a-13e.** The number of such fluid paths, however, have been reduced in comparison with the embodiment of FIG. 3. In addition, the smooth-walled fluid paths **11a-11i** of the embodiment of FIG. 3 have been replaced with fluid paths **13a-13e** that have "teeth" or flanges **16** formed, by extrusion, into the side walls. The flanges **16** may be identically-patterned on all sides of the fluid path, or, as shown in FIG. 3, may include a first pattern **16** along a wall or walls and a second pattern **17** along a different wall or walls. Protrusions, such as flanges **16** and **17,** into the fluid paths **13a-13e** promote the additional transfer of heat.

[0016] The number of fluid paths within an extruded tube, such as fluid paths **11a-11i** or **13a-13e,** may be selected to obtain the desired pressure drop and/or amount of heat transfer for a particular application. In addition, the fluid paths within a particular tube may differ from one another. FIG. 5 illustrates an example embodiment in which different types of fluid paths are incorporated into a single tube. Fluid path **15a** includes flanges **16** and **17,** whereas fluid path **15b** is smooth-walled. In addition, fluid path **15c** includes flanges of one type **17** along two walls, whereas fluid path **15d** includes flanges of a different type 16 along a different wall.

[0017] The dimensions of the flanges, teeth or other protrusions are selected to optimize the heat transfer characteristics of the heat exchanger. In a preferred embodiment, such protrusions have a feature size that relates to the size of the fluid path. The dimension of flanges **16** along the "W" axis, for example, is preferably between 10-30% of the opening of the fluid path along the same axis.

[0018] The dimension of these same flanges along the "H" axis, as another example, is preferably between 50-75% of the opening of the fluid path along the same axis, with individual flanges having dimensions ranging between 6-15% of the opening. Flanges **17** will have similar general dimensions, but such dimensions will be transposed along the "W" and "H" axes when compared with flanges **16.**

[0019] The number and types of fluid paths described above and in FIGS. 3-5 may be varied according to the desired performance characteristics of the heat exchanger. In addition, as illustrated in FIG. 6, a heat exchanger may be assembled with different types of tubes. A first type of cooling tube, such as prior art tube **6a** with a turbulator component **8,** may be assembled along with a second type of cooling tube, such as extruded metal tube **10,** and a third type of cooling tube, such as extruded metal tube 12. Metal tubes **10** and **12** may be extruded from any suitable metal, such as aluminum, steel or stainless steel.

[0020] Additionally, because of superior heat transfer characteristics, the tubes made according to the invention also can be used for cooling applications such as hybrid vehicle electronics. Usually such electronics are cooled by a separate coolant loop due to their relatively lower temperature operating characteristics (below 70C). Due to limited pump power in this second loop, however, the coolant flow is relatively lower when compared with the main radiator. Prior art radiator tubes, such as those illustrated in Fig. 2, are not well suited for this kind of application because there is not sufficient internal surface within such tubes to transfer heat. Tubes made according to the invention, as describe above, typically will have more surface area to transfer heat. FIG. 7 illustrates an exemplary arrangement of tubes within a combination heat exchanger that includes a first coolant loop or circuit for fluid cooling, schematically indicated by a first inlet manifold **4** and a first outlet manifold **5** and first bundle of tubes **10a-10c,** and a second coolant loop or circuit for coolant cooling, schematically indicated schematically indicated by a second inlet manifold **20** and a second outlet manifold **21** and second bundle of tubes **10d-10e.** In this arrangement, the first bundle of tubes **10a-10c** is of the same type as the second bundle of tubes **10d-10e.** The benefit of such an arrangement is that a single tube type can be disposed within a single heat exchanger, but between separate inlet and outlet chambers for different cooling applications.

[0021] While this invention has been described with an emphasis upon particular embodiments, it should be understood that the foregoing description has been limited to the presently contemplated best modes for practicing the invention. For example, the precise form of the flat tubes may be modified in accordance with the invention. It will be apparent that further modifications may be made to the invention, and that some or all of the advantages of the invention may be obtained. Also, the invention is not intended to require each of the abovedescribed features and aspects or combinations thereof. In many instances, certain features and aspects are not essential for practicing other features and aspects. The invention should only be limited by the appended claims and equivalents thereof, since the claims are intended to cover other variations and modifications even though not within their literal scope.

