US 20140020877A1

(19) **United States**

(12) **Patent Application Publication**

SUZUKI et al.

(10) **Pub. No.: US 2014/0020877 A1**

(43) **Pub. Date: Jan. 23, 2014**

(54) **HEAT EXCHANGER ELEMENT AND HEAT EXCHANGER**

(71) Applicant: **NGK INSULATORS, LTD.**, Nagoya-City (JP)

(72) Inventors: **Yoshio SUZUKI**, Nagoya-City (JP); **Yuta MATSUNO**, Nagoya-City (JP); **Hiroharu KOBAYASHI**, Nagoya-City (JP); **Tatsuo KAWAGUCHI**, Nagoya-City (JP)

(73) Assignee: **NGK INSULATORS, LTD.**, Nagoya-City (JP)

(21) Appl. No.: **14/036,379**

(22) Filed: **Sep. 25, 2013**

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2012/057928, filed on Mar. 27, 2012.

(30) **Foreign Application Priority Data**

Mar. 29, 2011 (JP) 2011-072255

Publication Classification

(51) **Int. Cl.**
F28F 1/02 (2006.01)

(52) **U.S. Cl.**
CPC ***F28F 1/02*** (2013.01)
USPC **165/181**

(57) **ABSTRACT**

There is provided a heat exchanger element and a heat exchanger which are smaller, lighter in weight, and lower in cost than conventional heat exchange bodies, heat exchangers and the like. In the honeycomb structure, $t \geq 0.2$, $\rho > 100$, $20 \leq t \times \rho \leq 250$, and $10{,}000 \leq \lambda \times \rho$ are satisfied when thermal conductivity of a material for the partition walls is taken as λ [W/K~m], and, regarding a cell structure of the honeycomb structure, a wall thickness of the partition walls is taken as t [mm], and a cell density is taken as ρ [cells/sq.in.].

