US 20070193732A1

(19) United States
(12) Patent Application Publication
Oofune et al.
(10) Pub. No.: US 2007/0193732 A1
(43) Pub. Date: Aug. 23, 2007

(54) HEAT EXCHANGER

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(21) Appl. No.: **11/700,985**

(22) Filed: **Feb. 1, 2007**

(30) **Foreign Application Priority Data**

Feb. 3, 2006 (JP) ................. 2006-027277
Jan. 23, 2007 (JP) ................. 2007-012991

**Publication Classification**

(51) **Int. Cl.**
*F28D 7/02* (2006.01)

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

(57) **ABSTRACT**

A heat exchanger has tubes defining first fluid passages through which a first fluid flows therein, an inlet part and an outlet part. Each tube has a first main wall and a second main wall. At least one of the first main wall and the second main wall has a projection projecting outside of the tube along a peripheral end and a first recess and a second recess recessed from the projection. The tubes are stacked such that the first and second main walls are opposed to each other and spaces are provided between the adjacent tubes by the projections. The spaces define second fluid passages through which a second fluid flows. The inlet part is in communication with the second fluid passages through the first recesses and the outlet part is in communication with the second fluid passages through the second recesses.

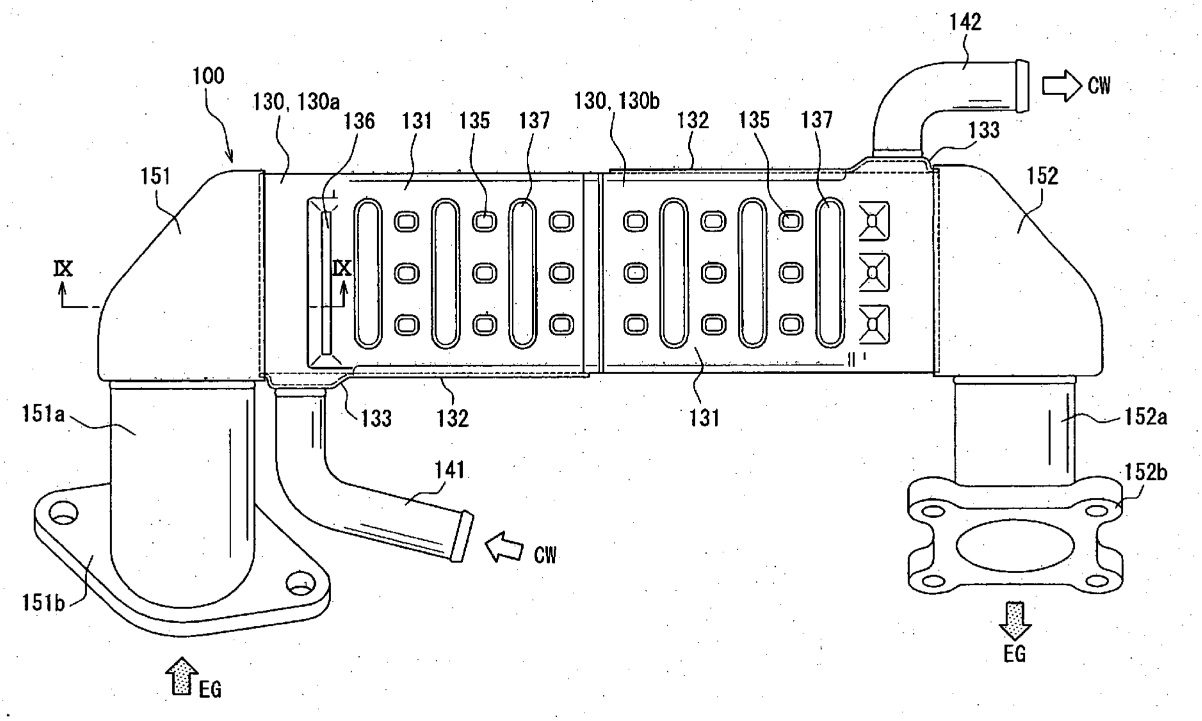
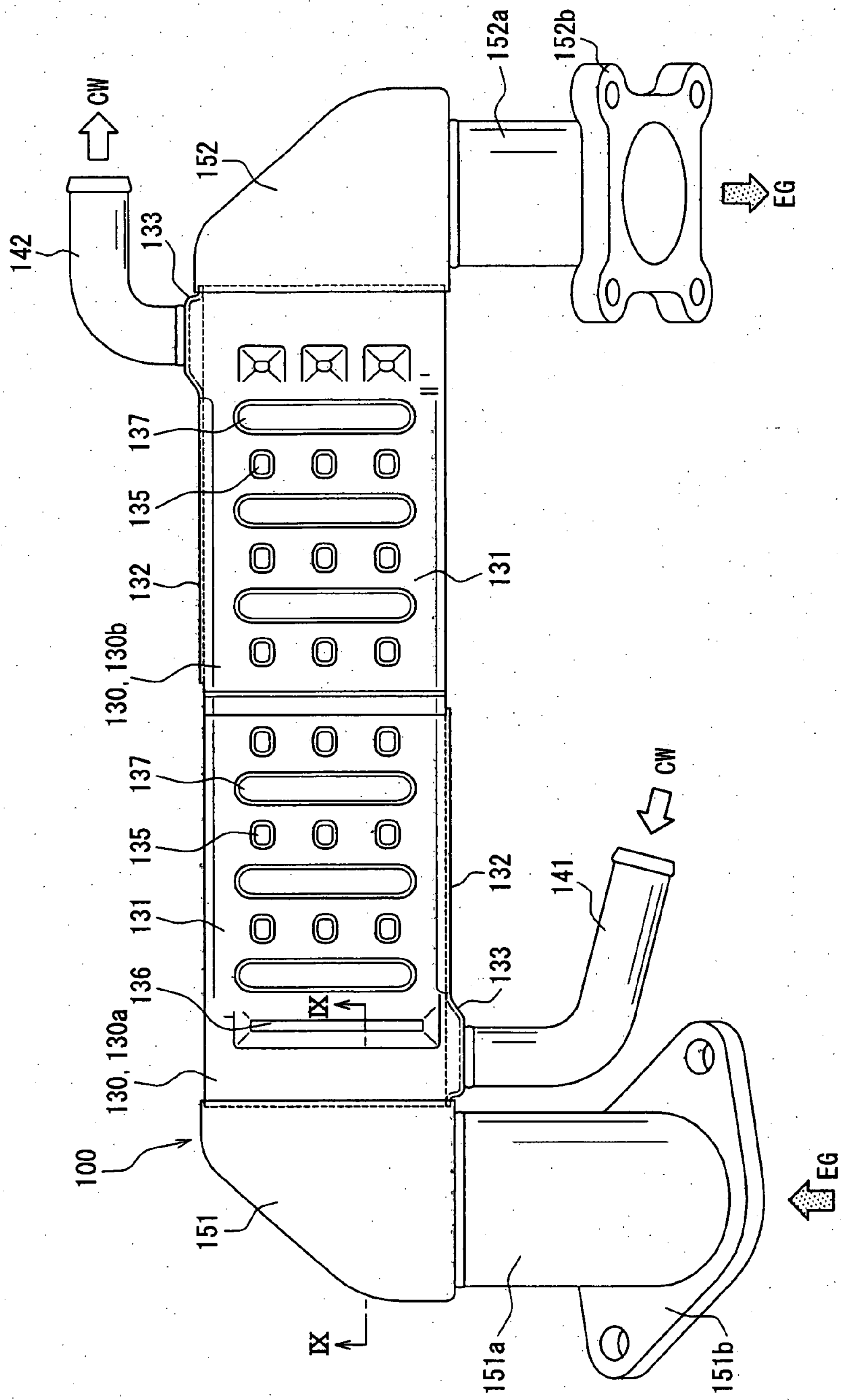