Claims

1. An heat exchanger for use in a motor vehicle, the heat exchanger comprising a inlet chamber, an outlet chamber, a plurality of extruded metal flat tubes arranged in rows and connected between the inlet and outlet chambers, a plurality of fins disposed between the rows of tubes, and wherein each of the tubes includes a plurality of extruded fluid paths.

2. The heat exchanger of claim 1, wherein the flat tubes are oil cooling tubes.

3. The heat exchanger of claim 1, wherein the flat tubes are charge air cooling tubes.

4. The heat exchanger of claim 1, wherein the flat tubes are exhaust gas tubes.

5. The heat exchanger of claim 1, wherein the flat tubes are aluminum.

6. The heat exchanger of claim 1, wherein the transverse cross-section of each extruded fluid path within a tube is identical.

7. The heat exchanger of claim 1, wherein the transverse cross-section of at least one of the extruded fluid paths within a tube is different than the transverse cross-section of at least one of the other extruded fluid paths.

8. The heat exchanger of claim 1, wherein the transverse cross-section of at least one of the extruded fluid paths is rectangular.

9. The heat exchanger of claim 8, wherein the transverse cross-section of at least one of the extruded fluid paths includes a plurality of flanges along at least one side.

10. The heat exchanger of claim 9, wherein the transverse cross-section of at least one of the extruded fluid paths includes a plurality of flanges along a first side and a plurality of flanges along a second side.

11. The heat exchanger of claim 10, wherein the plurality of flanges along the first side have the identical pattern to the plurality of flanges along the second side.

12. The heat exchanger of claim 8, wherein the transverse cross-section of at least one of the extruded fluid paths includes a plurality of flanges along four sides.

13. The heat exchanger of claim 9, wherein the dimension of the flanges along a first axis is in the range of about 10 percent to about 30 percent of the dimension of the at least one fluid path along the first axis.

14. The heat exchanger of claim 9, wherein the dimension of the flanges along a second axis is in the range of about 50 percent to about 75 percent of the dimension of the at least one fluid path along the second axis.

15. The oil-to-air heat exchanger of claim 1, wherein the transverse cross-section of at least one of the extruded aluminum fluid paths is oval.

16. A heat exchanger for transferring heat, the heat exchanger comprising: a fluid inlet, a fluid outlet and a plurality of fluid flow paths extending between the fluid inlet and the fluid outlet, wherein each flow path is defined by an extruded tube that includes a plurality of extruded fluid sub-paths.

17. An heat exchanger for use in a motor vehicle, the heat exchanger comprising:

a first coolant loop comprising a first inlet, a first outlet, a first bundle of extruded flat tubes arranged in rows and connected between the first inlet and first outlet chambers, and a plurality of fins disposed between the rows of tubes, wherein each of the flat tubes in the first bundle include a plurality of extruded fluid paths;
a second coolant loop comprising a second inlet, a second outlet, a second bundle of extruded flat tubes arranged in rows and connected between the second inlet and second outlet chambers, and a plurality of fins disposed between the rows of tubes, wherein each of the flat tubes in the second bundle include a plurality of extruded fluid paths;

18. The heat exchanger of claim 17, wherein the fluid paths in the first bundle are aluminum oil-cooling tubes.

19. The heat exchanger of claim 17, wherein the fluid paths in the first bundle are air cooling fluid paths.

20. The heat exchanger of claim 17, wherein the fluid paths in the first bundle are exhaust gas fluid paths.

21. The heat exchanger of claim 17, wherein the fluid paths in the second bundle are aluminum coolant-cooling tubes.

22. The heat exchanger of claim 17, wherein the transverse cross-section of each extruded fluid paths within a tube in the first and second bundle of tubes is identical.

23. The heat exchanger of claim 17, wherein the transverse cross-section of at least one of the extruded fluid paths is rectangular.