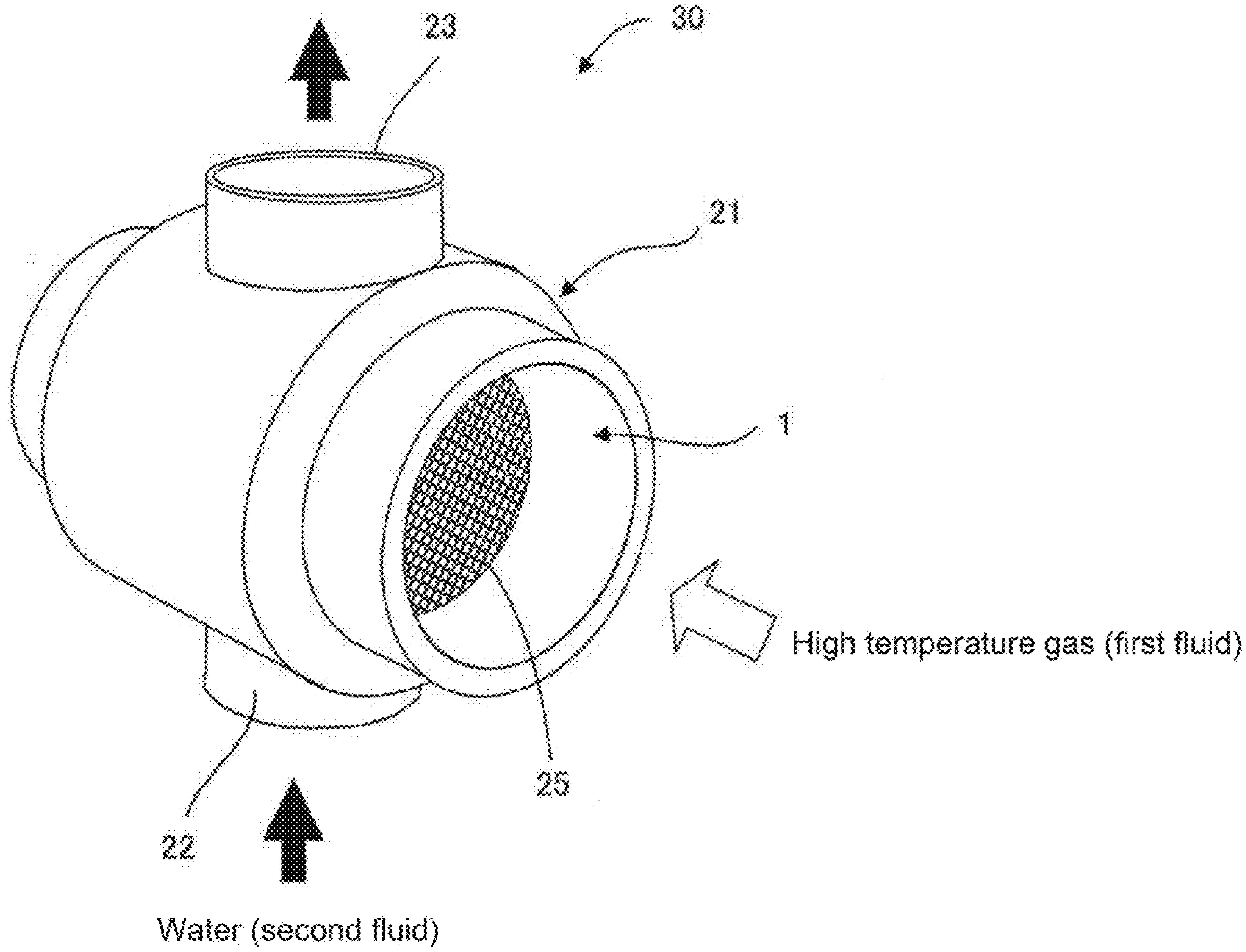


FIG.1A

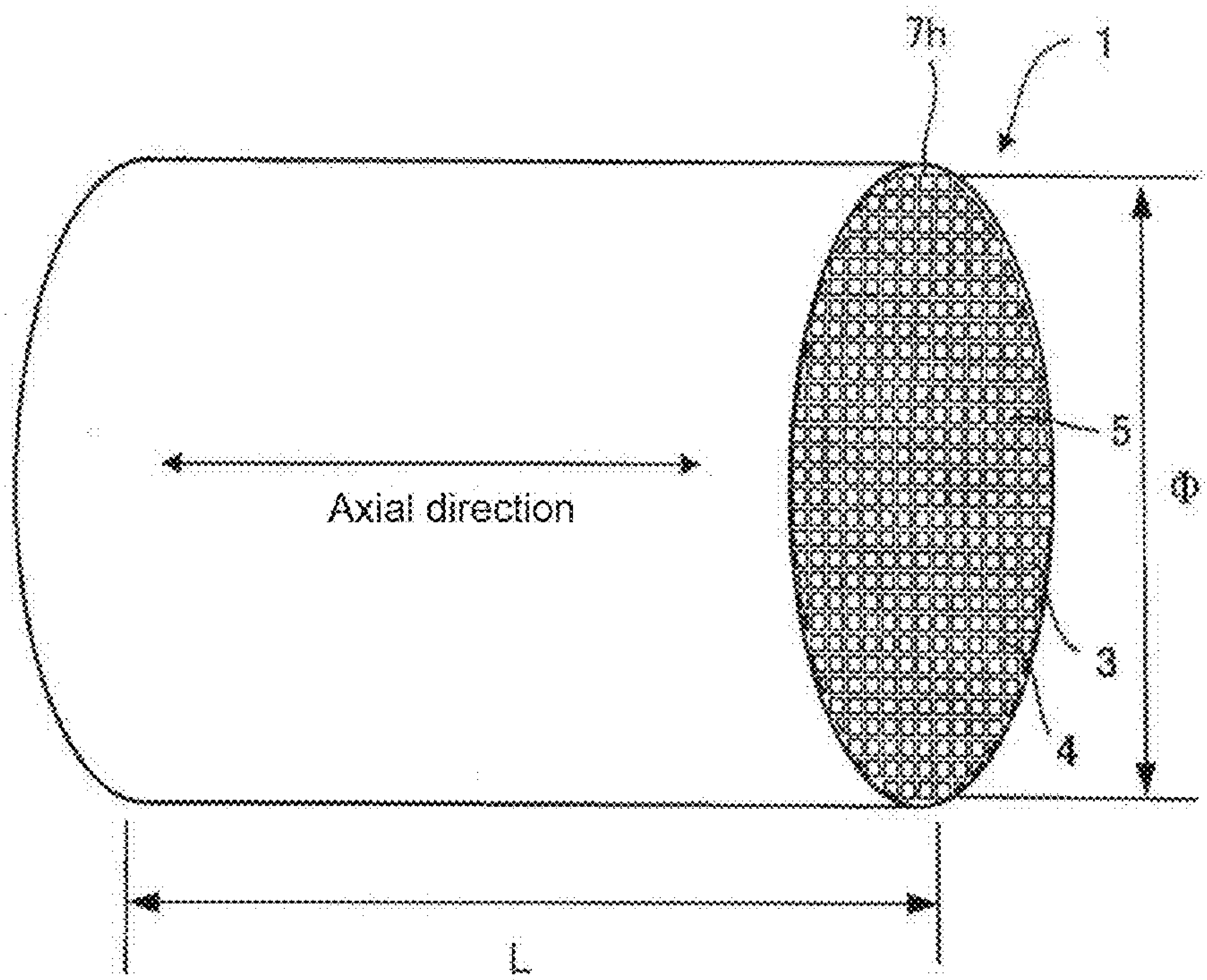


FIG.1B

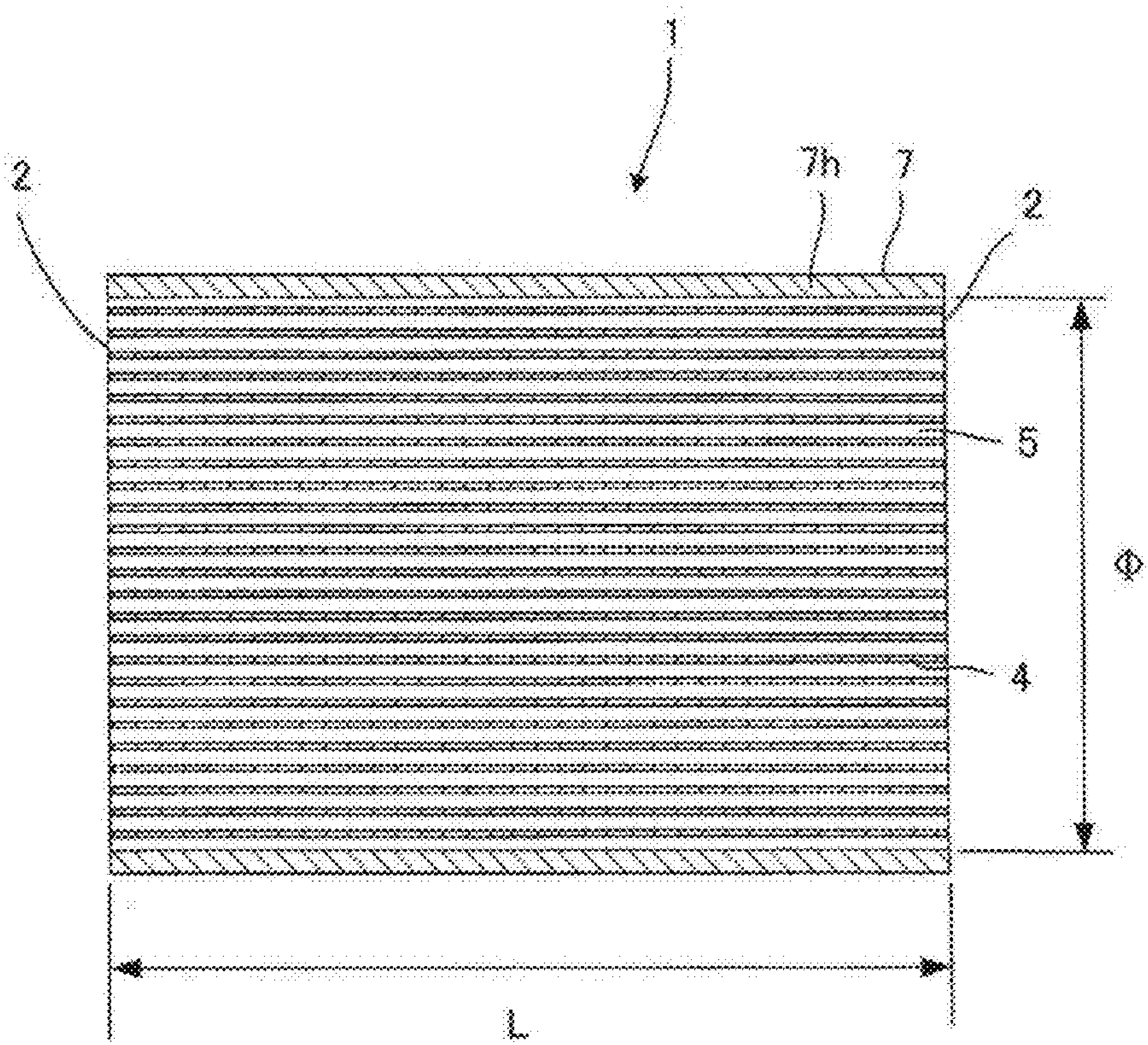


FIG.2A

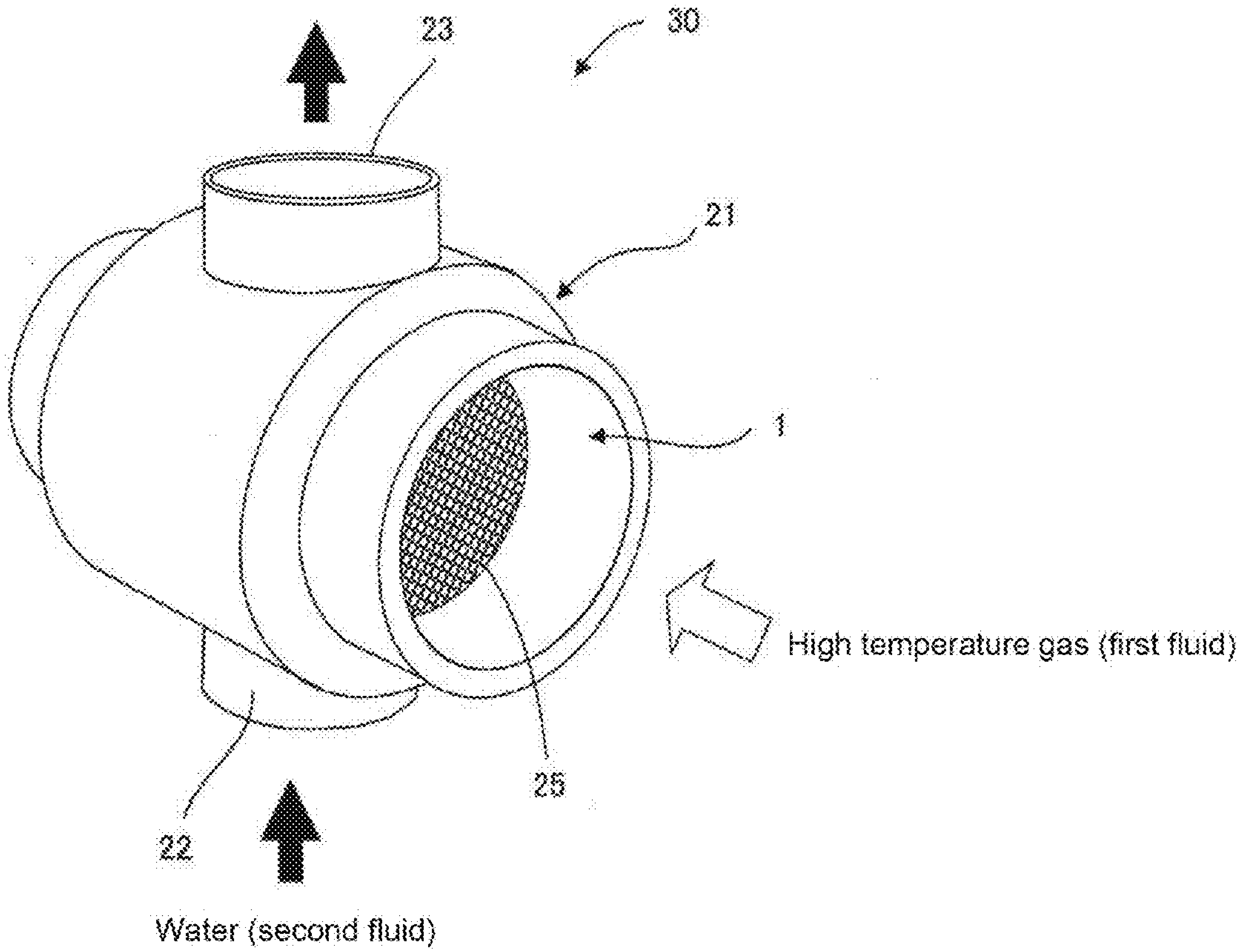

23
30
21
1
25
22
High temperature gas (first fluid)
Water (second fluid)

FIG.2B

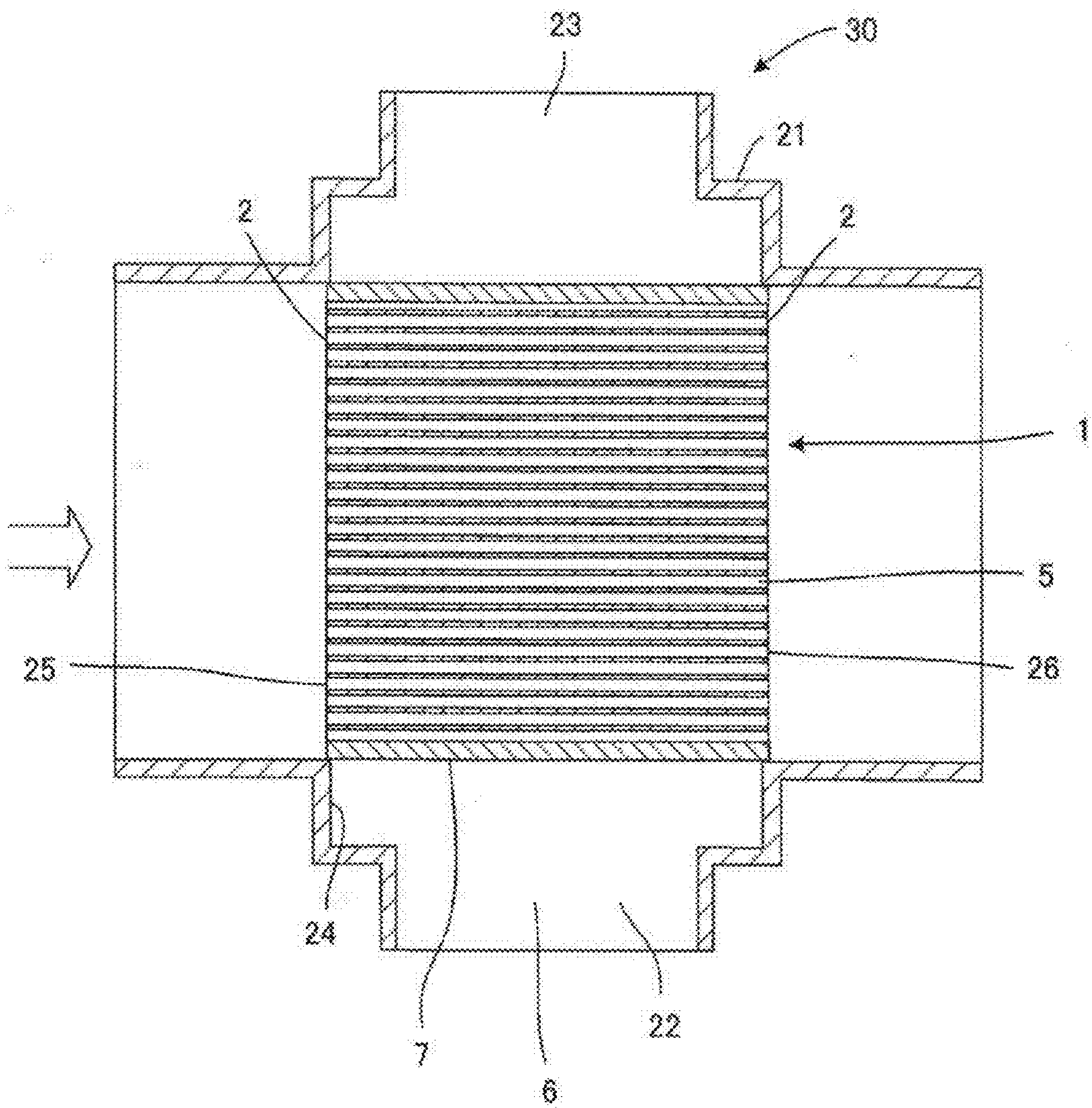


FIG.2C

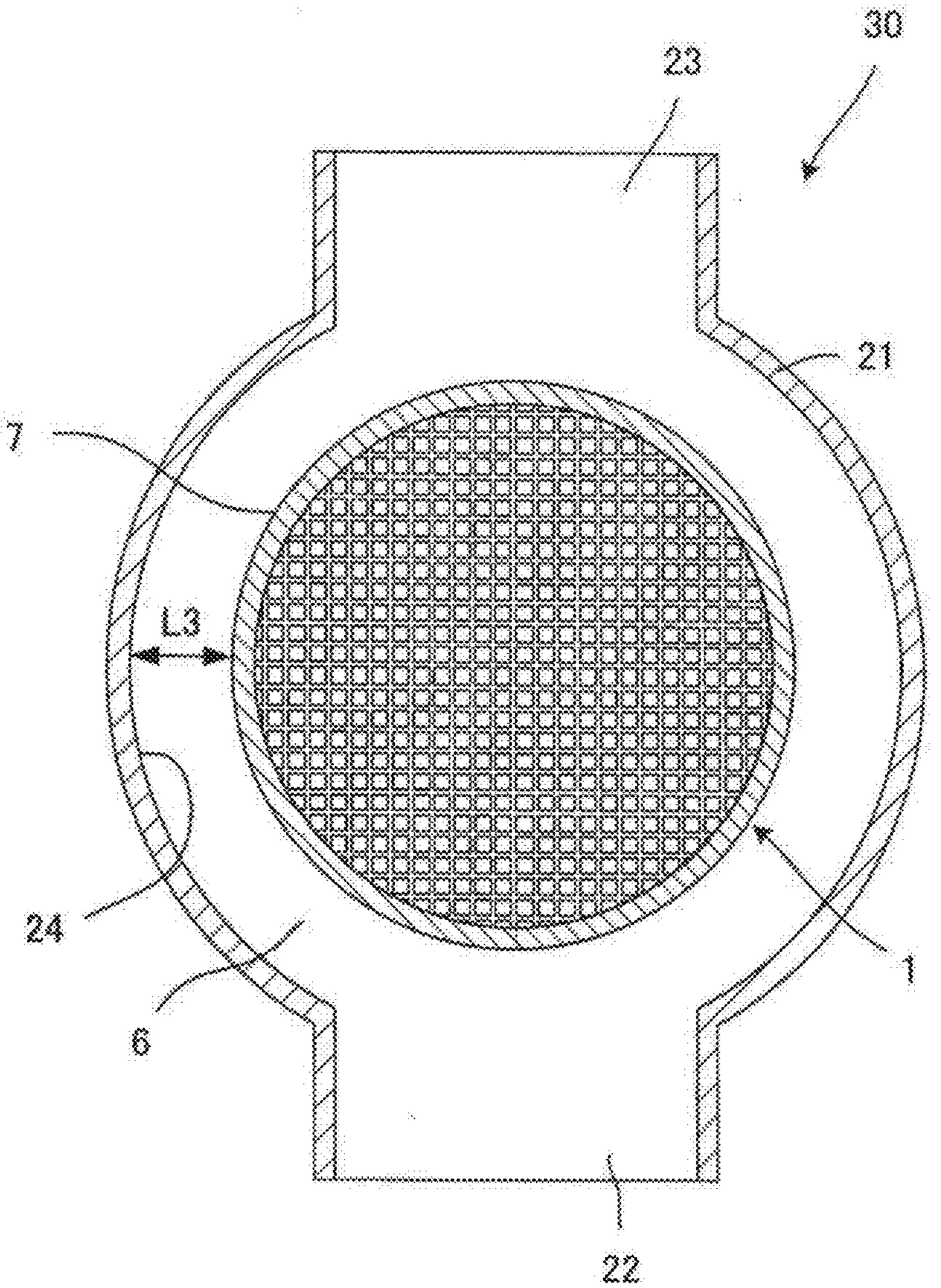


FIG.3A

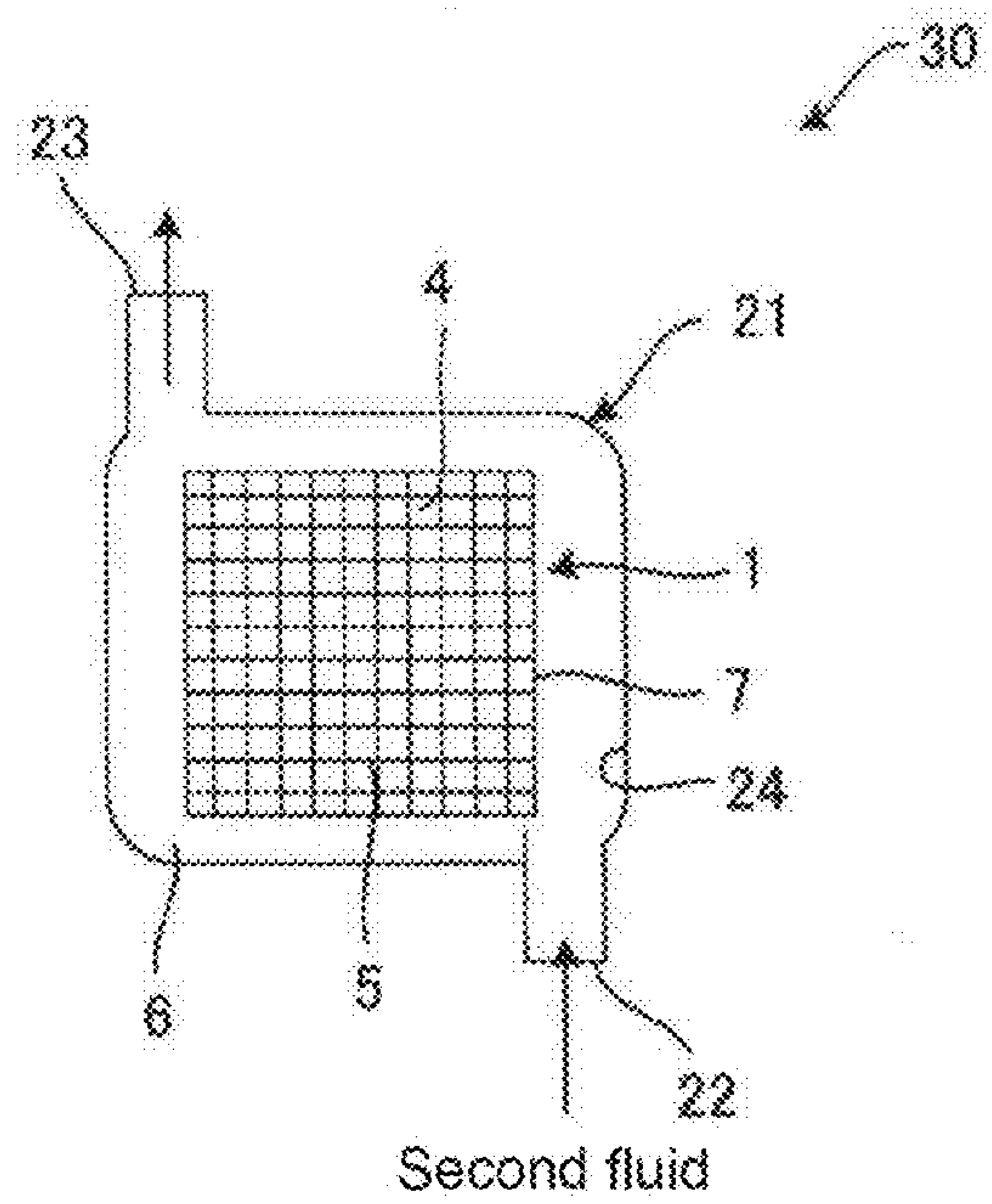

30
23
4
21
1
7
24
6
5
22
Second fluid

FIG.3B

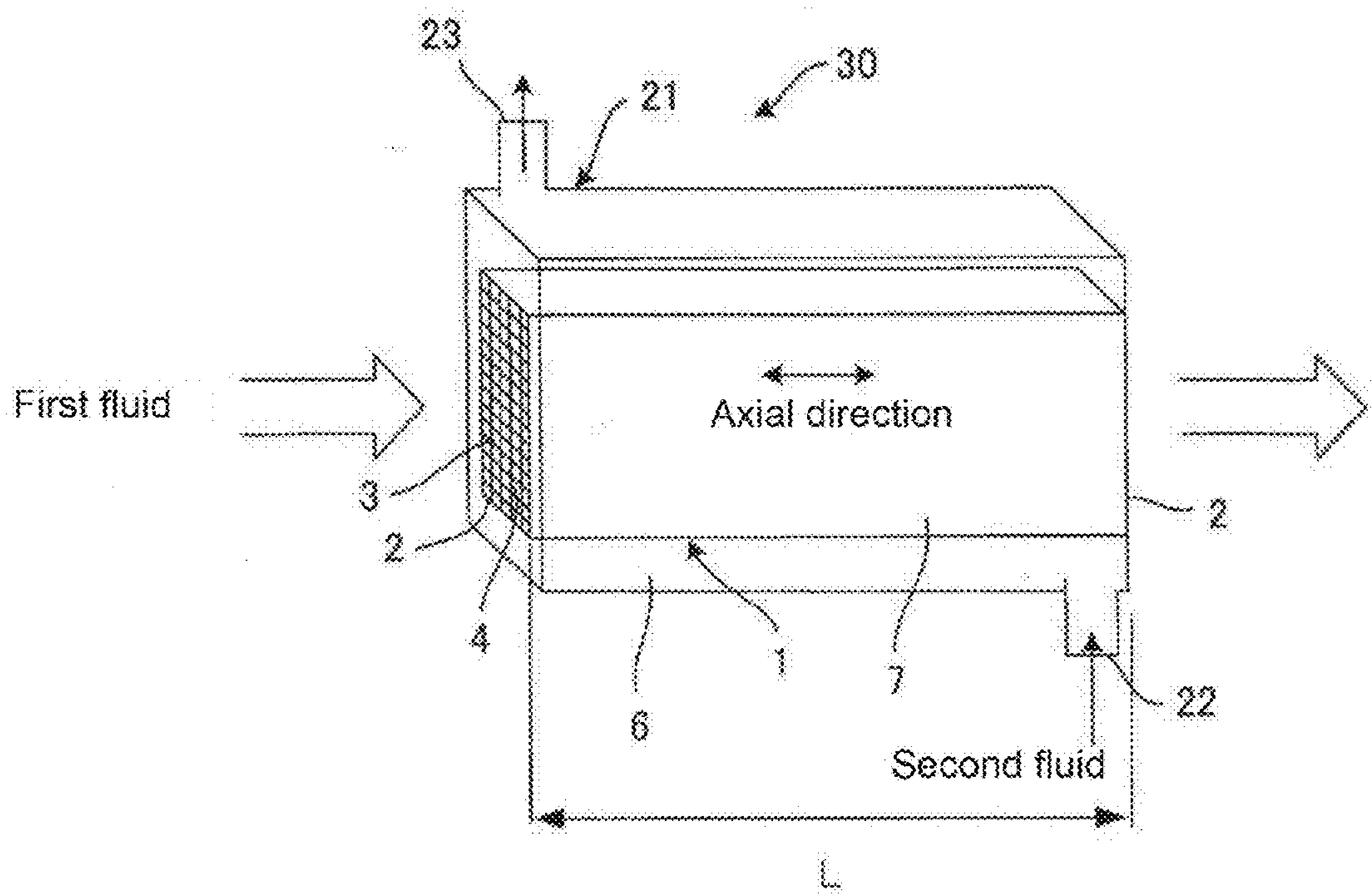

23
21
30
First fluid
Axial direction
3
2
2
4
6
1
7
22
Second fluid
L

FIG.4A

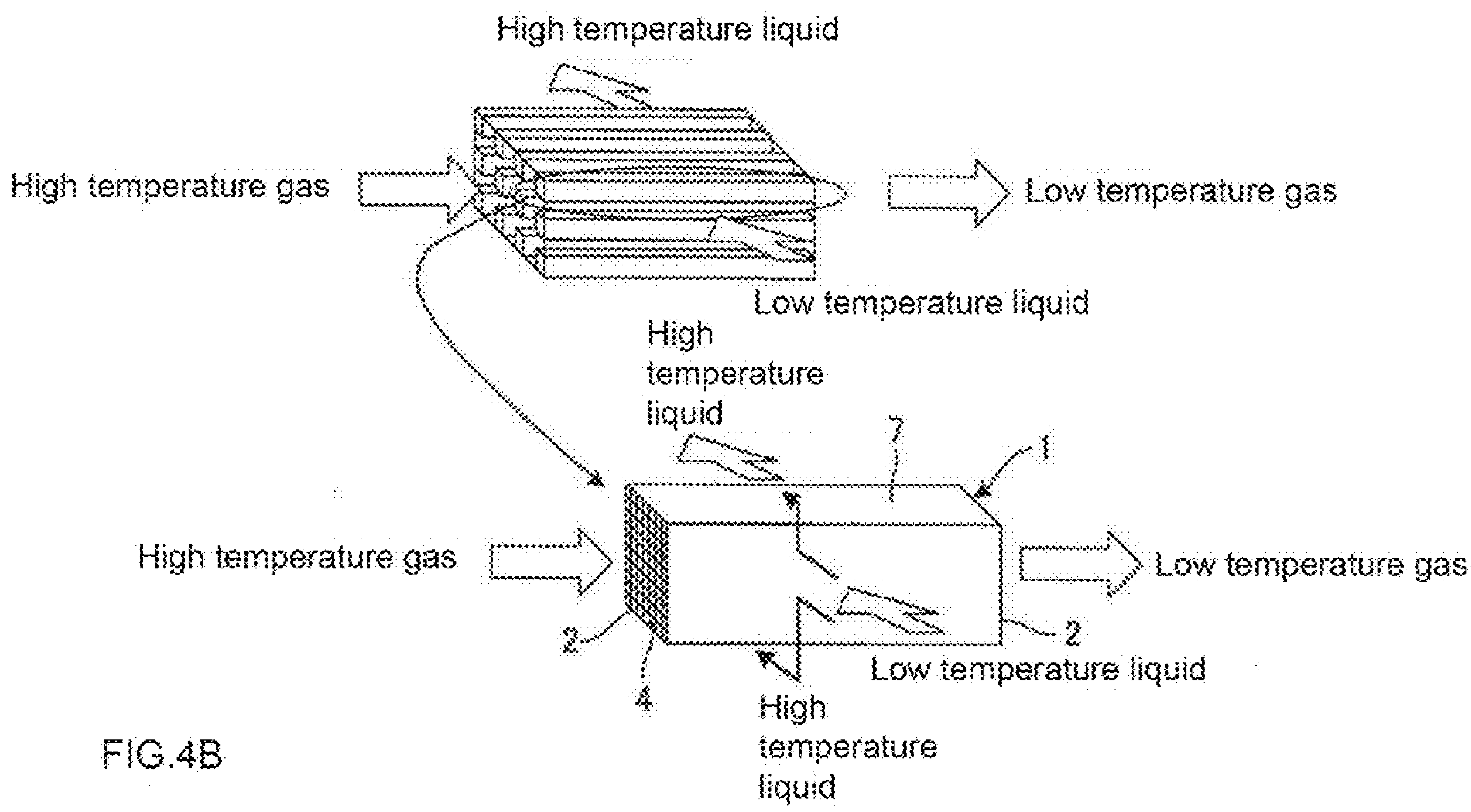


FIG.4B

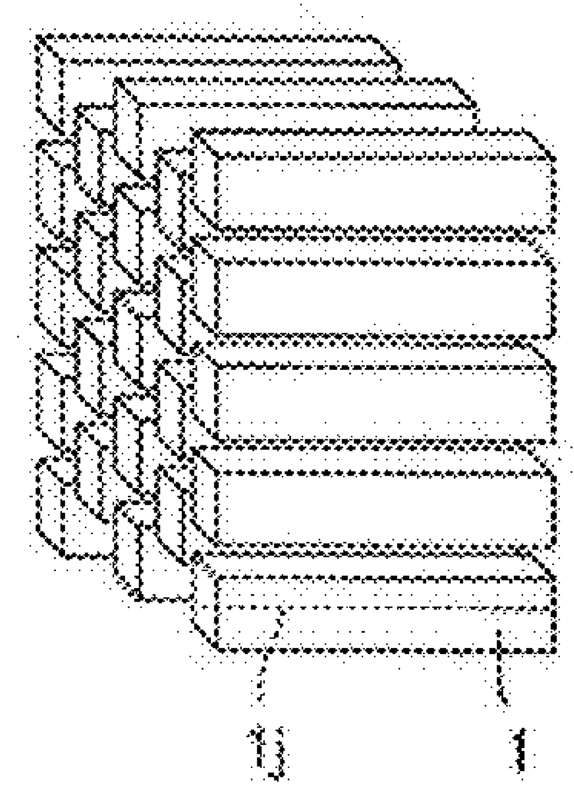


FIG.4C

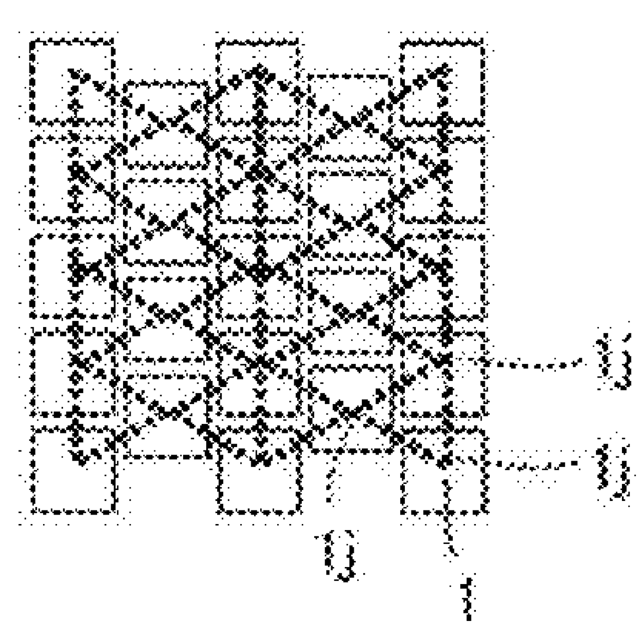


FIG.4D

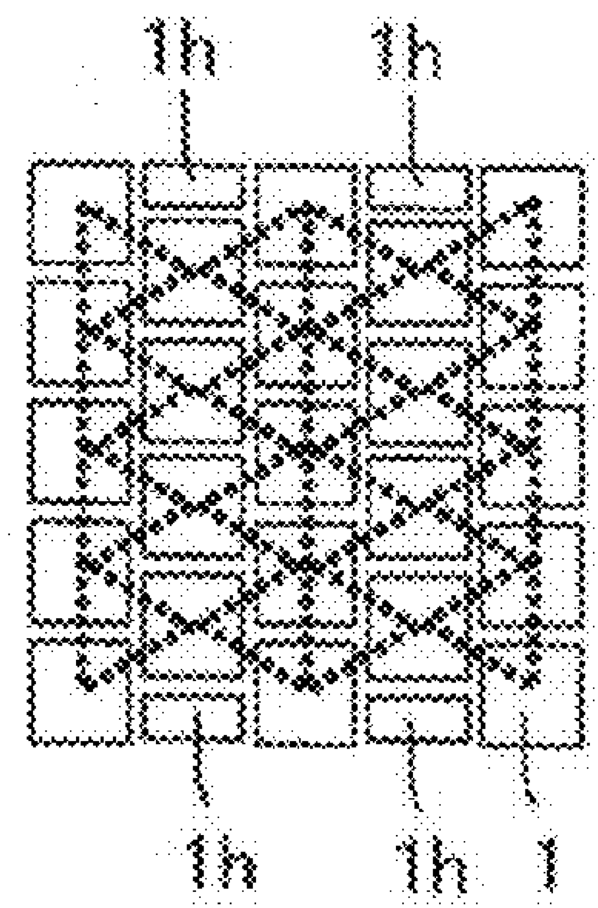


FIG.5A

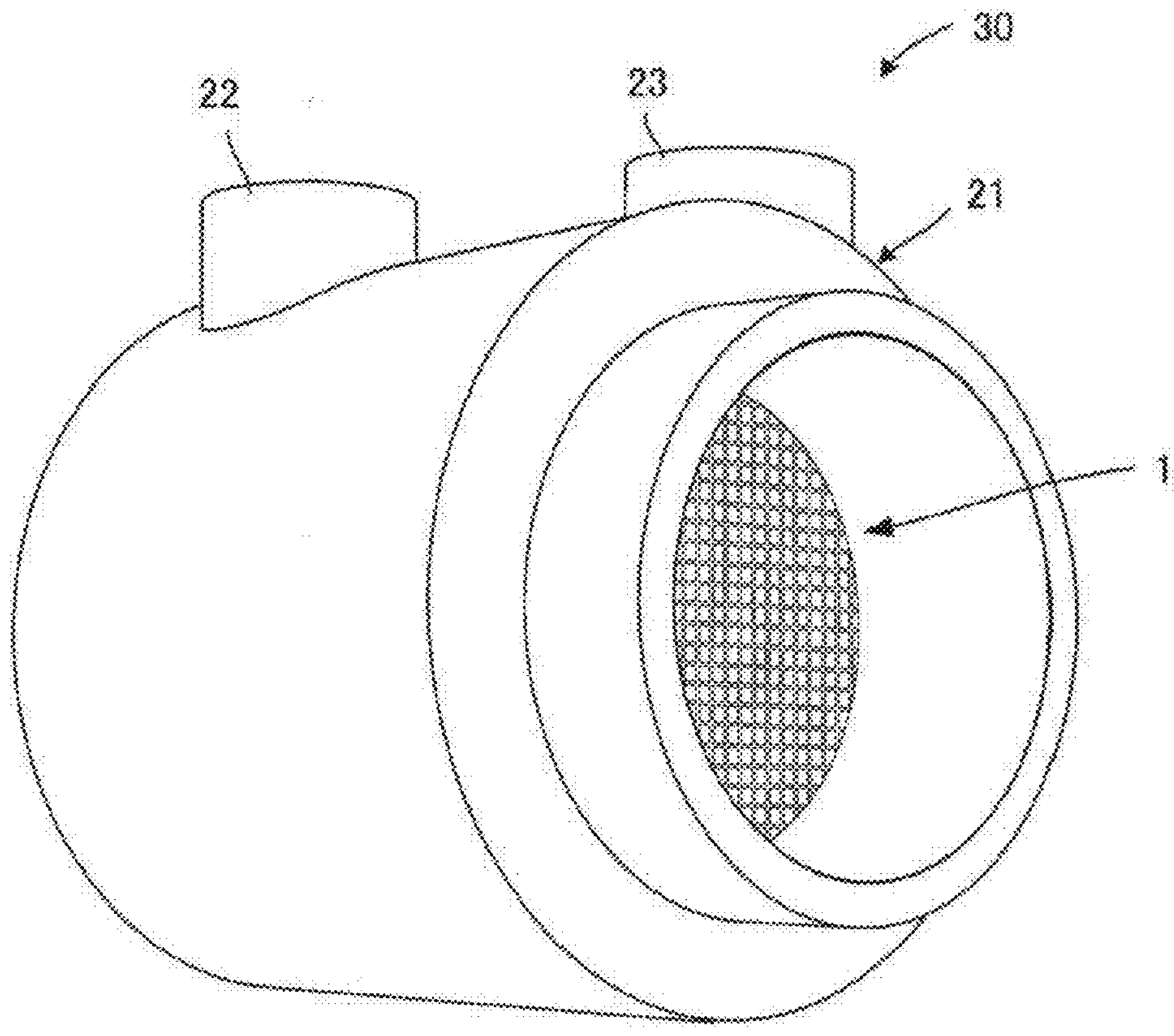


FIG.5B

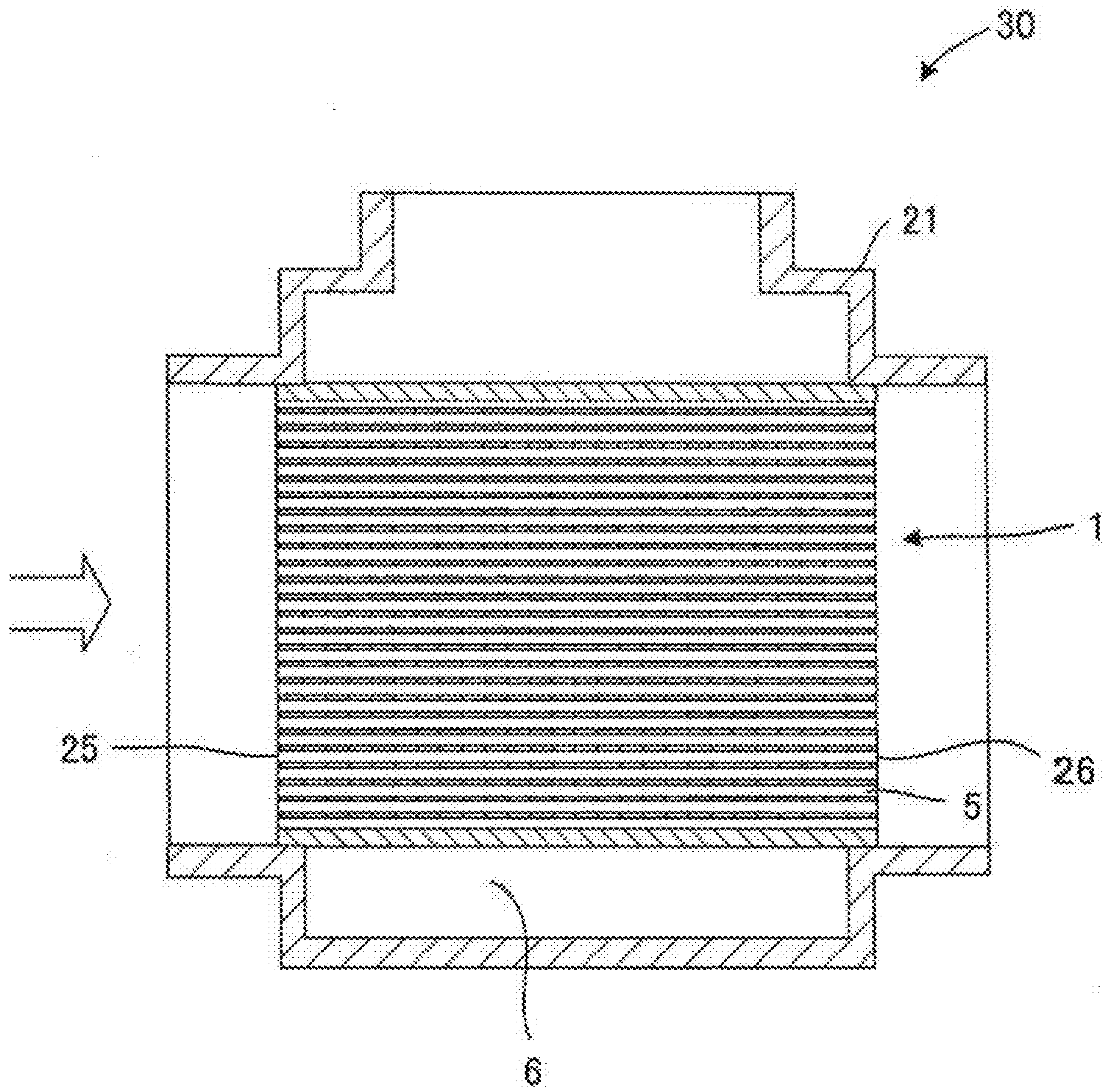


FIG.5C

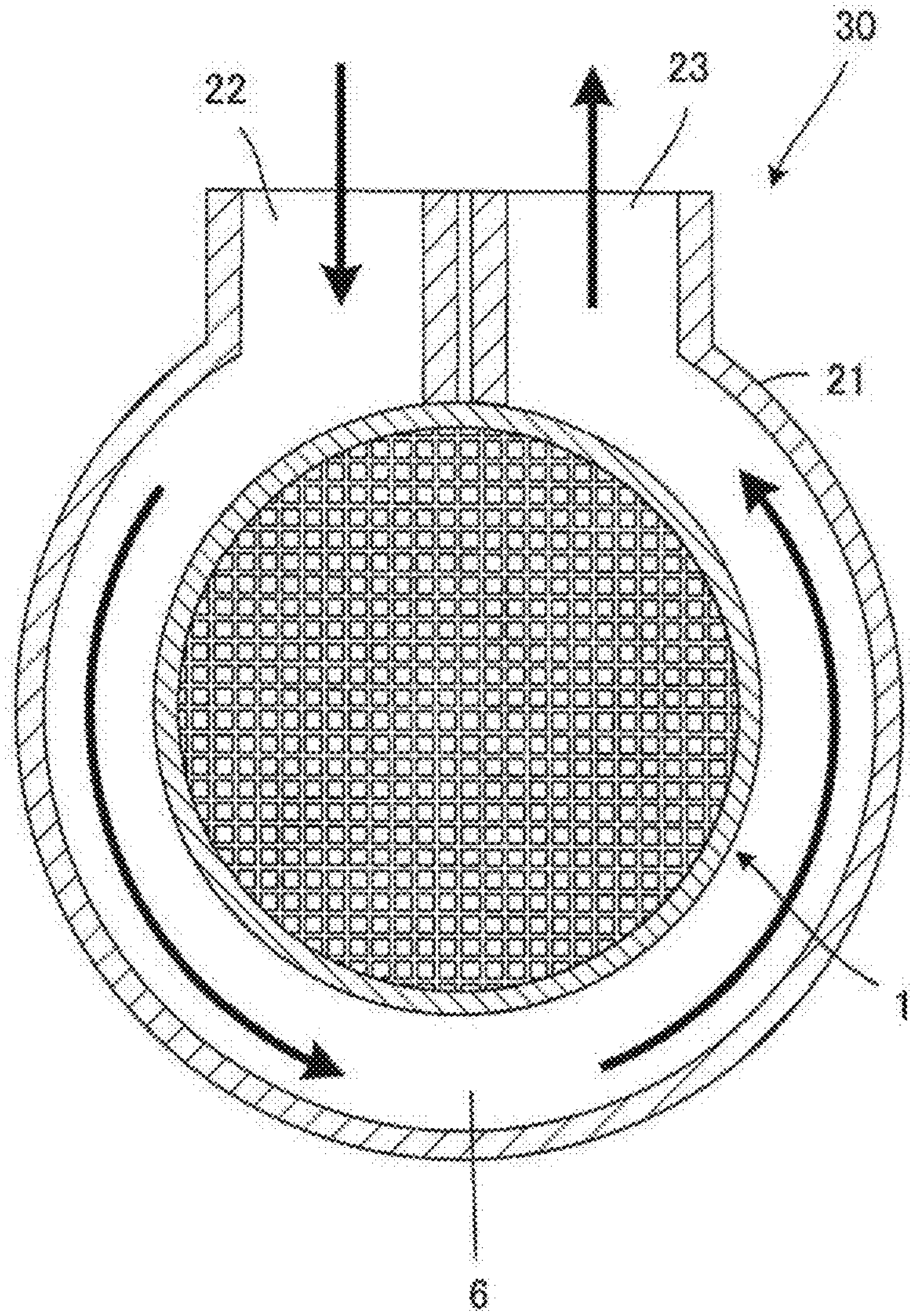


FIG.6

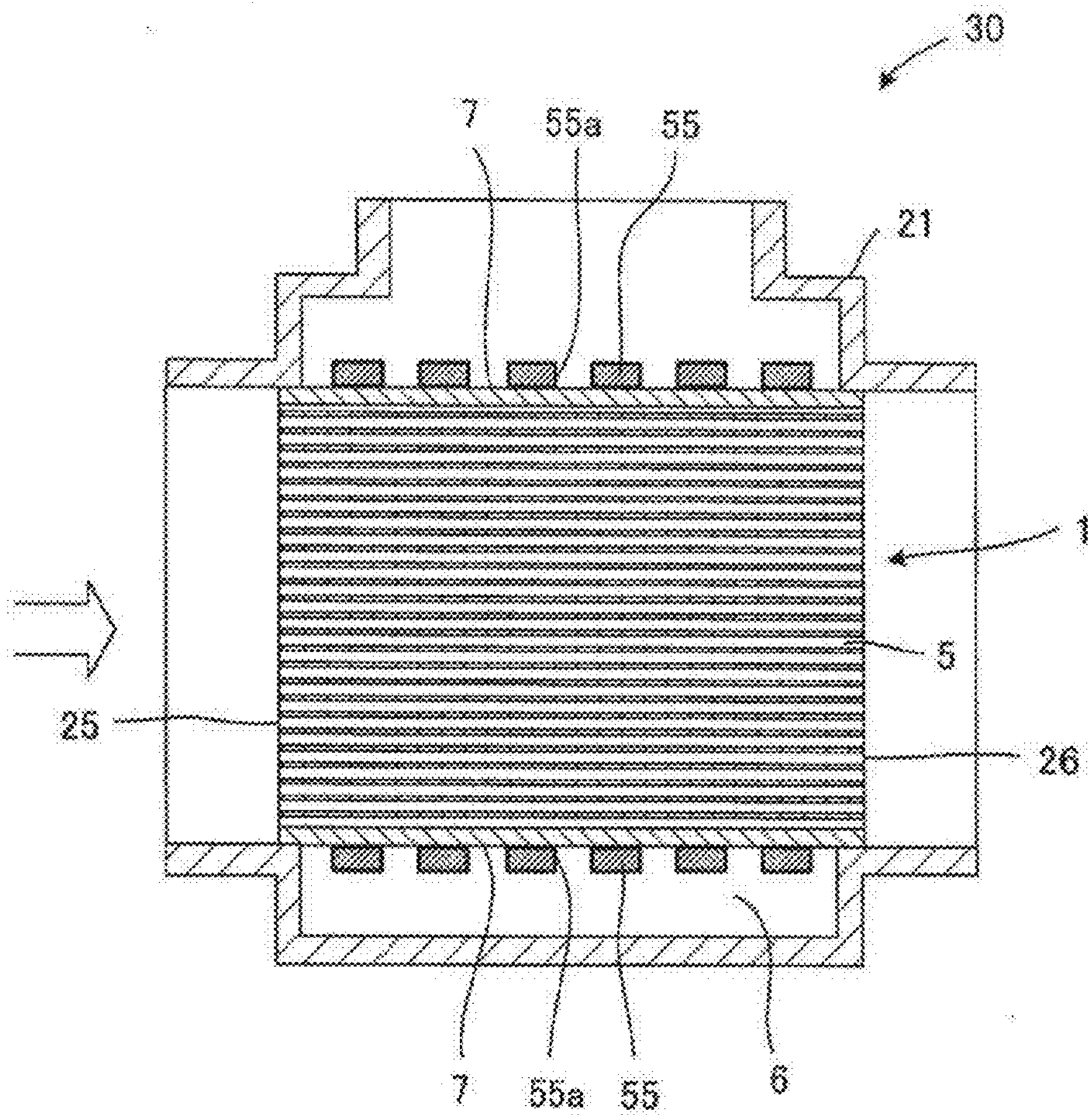


FIG.7A

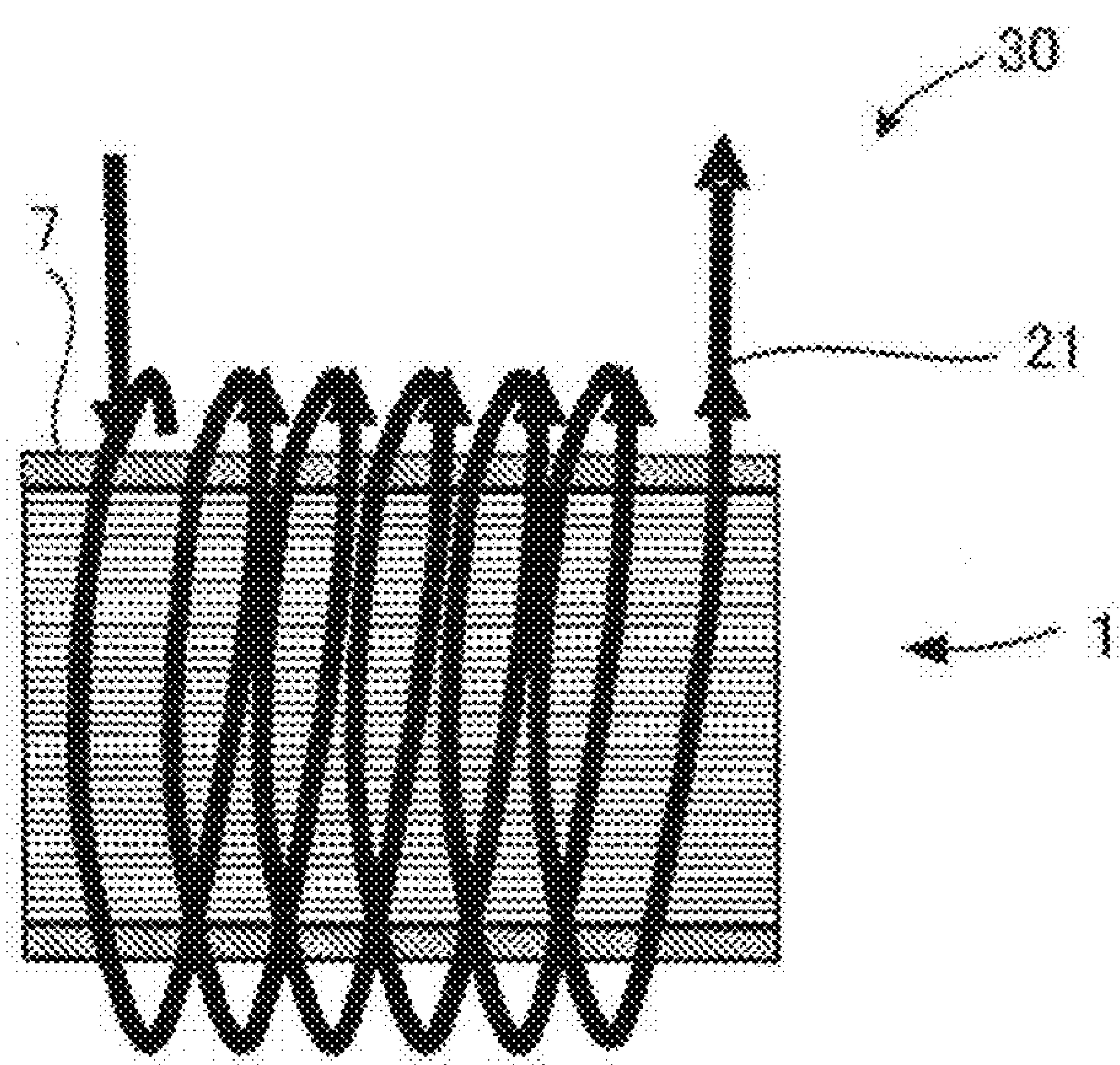


FIG.7B

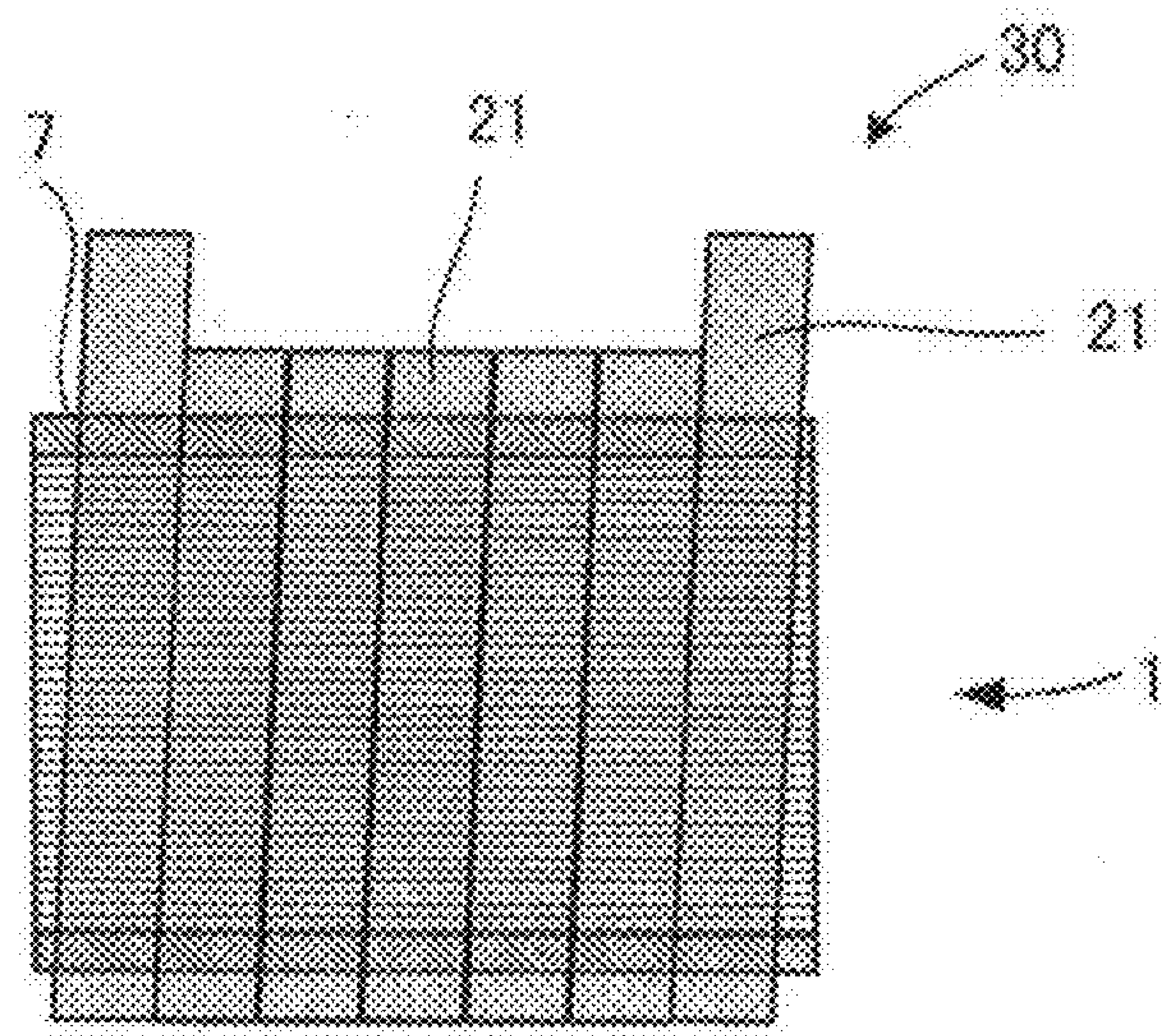
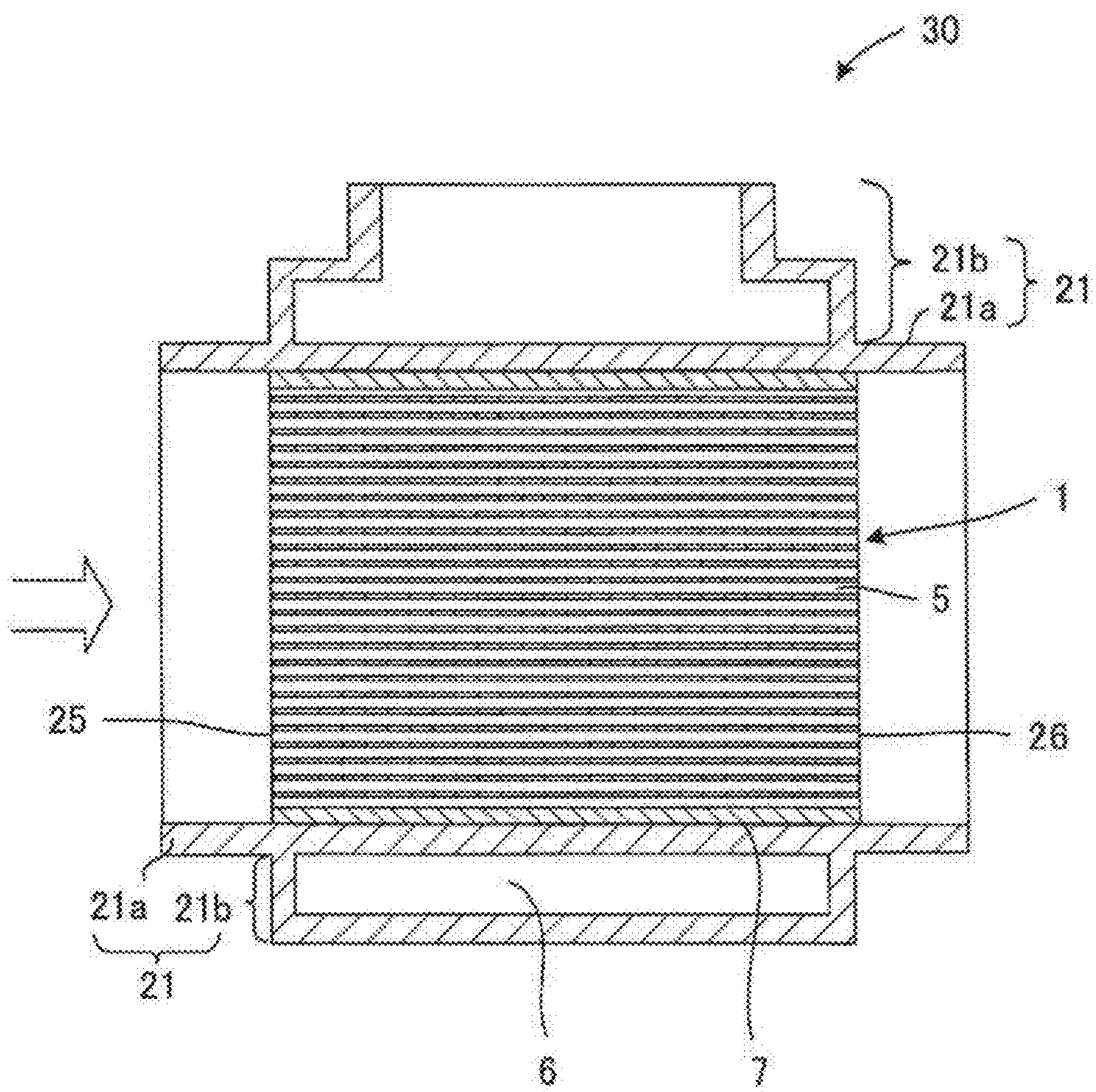


FIG.8



HEAT EXCHANGER ELEMENT AND HEAT EXCHANGER

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger element for transferring heat of the first fluid (high temperature side) to the second fluid (low temperature side) and a heat exchanger.

BACKGROUND ART

[0002] There is demanded a technique for heat recovery from high temperature gas such as combustion exhaust gas of an engine or the like. As a gas/liquid heat exchanger, fin-provided tube type heat exchangers of an automobile radiator and an air-conditioning outdoor unit are general. However, for recovering heat from gas such as automobile exhaust gas, it is difficult to use a common metallic heat exchanger at high temperature because of poor thermal resistance. Therefore, heat resistant metal and ceramic material, and the like having thermal resistance, thermal shock resistance, corrosion resistance, and so on are suitable. Though a heat exchanger made of heat resistant metal is known, heat resistant metal has problems of difficulty in machining, high density and high weight, and low thermal conduction in addition to high price.