24. The heat exchanger of claim 23, wherein the transverse cross-section of at least one of the extruded fluid paths includes a plurality of flanges along at least one side.

FIG. 1

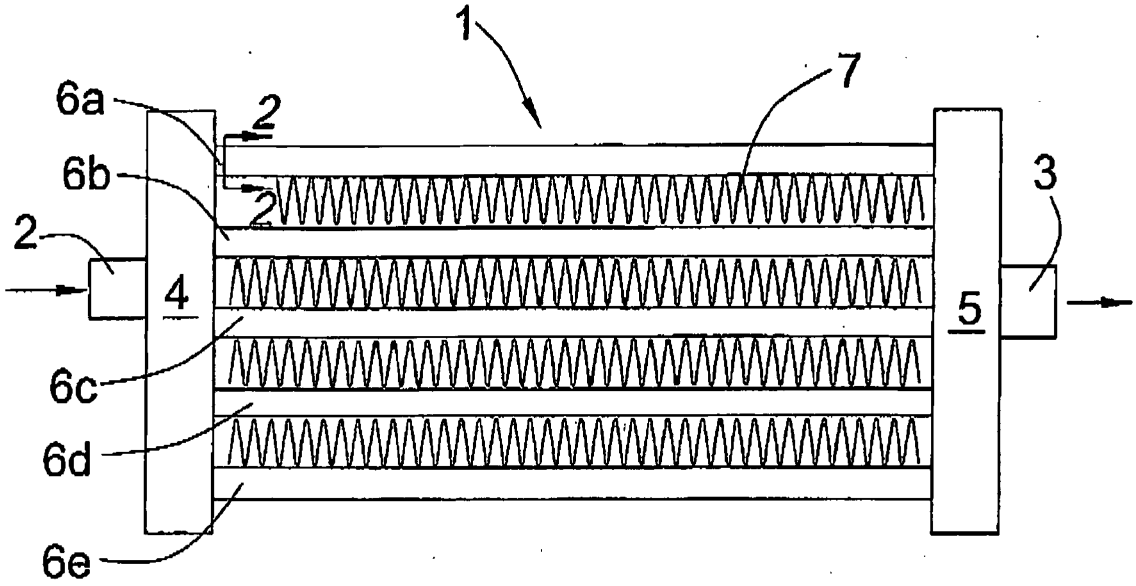


FIG. 2
(Prior Art)