[0003] In the Patent Document 1, there is disclosed a ceramic heat exchange body, wherein a heating body passage is disposed from one end face to the other end face of a ceramic main body, and wherein a passage for a body to be heated is formed between the heating body passages, and extending in the direction perpendicular to the heating body passages.

[0004] In the Patent Document 2, there is disclosed a ceramic heat exchanger, wherein a plurality of ceramic heat exchange bodies each having a heating fluid passage and a non-heating fluid passage formed therein are disposed in a casing with an unfired ceramic string-shaped seal material laid between the corresponding faces to be bonded together of the heat exchange bodies.

[0005] However, since the Patent Documents 1 and 2 have poor productivity because of a large number of steps such as plugging and slit-forming, the costs are high. In addition, since the passages of gas/liquid are disposed in every other row, the piping structure and seal structure of the fluid become complicated. Further, since a coefficient of heat transfer of liquid is generally 10 to 100 times larger than that of gas, the heat transfer area on the gas side is insufficient in these techniques, and the heat exchanger becomes large in proportion to the heat transfer area of the gas which limits the heat exchanger performance.

[0006] In the Patent Documents 3 and 4, since it is necessary that a honeycomb structural portion and a tube portion are bonded together after separately producing them, and the productivity is not good, the costs tend to be high.

PRIOR ART DOCUMENTS

Patent Documents

[0007] Patent Document 1: JP-A-S61-24997 bulletin

[0008] Patent Document 2: JP-B-S63-60319 bulletin

[0009] Patent Document 3: JP-A-S61-83897 bulletin

[0010] Patent Document 4: JP-A-H02-150691 bulletin

SUMMARY OF THE INVENTION

[0011] An object of the present invention is to provide a heat exchanger element and a heat exchanger which realize downsizing, weight saving, and cost reduction in comparison with a conventional heat exchange body, heat exchanger, and the like.

[0012] The present inventors have found out that the aforementioned object can be solved by specifying the relation between the size and the coefficient of thermal conductivity of a honeycomb structure functioning as a heat exchanger element in the case of heat exchange by putting a heat exchanger element formed as a honeycomb structure in a casing, passing the first fluid through the cells of the honeycomb structure, and passing the second fluid along the outer peripheral face of the honeycomb structure in the casing. That is, according to the present invention, there are provided the following honeycomb-structured heat exchanger element and heat exchanger having high temperature efficiency, small volume of the honeycomb portion, and small pressure drop of the first fluid.

[0013] [1] A heat exchanger element formed as a honeycomb structure having a plurality of cells partitioned by ceramic partition walls, passing through in an axial direction from one end face to the other end face, and functioning as a first fluid passage portion where a heating body as the first fluid passes; wherein at least one of the partition walls and an outer peripheral wall of the honeycomb structure is made so dense that the first fluid passing through the first fluid passage portion, and the second fluid receiving heat from the first fluid by passing along an outer peripheral face of the outer peripheral wall of the honeycomb structure are not mixed together, and wherein all of $t \geq 0.2$, $\rho > 100$, $20 \leq t \times \rho \leq 250$, and $10{,}000 \leq \lambda \times \rho$ are satisfied when thermal conductivity of a material for the partition walls of the honeycomb structure is taken as λ[W/K·m], and, a wall thickness of the partition walls is taken as t [mm] and a cell density is taken as ρ [cells/sq.in.] in a cell structure of the honeycomb structure.

[0014] [2] The heat exchanger element according to the aforementioned [1], wherein $20 \leq Ø \leq 60$ and $1.66 \leq L/Ø \leq 7.5$ are satisfied when, a circle-equivalent diameter of a cross-sectional area of a cross section perpendicular to the axial direction of the honeycomb structure is taken as Ø [mm], and the entire length in the axial direction of the honeycomb structure is taken as L [mm] in the cell structure of the honeycomb structure.