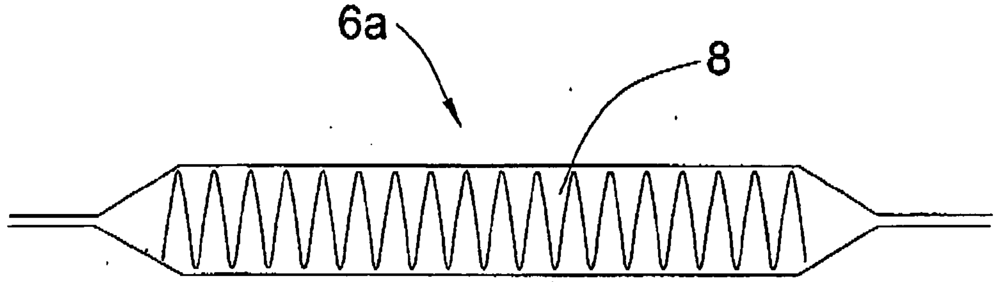


FIG. 3

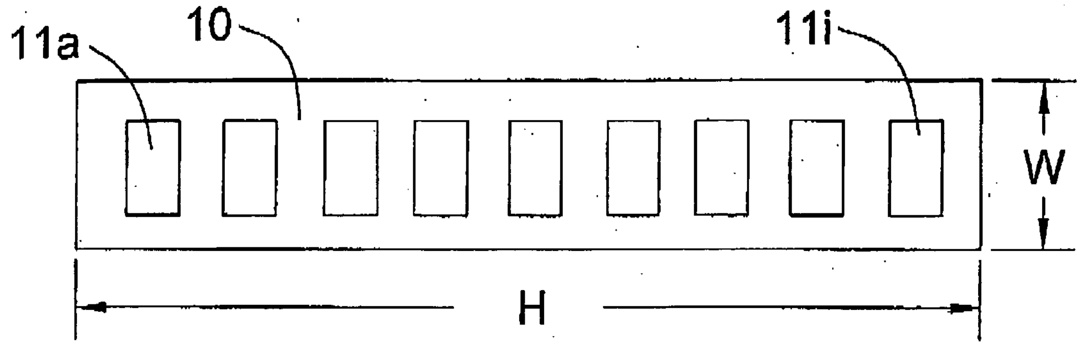


FIG. 4

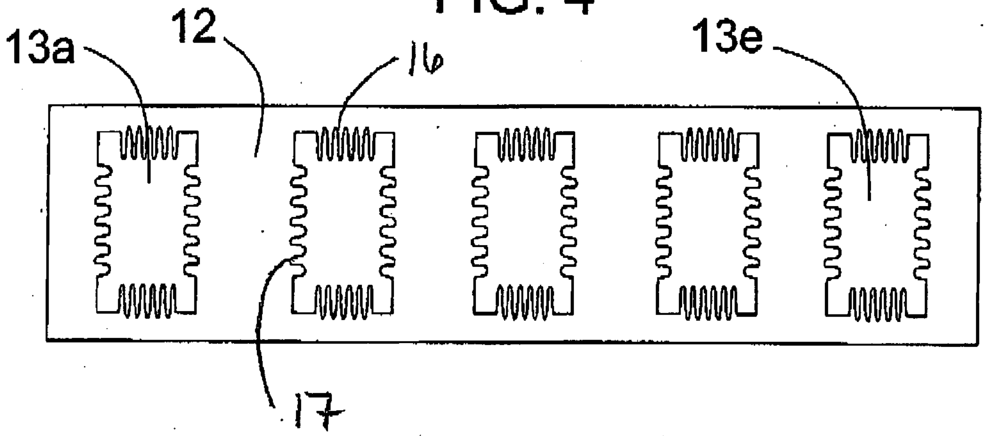


FIG. 5

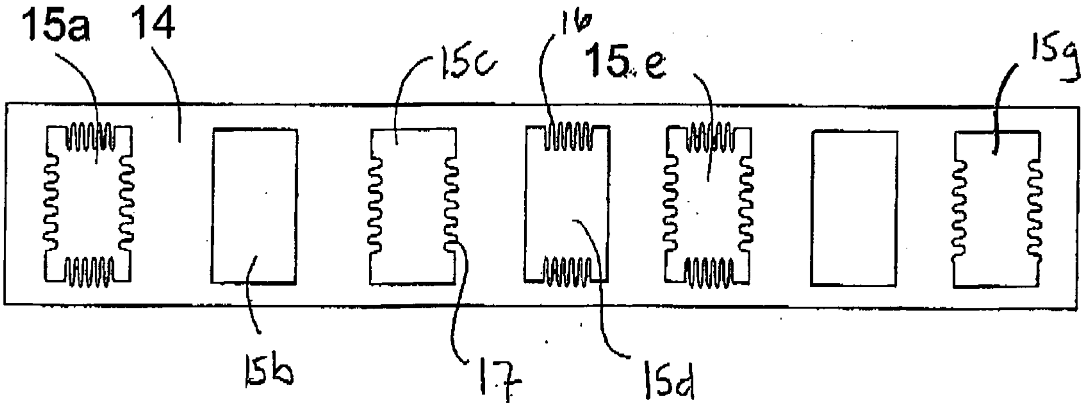


FIG. 6