[0015] [3] A heat exchanger provided with the honeycomb structure as the heat exchanger element according to the aforementioned [1] or [2] and a casing having an inlet port and an outlet port for the second fluid and containing the honeycomb structure therein, wherein an inside of the casing functions as the second fluid passage portion, and the second fluid receives heat from the first fluid by passing along the outer peripheral face of the honeycomb structure in the second fluid passage portion.

[0016] A heat exchanger element and a heat exchanger of the present invention have a structure which is not complicated and can realize downsizing, weight saving, and cost reduction in comparison with a conventional heat exchange body (heat exchanger or its device). In addition, they have equivalent or better temperature efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1**A is a perspective view showing a heat exchanger element formed as a cylindrical honeycomb structure.

[0018] FIG. **1**B is a cross-sectional view cut along a cross section parallel to the axial direction, showing a heat exchanger element formed as a cylindrical honeycomb structure.

[0019] FIG. **2**A is a perspective view showing a heat exchanger, wherein a heat exchanger element formed as a cylindrical honeycomb structure is housed in a casing.

[0020] FIG. **2**B is a cross-sectional view cut along a cross section parallel to the axial direction, showing a heat exchanger, wherein a heat exchanger element formed as a cylindrical honeycomb structure is housed in a casing.

[0021] FIG. **2**C is a cross-sectional view cut along a cross section perpendicular to the axial direction, showing a heat exchanger, wherein a heat exchanger element formed as a cylindrical honeycomb structure is housed in a casing.

[0022] FIG. **3**A is a schematic view showing an embodiment of a heat exchanger of the present invention, viewed from the first fluid inlet port side.

[0023] FIG. **3**B is a schematic view showing an embodiment of a heat exchanger of the present invention, where the first fluid and the second fluid exchange heat by a countercurrent.

[0024] FIG. **4**A is a view showing another embodiment of a heat exchanger of the present invention, where the first fluid and the second fluid exchange heat by a cross flow, schematically showing an arrangement where a plurality of honeycomb structures are stacked in layers.

[0025] FIG. **4**B is a perspective view showing an embodiment having an equilateral staggered arrangement of a plurality of honeycomb structures.

[0026] FIG. **4**C shows an embodiment having an equilateral staggered arrangement of a plurality of honeycomb structures viewed from the first fluid inlet port side.

[0027] FIG. **4**D is a view showing an embodiment including honeycomb structures having different sizes.

[0028] FIG. **5**A is a perspective view showing another embodiment of a heat exchanger, wherein a cylindrical honeycomb structure is housed in a casing.

[0029] FIG. **5**B is a cross-sectional view cut along a cross section parallel to the axial direction, showing another embodiment of a heat exchanger, wherein a cylindrical honeycomb structure is housed in a casing.

[0030] FIG. **5**C is a cross-sectional view cut along a cross section perpendicular to the axial direction, showing another embodiment of a heat exchanger, wherein a cylindrical honeycomb structure is housed in a casing.

[0031] FIG. **6** is a cross-sectional view cut along across section parallel to the axial direction, showing an embodiment of a heat exchanger, wherein a honeycomb structure provided with a punching metal is housed in a casing.

[0032] FIG. **7**A is a schematic view for explaining the state where the casing is spirally looped around the honeycomb structure on its outer peripheral face.

[0033] FIG. **7**B is a schematic view in a direction parallel to the axial direction, for explaining the state where the casing is spirally looped around the honeycomb structure on its outer peripheral face.

[0034] FIG. **8** is a cross-sectional view cut along a cross section parallel to the axial direction, showing an embodiment of a heat exchanger, wherein the casing is provided with a tubular portion and an outside casing portion as a single unit.

MODE FOR CARRYING OUT THE INVENTION

[0035] Hereinbelow, embodiments of the present invention will be described with referring to drawings. The present invention is not limited to the following embodiments, and changes, modifications, and improvements may be made as long as they do not deviate from the scope of the invention.

[0036] FIG. **1**A is a perspective view showing a heat exchanger element of an embodiment of the present invention. FIG. **1**B is a cross-sectional view cut along a cross section parallel to the axial direction, where the heat exchanger element is formed as a cylindrical honeycomb structure **1**. FIG. **2**A shows a perspective view of a heat exchanger **30** where a heat exchanger element having a cylindrical honeycomb structure **1** is housed in a casing **21**, FIG. **2**B shows a cross-sectional view cut along a cross section parallel to the axial direction, and FIG. **2**C shows a cross-sectional view cut along a cross section perpendicular to the axial direction.

[0037] As shown in FIGS. **1**A and **1**B, the honeycomb structure **1** of the heat exchanger element is formed into a cylindrical shape. As shown in FIGS. **2**A to **2**C, the casing **21** of the heat exchanger **30** of the present embodiment is formed linearly in such a manner that the honeycomb structure **1**, which forms the first fluid passage portion **5** from the first fluid inlet port **25** to the first fluid outlet port **26**, engages with the casing **21**. Also, the second fluid passage portion **6** from the second fluid inlet port **22** to the second fluid outlet port **23** is formed linearly. There is given a cross structure where the first fluid passage portion **5** and the second fluid passage portion **6** cross each other. The honeycomb structure **1** is provided to be engaged with the casing **21**. The inlet port **22** and the outlet port **23** of the second fluid are formed oppositely across the honeycomb structure **1**.

[0038] As shown in FIG. **2**B, the heat exchanger **30** is provided with the first fluid passage portion **5** and the second fluid passage portion **6**. The first fluid passage portion **5** is formed of a honeycomb structure **1** having a plurality of cells **3** partitioned by ceramic partition walls **4**, passing through in the axial direction from one end face **2** to the other end face **2**, and allowing the heating body as the first fluid to pass therethrough. The second fluid passage portion **6** is formed of the casing **21** containing the honeycomb structure **1** therein, wherein the second fluid inlet port **22** and the second fluid outlet port **23** are formed in the casing **21**, and the second fluid flows over the outer peripheral face **7** of the honeycomb structure **1** inside the casing **21** to receive heat from the first fluid. In order to avoid the first fluid and the second fluid from being mixed together, at least one of the partition walls **4** and the outer peripheral wall **7***h* of the honeycomb structure **1** is made dense. Incidentally, "the second fluid flows over the outer peripheral face **7** of the honeycomb structure **1**" includes both of the case where the second fluid is brought into direct contact with the outer peripheral face **7** of the honeycomb structure **1** and the case where the second fluid is not brought into direct contact with the outer peripheral face **7** of the honeycomb structure **1**.

[0039] The honeycomb structure **1** as a heat exchanger element housed in the casing **21** has a plurality of cells **3** partitioned by ceramic partition walls **4**, passing through from one end face **2** to the other end face **2**, and allowing a heating body as the first fluid to pass therethrough. The heat exchanger **30** is configured in such a manner that the first fluid, which has higher temperature than the second fluid, passes through the cells **3** of the honeycomb structure **1**.

[0040] In addition, the second fluid passage portion **6** is formed by the inner peripheral face **24** of the casing **21** and the outer peripheral face **7** of the honeycomb structure **1**. The second fluid passage portion **6** is a passage portion for the second fluid, which is formed by the casing **21** and the outer peripheral face **7** of the honeycomb structure **1**. The second fluid passage portion **6** is separated from the first fluid passage portion **5** by the partition walls **4** of the honeycomb structure **1** to be able to conduct heat, receives heat of the first fluid passing through the first fluid passage portion **5** via the partition walls **4**, and transfers heat to the body to be heated, which is the second fluid passing therethrough. The first fluid and the second fluid are completely separated from each other and never mixed together.

[0041] As shown in FIG. **1**A, the first fluid passage portion **5** is formed as a honeycomb structure. In the case of a honeycomb structure, when a fluid passes through a cell **3**, the fluid cannot flow into another cell **3** because of the partition walls **4** and linearly moves from the inlet port to the outlet port of the honeycomb structure **1**. The honeycomb structure **1** in a heat exchanger **30** of the present invention is not plugged, the heat transfer area of the fluid is increased, and the size of the heat exchanger can be reduced. This enables to increase the heat transfer amount per unit volume of the heat exchanger. Further, since it is not necessary to form plugging portions or to form slits in the honeycomb structure **1**, the heat exchanger **30** enables to reduce production costs.

[0042] In a heat exchanger element of the present invention, when thermal conductivity of a material for the partition walls **4** of the honeycomb structure **1** forming the first fluid passage portion **5** is taken as 2 λ [W/K·m], and the wall thickness of the partition walls **4** is taken as t [mm], and the cell density is taken as ρ [cells/sq.in.] in a cell structure of the honeycomb structure **1**; $t \geq 0.2$, $\rho > 100$, $20 \leq t \times \rho \leq 250$, and $10{,}000 \leq \lambda \times \rho$.

[0043] As to $t \times \rho$, $20 \leq t \times \rho \leq 250$, preferably $80 \leq t \times \rho \leq 250$. Such a range of $t \times \rho$ enables to transfer heat of the first fluid effectively to the outer peripheral wall **7***h* portion which exchanges heat with the second fluid and to reduce pressure drop generated by the first fluid while maintaining the temperature efficiency. As to $\lambda \times \rho$, $10{,}000 \leq \lambda \times \rho$, more preferably $20{,}000 \leq \lambda \times \rho$. Such a range of $\lambda \times \rho$ enables to efficiently transfer the heat of the first fluid to the outer peripheral wall **7***h* portion which exchanges heat with the second fluid while keeping the pressure drop small.

[0044] Ø [mm] means a circle-equivalent diameter, which is a diameter of a circle having the same area as the area of the heat collection portion. The heat collection portion means the portion collecting heat from the first fluid, and in case of the honeycomb structure **1**, it means the portion where the cells **3** are formed (excluding the outer peripheral wall **7***h*). If the honeycomb structure **1** has a cylindrical shape, the diameter of the portion excluding the outer peripheral wall **7***h* is Ø. If a cross sectional area of cross sections perpendicular to the axial direction of the honeycomb structure **1** is the same, regardless of the shape of the honeycomb structure **1**, since the average distance from each point of the heat collection portion to the outer peripheral wall **7***h* becomes the same, the heat exchange amount becomes almost the same. Therefore, the temperature efficiency can be improved by specifying parameters including the circle-equivalent diameter.

[0045] As to Ø, $20 \leq Ø \leq 60$ is preferable, more preferably $30 \leq Ø \leq 50$. When the entire length of the honeycomb structure **1** in the axial direction is taken as L [mm], L/Ø is preferably $1.66 \leq L/Ø \leq 7.5$, more preferably $2 \leq L/Ø \leq 5$. Such ranges of Ø and L/Ø enable to efficiently transfer the heat of the first fluid to the outer peripheral wall portion which exchanges heat with the second fluid and to obtain a heat exchanger element capable of reducing the pressure drop generated by the first fluid while maintaining the temperature efficiency.

[0046] In a heat exchanger **30** of the present invention, it is preferable that the first fluid having higher temperature than the second fluid is passed so that heat is transferred from the first fluid to the second fluid. When a gas is passed as the first fluid, and a liquid is passed as the second fluid, heat exchange between the first fluid and the second fluid can efficiently be performed. That is, a heat exchanger **30** of the present invention can be applied as a gas/liquid heat exchanger.

[0047] In a heat exchanger **30** of the present invention, by passing the first fluid having higher temperature than the second fluid through the cells of the honeycomb structure **1**, heat of the first fluid can efficiently be transferred to the honeycomb structure **1**. That is, the total resistance of heat transfer is the heat resistance from the first fluid to the honeycomb structure **1**+the heat resistance of the partition walls **4**+the heat resistance from the honeycomb structure **1** to the second fluid, and the rate-determining factor is the heat resistance from the first fluid to the honeycomb structure **1**. In the heat exchanger **30**, since the first fluid passes through the cells **3**, the contact area between the first fluid and the honeycomb structure **1** is large, and the heat resistance from the first fluid to the honeycomb structure **1**, which is the rate-determining factor, can be reduced. Therefore, in the heat exchanger element shown in FIG. **1**B, even if the length of the honeycomb structure **1** in the axial direction is made smaller than the circle-equivalent diameter having the same area as the cross-sectional area of a cross section in the axial direction, heat exchange can be performed more sufficiently than ever before.

[0048] Whereas manufacturing of a ceramic heat exchanger of prior art needs steps of plugging process, slit opening process, and process for bonding a plurality of formed bodies or fired bodies; the present invention needs a very small number of steps because, basically, extrusion can be used as it is. In addition, whereas manufacturing of the same structure with a heat resistant metal needs steps of pressing process, welding process, and the like, the present invention does not need such steps. Therefore, the production costs can be reduced, and sufficient temperature efficiency can be obtained.

[0049] A heat exchanger **30** of the present invention is constructed of the honeycomb structure **1** serving as the first fluid passage portion **5** (high temperature side) of the honeycomb structure, where the first fluid (heating body) passes, and the casing **21**, whose inside serves as the second fluid passage portion **6**. Since the first fluid passage portion **5** is formed of the heat exchanger element of the honeycomb structure **1**, the heat exchange can efficiently be performed. In the honeycomb structure **1**, a plurality of cells **3** functioning as passages by the partition walls **4** are separated and formed, and, for the cell shape, a desired shape may appropriately be selected from a circle, an ellipse, a triangle, a quadrangle, other polygons, and the like. Incidentally, when it is desired to make the heat exchanger **30** large, a module structure, to which a plurality of honeycomb structures **1** are bonded, can be employed (see FIG. **4**A).

[0050] Though the shape of the honeycomb structure **1** shown in FIGS. **1**A and **1**B is cylindrical, the shape is not limited to this and may be another shape such as a quadrangular prism (see FIG. **3**A) or a structure of a honeycomb assembly satisfying the conditions (see FIGS. **4**A to **4**C).

[0051] The embodiment shown in FIGS. **3**A and **3**B is a heat exchanger **30** where the first fluid and the second fluid exchange heat by a countercurrent. The countercurrent means that the second fluid flows in the reverse direction parallel to the direction of the flow of the first fluid. The direction of passing the second fluid is not limited to the opposite direction (countercurrent) of the first fluid-flowing direction and can appropriately be selected and designed, such as the same direction (parallel flow) or at a certain angle ($0° < x < 180°$: excluding a right angle).