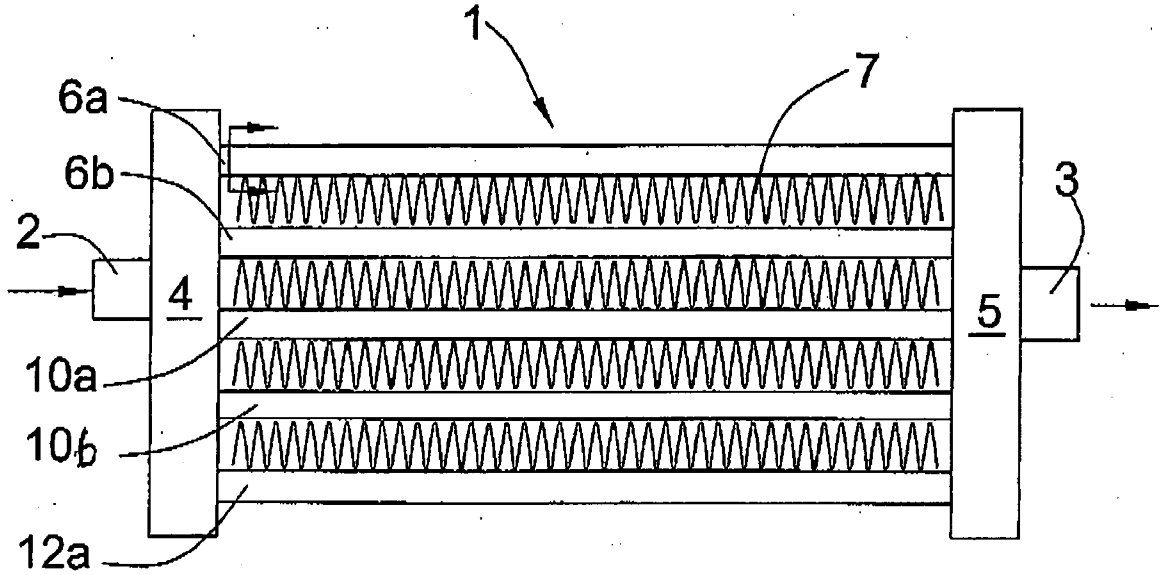
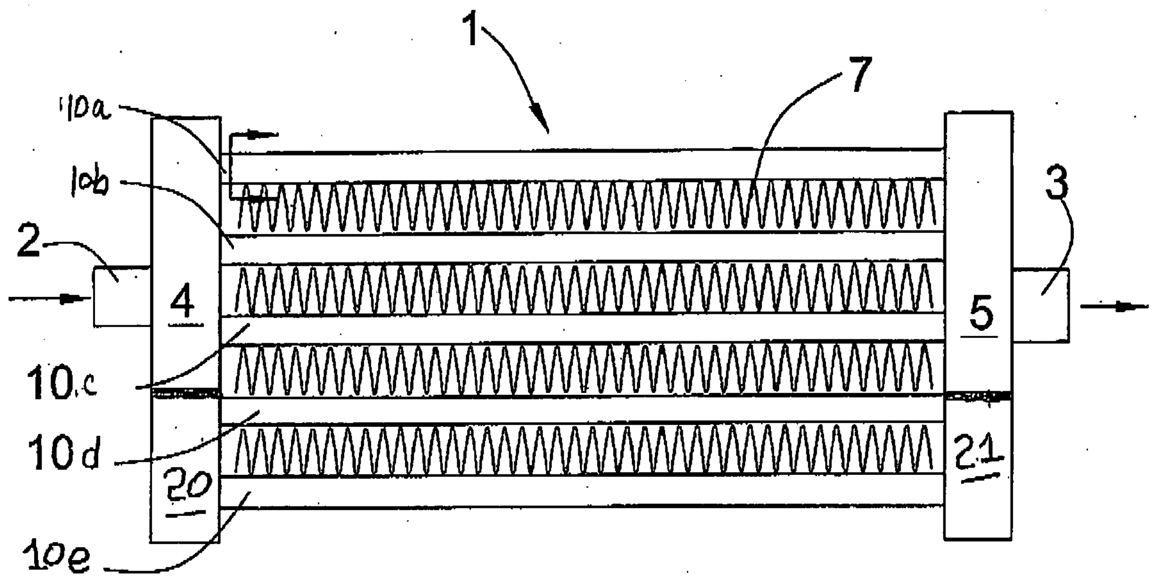


FIG. 7



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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