[0052] In the heat exchanger **30** shown in FIG. **4**A, a plurality of honeycomb structures **1** are disposed in the casing **21** with the outer peripheral faces **7** facing one another in the state that the honeycomb structures **1** mutually have a gap where the second fluid passes. Incidentally, FIG. **4**A schematically shows the arrangement of the honeycomb structures **1**, where the casing **21** and the like are omitted. Specifically, the honeycomb structures **1** are stacked in three rows vertically and four rows horizontally with gaps. Such a configuration increases the number of cells **3** where the first fluid passes and can pass a large amount of the first fluid. In addition, since a plurality of honeycomb structures **1** are disposed with the outer peripheral faces **7** facing one another in the state of having gaps, the contact area between the outer peripheral faces **7** of the honeycomb structures **1** and the second fluid is large, and therefore the heat exchange between the first fluid and the second fluid can effectively be performed. Incidentally, the circle-equivalent diameter Ø is a value obtained regarding each honeycomb structure **1**.

[0053] FIGS. **4**B and **4**C show an embodiment having an equilateral staggered arrangement of a plurality of honeycomb structures **1**. FIG. **4**B is a perspective view, and FIG. **4**C is a view from the first fluid inlet port side. The plural honeycomb structures **1** are disposed in such a manner that the lines joining the central axes **1***j* of the honeycomb structures **1** form equilateral triangles. Such arrangement enables to pass the second fluid uniformly between the honeycomb structures **1** (among the modules), thereby improving the temperature efficiency. Therefore, in the case of disposing a plurality of honeycomb structures **1**, an equilateral staggered arrangement is preferable. The equilateral staggered arrangement gives a kind of a fin structure to make the flow of the second fluid turbulent, thereby making heat exchange with the first fluid easier.

[0054] FIG. **4**D shows an embodiment where honeycomb structures **1** having different sizes are included. In the embodiment of FIG. **4**D, complementary honeycomb structures **1***h* are disposed in the gaps among the honeycomb structures **1** having an equilateral staggered arrangement. The complementary honeycomb structures **1***h* are for filling up the gaps, and the size and shape are different from those of the other general honeycomb structures **1**. That is, it is not necessary that all the honeycomb structures **1** have the same size and shape. By thus employing the complementary honeycomb structures lh having different size and shape, the gaps between the casing **21** and the honeycomb structures **1** are filled up, thereby improving the temperature efficiency.

[0055] The density of the partition walls **4** of the cells **3** of the honeycomb structure **1** is preferably 0.5 to 5 g/cm^3. When the density is below 0.5 g/cm^3, the partition walls **4** have insufficient strength, and the partition walls **4** may break due to pressure when the first fluid passes through the passage. In addition, when it is above 5 g/cm^3, the honeycomb structure **1** itself becomes heavy, and the characteristic of weight reduction may be impaired. The density within the aforementioned range enables to make the honeycomb structure **1** strong. In addition, an effect of improving thermal conductivity can be obtained.

[0056] It is preferable to use ceramic excellent in heat resistance for the honeycomb structure **1**, and silicon carbide is particularly preferable in consideration of heat-transfer performance. However, it is not necessary that the entire honeycomb structure **1** is constituted of silicon carbide as long as silicon carbide is contained in the main body. That is, the honeycomb structure **1** is preferably formed of electrical conductive ceramic containing silicon carbide. As a physical property of the honeycomb structure **1**, thermal conductivity λ [W/mK] at room temperature is preferably $10 \le \lambda \le 300$ though it is not limited thereto. In place of the electrical conductive ceramic, there can be used a corrosion resistant metal material such as Fe—Cr—Al-based alloy.

[0057] In order for a heat exchanger **30** of the present invention to obtain a high temperature efficiency, it is more preferable to use a material containing silicon carbide having high thermal conduction as the material for the honeycomb structure **1**. However, since even silicon carbide cannot obtain high coefficient of thermal conductivity when it is a porous body, it is more preferable to obtain a dense body structure by impregnating the porous body with silicon in the production process of the honeycomb structure **1**. By the dense body structure, high coefficient of thermal conductivity can be obtained. For example, in the case of a silicon carbide porous body, it is about 20 W/mK. However, by densifying the body, it can be made about 150 W/mK.

[0058] That is, though Si-impregnated SiC, (Si+Al)-impregnated SiC, metal composite SiC, Si_3N_4, and SiC (in particular, densified material consisting of SiC is preferable), and the like can be employed as the ceramic material; it is more desirable to employ Si-impregnated SiC or (Si+Al)-impregnated SiC in order to obtain a dense body structure for obtaining high temperature efficiency. Since Si-impregnated SiC has a structure where a solidification of metal silicon melt surrounds the surface of a SiC particle and where SiC is unitarily bonded by means of metal silicate, silicon carbide is blocked from an atmosphere containing oxygen and inhibited from oxidation. Further, though SiC is characterized by high thermal conductivity and easy heat dissipation, SiC impregnated with Si is formed densely while showing high thermal conductivity and heat resistance, thereby showing sufficient strength as a heat transfer member. That is, a honeycomb structure **1** formed of a Si—SiC based (Si-impregnated SiC, (Si+Al)-impregnated SiC) material shows a characteristic excellent in corrosion resistance against acid and alkali in addition to thermal resistance, thermal shock resistance, and oxidation resistance and shows high thermal conductivity.

[0059] More specifically, in the case where the honeycomb structure **1** employs Si-impregnated SiC composite material or (Si+Al)-impregnated SiC as the main component, when the Si content specified by Si/(Si+SiC) is too small, bonding of adjacent SiC particles by a Si phase becomes insufficient because of the insufficient bonding material, which not only lowers thermal conductivity, but also makes it difficult to obtain strength capable of maintaining a thin wall structure such as a honeycomb structure. Conversely, when the Si content is too large, it is not preferable in that negative effects such as lowering of porosity and reduction in the average pore size are caused in combination by excessive shrinkage of the honeycomb structure **1** by firing due to the excess presence of metal silicon than necessary for appropriately bonding the SiC particles together. Therefore, the Si content is preferably 5 to 50 mass %, more preferably 10 to 40 mass %.

[0060] Such Si-impregnated SiC or (Si+Al)-impregnated SiC has pores filled up with metal silicon to have a porosity of 0 or nearly 0, is excellent in oxidation resistance and durability, and is capable of use for a long period of time under a high temperature atmosphere. Since an oxidation protective coat is formed when it is once oxidized, oxidation deterioration is not generated. In addition, since it has high strength from ordinary temperature to high temperature, a thin and light structure can be formed. Further, it has high thermal conductivity, which is almost the same as those of copper and aluminum metals, and high far infrared radiation emissivity, and it hardly has static electricity because it has electrical conductivity.

[0061] In the case where the first fluid (high temperature side) passed through a heat exchanger **30** of the present invention is exhaust gas, it is preferable that a catalyst is loaded on the partition walls inside the cells **3** of the honeycomb structure **1** where the first fluid (high temperature side) passes. It is because it becomes possible to exchange also reaction heat (exothermic reaction) generated upon exhaust gas purification in addition to the role of purifying exhaust gas. It is good to contain at least one kind of an element selected from the group consisting of noble metals (platinum, rhodium, palladium, ruthenium, indium, silver, and gold), aluminum, nickel, zirconium, titanium, cerium, cobalt, manganese, zinc, copper, zinc, tin, iron, niobium, magnesium, lanthanum, samarium, bismuth, and barium. These may be metals, oxides, or other compounds. The amount of the catalyst (catalyst metal+carrier) loaded on the first fluid passage portion **5** of the honeycomb structure **1** where the first fluid (high temperature side) passes is preferably 10 to 400 g/L, and if it is noble metal, more preferably 0.1 to 5 g/L. When the amount of the catalyst (catalyst metal+carrier) loaded is below 10 g/L, exhibition of the catalysis may be difficult. On the other hand, when it is above 400 g/L, production costs may increase in addition to increase of pressure drop. A catalyst is loaded on the partition walls **4** of the cells **3** of the honeycomb structure **1** as necessary. In the case of loading a catalyst, masking is provided on the honeycomb structure **1** so that the catalyst is loaded on the honeycomb structure **1**. After impregnating a ceramic powder functioning as carrier microparticles with an aqueous solution containing a catalyst component in advance, catalyst coated microparticles are obtained by drying and firing. A dispersant (water or the like) and other additives are added to the catalyst coated microparticles to prepare coating liquid (slurry), and, after the partition walls **4** of the honeycomb structure **1** are coated with the slurry, drying and firing are performed to load a catalyst on the partition walls **4** of the cells **3** of the honeycomb structure **1**. Incidentally, upon firing, the mask on the honeycomb structure **1** is removed.

[0062] There is no particular limitation on the heating body as the first fluid being passed through a heat exchanger **30** of the present invention having such a configuration as long as it is a medium having heat, such as gas and liquid. For example, an automobile exhaust gas can be mentioned as the gas. In addition, there is no particular limitation on the body to be heated as the second fluid, which receives heat (exchanges heat) from the heating body, as long as it is a medium having lower temperature than the heating body, such as gas and liquid. Since at least one of the partition walls **4** and the outer peripheral wall **7*h*** is formed densely, liquid is preferably used as the second fluid, and water is preferable in consideration of handling. However, it is not particularly limited to water.

[0063] As described above, since the honeycomb structure **1** has high heat conductivity and a plurality of positions serving as passages by the partition walls **4**, high temperature efficiency can be obtained. Therefore, the entire honeycomb structure **1** can be downsized, and therefore it can be mounted on vehicles.

[0064] A further description will be given regarding another embodiment in the case where the honeycomb structure **1** as the heat exchanger element has a cylindrical shape. FIG. **5**A is a perspective view showing another embodiment of a heat exchanger **30** where a cylindrical honeycomb structure **1** is housed in a casing **21**, FIG. **5**B is a cross-sectional view cut along a cross section parallel to the axial direction, and FIG. **5**C is a cross-sectional view cut along a cross section perpendicular to the axial direction.

[0065] In the embodiment of FIGS. **5**A to **5**C, the inlet port **22** and the outlet port **23** of the second fluid are formed on the same side with respect to the honeycomb structure **1**. According to the installation location, piping, and the like of the heat exchanger **30**, it is possible to have such a structure of the present embodiment. In the present embodiment, the second fluid passage portion **6** has an enclosing structure, wherein it encloses the outer periphery of the honeycomb structure **1**. That is, the second fluid passes so as to enclose the outer periphery of the honeycomb structure **1**.

[0066] FIG. **6** shows a cross-sectional view cut along a cross section parallel to the axial direction, showing an embodiment of a heat exchanger **30** where a honeycomb structure **1** is provided with a punching metal **55** of a hole-provided metal plate having a plurality of holes on the outer peripheral face **7** thereof in the second fluid passage portion **6**. A cylindrical honeycomb structure **1** is housed in the casing **21**. The punching metal **55** is provided so as to engage with the outer peripheral face **7** of the honeycomb structure **1** in the second fluid passage portion **6**. The punching metal **55** is a metal plate subjected to a hole-making process and is formed into a tubular shape along the shape of the outer peripheral face **7** of the honeycomb structure **1**. That is, since the punching metal **55** has pores **55*a***, there are portions where the second fluid is brought into direct contact with the honeycomb structure **1**, which inhibits reduction of heat transfer. By protecting the honeycomb structure **1** by covering the outer peripheral face **7** of the honeycomb structure **1** with the punching metal **55**, breakage of the honeycomb structure **1** can be suppressed. Incidentally, the hole-provided metal plate means a metal plate having a plurality of holes and is not limited to the punching metal **55**.

[0067] FIGS. **7**A and **7**B show a heat exchanger **30** of an embodiment where the casing **21** is formed into a tubular shape and spirally looped around the honeycomb structure **1** on its outer peripheral face **7**. FIG. **7**A is a schematic view for explaining the state where the casing **21** is spirally looped around the honeycomb structure **1** on its outer peripheral face

7. FIG. 7B is a schematic view in a direction parallel to the axial direction, for explaining the state where the casing **21** is spirally looped around the honeycomb structure **1** on its outer peripheral face **7**. In the present embodiment, since the inside of the tube functions as the second fluid passage portion **6**, and the casing **21** has a shape where it is looped around the honeycomb structure **1** on its outer peripheral face **7**, the second fluid passing through the second fluid passage portion **6** flows on the outer peripheral face **7** of the honeycomb structure **1** in a spiral manner without being brought into direct contact with the outer peripheral face **7** of the honeycomb structure **1** to exchange heat. Such a configuration can inhibit leakage and mixing of the first fluid and the second fluid even if the honeycomb structure **1** has a breakage.

[0068] FIG. **8** shows an embodiment of a heat exchanger **30** where the casing **21** is provided with a tubular portion **21***a* engaged with the outer peripheral face **7** of the honeycomb structure **1** and an outside casing portion **21***b* forming the second fluid passage portion **6** outside the tubular portion **21***a* as a single unit. The tubular portion **21***a* has a shape corresponding to the shape of the outer peripheral face **7** of the honeycomb structure **1**, and the outside casing portion **21***b* has a tubular shape having a space where the second fluid flows outside the tubular portion **21***a*. The inlet port **22** and the outlet port **23** for the second fluid are formed in a part of the outside casing portion **21***b*. In the present embodiment, the second fluid passage portion **6** is formed by being surrounded by the tubular portion **21***a* and outside casing portion **21***b*, and the second fluid flowing through the second fluid passage portion **6** flows in the circumferential direction without being brought into direct contact with the outer peripheral face **7** of the honeycomb structure **1** on the outer peripheral face **7** of the honeycomb structure **1** to exchange heat. Such a configuration can inhibit leakage and mixing of the first fluid and the second fluid even if the honeycomb structure **1** has a breakage.

[0069] Next, a manufacturing method of a heat exchanger **30** of the present invention will be described. In the first place, a ceramic forming raw material is extruded to form a honeycomb formed body having a plurality of cells **3** partitioned by ceramic partition walls **4**, passing through in the axial direction from one end face **2** to the other end face **2**, and functioning as fluid passages separated and formed therein.

[0070] Specifically, it can be manufactured as follows. After forming a honeycomb formed body by extruding a kneaded material containing a ceramic powder into a desired shape, drying and firing are performed to obtain a honeycomb structure **1** where a plurality of cells **3** functioning as gas passages are separated and formed by partition walls **4**.

[0071] As a material for the honeycomb structure **1**, the aforementioned ceramic materials can be used. For example, in the case of manufacturing a honeycomb structure having a Si-impregnated SiC composite material as the main component, in the first place, predetermined amounts of C powder, SiC powder, binder, and water or an organic solvent are kneaded together and formed to obtain a formed body having a desired shape. Next, the formed body is put in a pressure-reduced inert gas or vacuum under a metal Si atmosphere to impregnate the formed body with metal Si.

[0072] Incidentally, also, in the case of employing Si_3N_4, SiC, or the like, the forming raw material is made into a kneaded material, and extruding the kneaded material in the forming step enables to form a honeycomb-shaped formed body having a plurality of cells **3** separated by partition walls **4** and functioning as exhaust gas passages. This is dried and fired to obtain a honeycomb structure **1**. Then, the honeycomb structure **1** is housed in a casing **21** to manufacture a heat exchanger **30**.

[0073] In a heat exchanger **30** of the present invention, the heat exchanger **30** itself can be downsized because it shows high temperature efficiency in comparison with conventional ones. Further, since it can be manufactured from a single unitary die by extrusion, costs can be saved. The heat exchanger **30** can suitably be used in the case where the first fluid is gas whereas the second fluid is liquid, and can suitably be used for exhaust heat recovery and the like for improving automobile fuel consumption, for example.

EXAMPLES

[0074] Hereinbelow, the present invention will be described in more detail on the basis of Examples. However, the present invention is not limited to these Examples.

Examples 1 to 15, Comparative Examples 1 to 6

[0075] A heat exchanger **30** having the first fluid passage portion and the second fluid passage portion formed therein by the honeycomb structure **1** and the casing **21** was manufactured as follows.

[0076] (Manufacturing of Honeycomb Structure)

[0077] After a kneaded material containing a ceramic powder was extruded into a desired shape, it was dried and fired to manufacture a honeycomb structure **1** employing silicon carbide as the material and having a main body size as described in Table 1. Regardless of the external shape of the honeycomb structure **1**, the circle-equivalent diameter Ø, which is the diameter of a circle having the same area as the area of the heat collection portion, was 40 mm, and the entire length L [mm] of the honeycomb structure **1** in the axial direction was 100 mm. In addition, in Table 1, there were described thermal conductivity λ [W/K·m] of the material for the partition walls **4**, wall thickness t [mm] of the partition walls **4**, and cell density ρ [cell/sq.in.].

[0078] (Casing)

[0079] A stainless steel casing **21** was used as the outside container of the honeycomb structure **1**. In Examples 1 to 15, one honeycomb structure **1** was disposed in the casing **21** (see FIGS. **1**A and **2**C). The first fluid passage portion **5** was formed in the honeycomb structure, and the second fluid passage portion **6** was formed in the casing **21** so as to flow along the outer periphery of the honeycomb structure **1** (outside structure). In addition, the casing **21** was provided with pipes for introducing the first fluid into the honeycomb structure **1** and the second fluid into the casing **21** and for discharging them. Incidentally, the two pathways are completely separated from each other to avoid the first fluid and the second fluid from being mixed together (outer periphery flow structure). The honeycomb structures **1** of Examples 1 to 15 had the same external shape. In FIG. **2**C, the gap L**3** between the outer peripheral face **7** of the honeycomb structure **1** and the inner peripheral face **24** of the casing **21** was 1 mm.

[0080] (First Fluid and Second Fluid)

[0081] The same inlet port temperature and the same flow rate into the honeycomb structure **1** of the first fluid and the second fluid were employed. As the first fluid, nitrogen gas (N_2) having a temperature of 500° C. was used. As the second fluid, water was used.

[0082] (Test Method)

[0083] Nitrogen gas was passed through the first fluid passage portion **5** of the honeycomb structure **1**, and (cooling) water was passed through the second fluid passage portion **6** in the casing **21**. The flow rate of the nitrogen gas with respect to the honeycomb structure **1** was 6 L/s. The flow rate of the (cooling) water was 15 L/min. All the test conditions such as flow rate of the first fluid and the second fluid were made the same. Example 1 employed one having the passage for the second fluid in the outer peripheral portion of the pipe functioning as the first fluid passage (see FIG. **2**B). It was configured so that (cooling) water flowed outside the pipe (the gap (L**3**) was 1 mm) (see FIG. **2**C). The pipe capacity of Example 1 means the volume with the first fluid passage. A pressure gauges were disposed in the first fluid passage pipe in the upstream and the downstream of the honeycomb structure **1**, and pressure drop of the honeycomb structure **1** was determined.

[0084] (Test Result)

[0085] Table 1 shows temperature efficiency and pressure drop. The temperature efficiency (%) was calculated by the formula 1 by calculating the ΔT° C. (outlet port temperature−inlet port temperature of the honeycomb structure **1**) of each of the first fluid (nitrogen gas) and the second fluid (water). (Formula 1) Temperature efficiency (%)=(inlet port temperature of the first fluid (gas)−outlet port temperature of the second fluid (cooling water))/(inlet port temperature of the first fluid (gas)−outlet port temperature of the first fluid (gas))×100

TABLE 1

	Partition wall thickness t [mm]	Thermal conductivity λ [W/K · m]	Cell density ρ [cells/ sq. in.]	t × ρ	λ × ρ	Temperature efficiency [%]	Pressure drop [kPa]
Comp. Ex. 1	0.1	100	100	10	10000	30	0.15
Comp. Ex. 2	0.1	100	500	50	50000	40	2.8
Comp. Ex. 3	0.2	100	100	20	10000	35	0.3
Example 1	0.2	100	500	100	50000	70	3.4
Example 2	0.3	100	200	60	20000	70	1
Example 3	0.3	100	300	90	30000	80	1.6
Example 4	0.3	100	600	180	60000	85	4.6
Comp. Ex. 4	0.4	100	100	40	10000	40	0.5
Example 5	0.4	100	200	80	20000	75	1.2
Example 6	0.4	100	300	120	30000	85	1.8
Example 7	0.4	100	500	200	50000	85	2.9
Example 8	0.5	100	200	100	20000	80	1.5
Example 9	0.5	100	300	150	30000	85	1.9
Example 10	0.5	100	400	200	40000	85	2.6
Example 11	0.5	100	500	250	50000	85	3.3
Comp. Ex. 5	0.6	100	100	60	10000	45	0.7
Example 12	0.6	100	200	120	20000	80	1.6
Example 13	0.6	100	300	180	30000	85	2.2
Example 14	0.6	100	400	240	40000	85	3.1
Comp. Ex. 6	0.7	100	100	70	10000	45	0.8
Example 15	0.7	100	200	140	20000	80	1.7

[0086] Table 1 shows the temperature efficiency and pressure drop when the cell structure (thickness t of the partition walls **4** of the cells, and cell density ρ) was changed while the entire honeycomb length (L=100 mm) of the heat collection portion and thermal conductivity (100 [W/K·m]) of the material for the partition walls **4** of the honeycomb were made up the same number. At this time, by satisfying both a pressure drop of below 5.0 [kPa] and a temperature efficiency of above 50%, there can be achieved a weight-reduced and simple structure in comparison with a conventional product. The pressure drop becomes larger as the partition walls of the cells and the cell density increases, and the pressure drop exceeds 5.0 [kPa] when the wall thickness is 0.3 with a cell density of 600. On the other hand, when the wall thickness is 0.1 with a cell density of 100, the temperature efficiency does not exceed 50%.

Examples 16 to 23, Comparative Examples 7 to 9

[0087] Next, honeycomb structures were manufactured by varying thermal conductivity of the material of the partition walls **4** with the same external shape (circle-equivalent diameter Ø of 45 mm and entire length L of 100 mm) of the honeycomb structure **1** and the same wall thickness t of the partition walls **4**. The results are shown in Table 2.

TABLE 2

	Partition wall thickness t [mm]	Thermal conductivity λ [W/K · m]	Cell density ρ [cells/ sq. in.]	t × ρ	λ × ρ	Temperature efficiency [%]	Pressure drop [kPa]
Comp. Ex. 7	0.5	50	100	50	5000	40	0.6
Example 16	0.5	50	200	100	10000	70	0.9

TABLE 2-continued

	Partition wall thickness t [mm]	Thermal conductivity λ [W/K · m]	Cell density ρ [cells/ sq. in.]	t × ρ	λ × ρ	Temperature efficiency [%]	Pressure drop [kPa]
Example 17	0.5	50	300	150	15000	85	1.6
Example 18	0.5	50	500	250	25000	85	2.3
Comp. Ex. 8	0.5	100	100	50	10000	45	0.4
Example 19	0.5	100	200	100	20000	80	0.7
Example 20	0.5	100	300	150	30000	85	1.5
Comp. Ex. 9	0.5	150	100	50	15000	45	0.4
Example 21	0.5	150	200	100	30000	80	0.7
Example 22	0.5	150	300	150	45000	85	1.5
Example 23	0.5	150	500	250	75000	85	2.2

[0088] Though the temperature efficiency is low when the cell density is 100, it tends to become larger as the coefficient of thermal conductivity of the partition walls and the cell density increase. In order to satisfy the requirements of a heat exchanger element having better performance than a conventional one, specifically, a pressure drop of below 5.0 [kPa] and a temperature efficiency of above 50%; from Tables 1 and 2, it is necessary to satisfy all of $t \geq 0.2$, $\rho \geq 100$, $20 \leq t \times \rho \leq 250$, and $10{,}000 \leq \lambda \times \rho$ when the coefficient of thermal conductivity of the partition walls of the honeycomb structure is taken as λ [W/K·m], the wall thickness of the partition walls is taken as t [mm], and the cell density is taken as ρ [cells/sq.in.].

Examples 24 to 34

[0089] Next, thermal conductivity of the partition walls of the honeycomb structure **1** was determined as λ [W/K·m], the wall thickness of the partition walls was determined as t [mm], and the cell density was determined as ρ [cells/sq.in.]. Honeycomb structures **1** where the outer diameter (circle-equivalent diameter Ø) and the entire length (L) were changed with employing the same thermal conductivity, wall thickness, and the cell density. The results are shown in Table 3.

TABLE 3

	Partition wall thickness t [mm]	Thermal conductivity λ [W/K · m]	Cell density ρ [cells/ sq. in.]	t × ρ	λ × ρ	Circle-equivalent diameter Ø [mm]	Entire length L [mm]	L/Ø	Temperature efficiency [%]	Pressure drop [kPa]
Example 24	0.4	120	300	120	36000	10	100	10.0	60	4.7
Example 25	0.4	120	300	120	36000	20	100	5.0	70	3.1
Example 26	0.4	120	300	120	36000	20	150	7.5	85	3.4
Example 27	0.4	120	300	120	36000	30	100	3.3	85	2.4
Example 28	0.4	120	300	120	36000	40	100	2.5	85	1.9
Example 29	0.4	120	300	120	36000	50	100	2.0	80	1.3
Example 30	0.4	120	300	120	36000	50	150	3.0	85	1.5
Example 31	0.4	120	300	120	36000	60	100	1.7	60	0.6
Example 32	0.4	120	300	120	36000	60	200	3.3	70	0.75
Example 33	0.4	120	300	120	36000	70	100	1.4	50	0.3
Example 34	0.4	120	300	120	36000	70	300	4.3	55	0.35

[0090] The temperature efficiency has a tendency to rise as the outer diameter (circle-equivalent diameter Ø) increases and fall after it reaches a peak whereas the pressure drop has a tendency to decrease. In order to satisfy the aforementioned volume, pressure drop, and temperature efficiency, it is necessary to satisfy all of $20 \leq Ø \leq 60$, and $1.66 \leq L/Ø \leq 7.5$.

INDUSTRIAL APPLICABILITY

[0091] There is no restriction as to the use as far as the heat exchanger of the present invention is used for the heat exchange purpose between a heating body (high temperature side) and a body to be heated (low temperature side) even in the automobile fields and industrial fields. In the case where it is used for exhaust heat recovery from exhaust gas in the automobile fields, it can be used to improve fuel consumption of an automobile.

DESCRIPTION OF REFERENCE NUMERALS

[0092] **1**: honeycomb structure, **1***h*: complementary honeycomb structure, **1***j*: central axis, **2**: end face (in the axial direction), **3**: cell, **4**: partition wall, **5**: first fluid passage portion, **6**: second fluid passage portion, **7**: outer peripheral face, **7***h*: outer peripheral wall, **21**: casing, **21***a*: tubular portion, **21***b*: outside casing portion, **22**: inlet port (for second fluid), **23**: outlet port (for second fluid), **24**: inner peripheral face, **25**: inlet port of (first fluid), **26**: outlet port (for first fluid), **30**: heat exchanger, **55**: punching metal, **55***a*: hole (of punching metal)

1. A heat exchanger element formed as a honeycomb structure having a plurality of cells partitioned by ceramic partition walls, passing through in an axial direction from one end face to the other end face, and functioning as a first fluid passage portion where a heating body as the first fluid passes;

wherein at least one of the partition walls and an outer peripheral wall of the honeycomb structure is made dense to avoid the first fluid passing through the first fluid passage portion and a second fluid receiving heat from the first fluid by passing along an outer peripheral face of the outer peripheral wall of the honeycomb structure from being mixed together, and

all of $t \geq 0.2$, $\rho > 100$, $20 \leq t \times \rho \leq 250$, and **10,000**$\leq \lambda \times \rho$ are *satisfied* when thermal conductivity of a material for the *partition* walls of the honeycomb structure is taken as λ [W/K·*m*], *and*, in a cell structure of the honeycomb *structure*, *a* wall thickness of the partition walls is taken as t [*mm*] and a cell density is taken as ρ [*cells*/*sq*.*in*.].

2. The heat exchanger element according to claim **1**, wherein $20 \leq Ø \leq 60$ and $1.66 \leq L/Ø < 7.5$ are satisfied when, in the cell structure of the honeycomb structure, a circle-equivalent diameter of a cross-sectional area of a cross section perpendicular to the axial direction of the honeycomb structure is taken as Ø [mm], and the entire length in the axial direction of the honeycomb structure is taken as L [mm].

3. A heat exchanger provided with the honeycomb structure as the heat exchanger element according to claim **1** and a casing having an inlet port and an outlet port for the second fluid and containing the honeycomb structure therein,

wherein an inside of the casing functions as the second fluid passage portion, and the second fluid receives heat from the first fluid by passing along the outer peripheral face of the honeycomb structure in the second fluid passage portion.

4. A heat exchanger provided with the honeycomb structure as the heat exchanger element according to claim **2** and a casing having an inlet port and an outlet port for the second fluid and containing the honeycomb structure therein,

wherein an inside of the casing functions as the second fluid passage portion, and the second fluid receives heat from the first fluid by passing along the outer peripheral face of the honeycomb structure in the second fluid passage portion.

* * * * *