FIG. 1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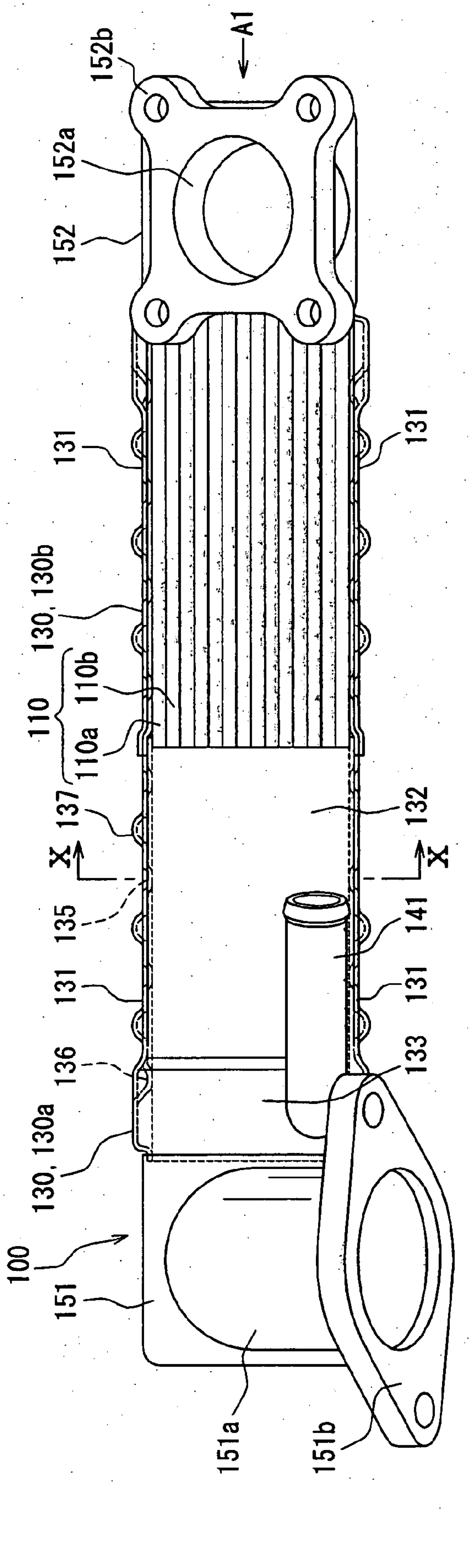
130, 130a
130, 130b
131
132
133
135
136
137
141
142
151
151a
151b
152
152a
152b
CW
EG
IX
II

FIG. 2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152
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131
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110b
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131
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133
130, 130a
100
151
151a
151b

FIG. 3

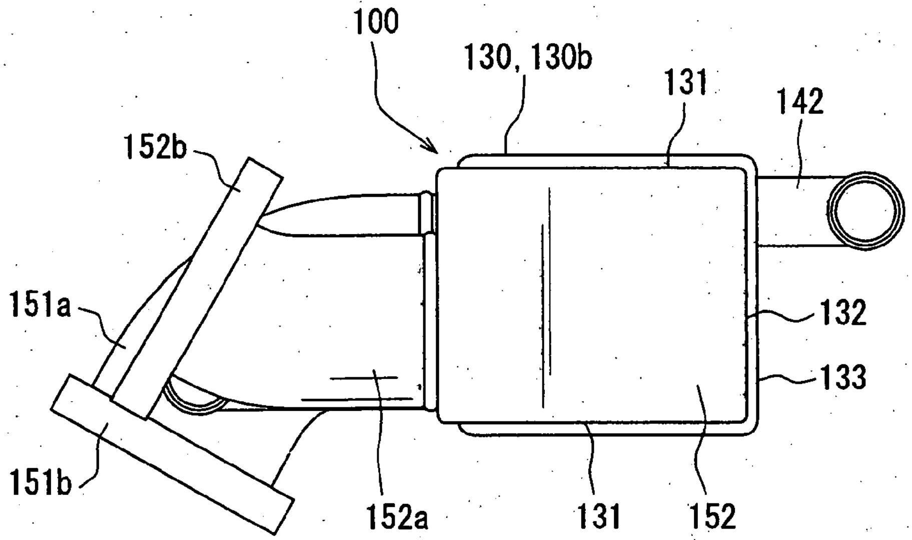



FIG. 6

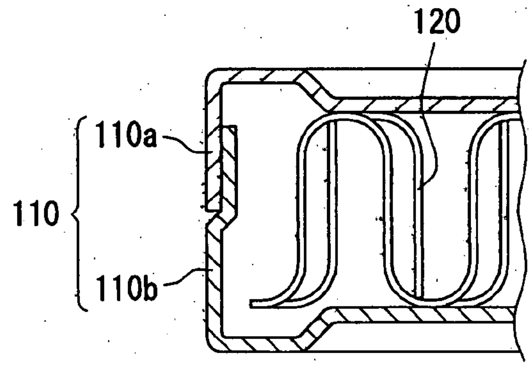



FIG. 7

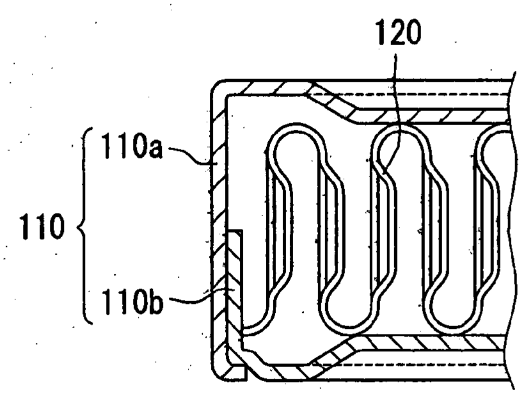
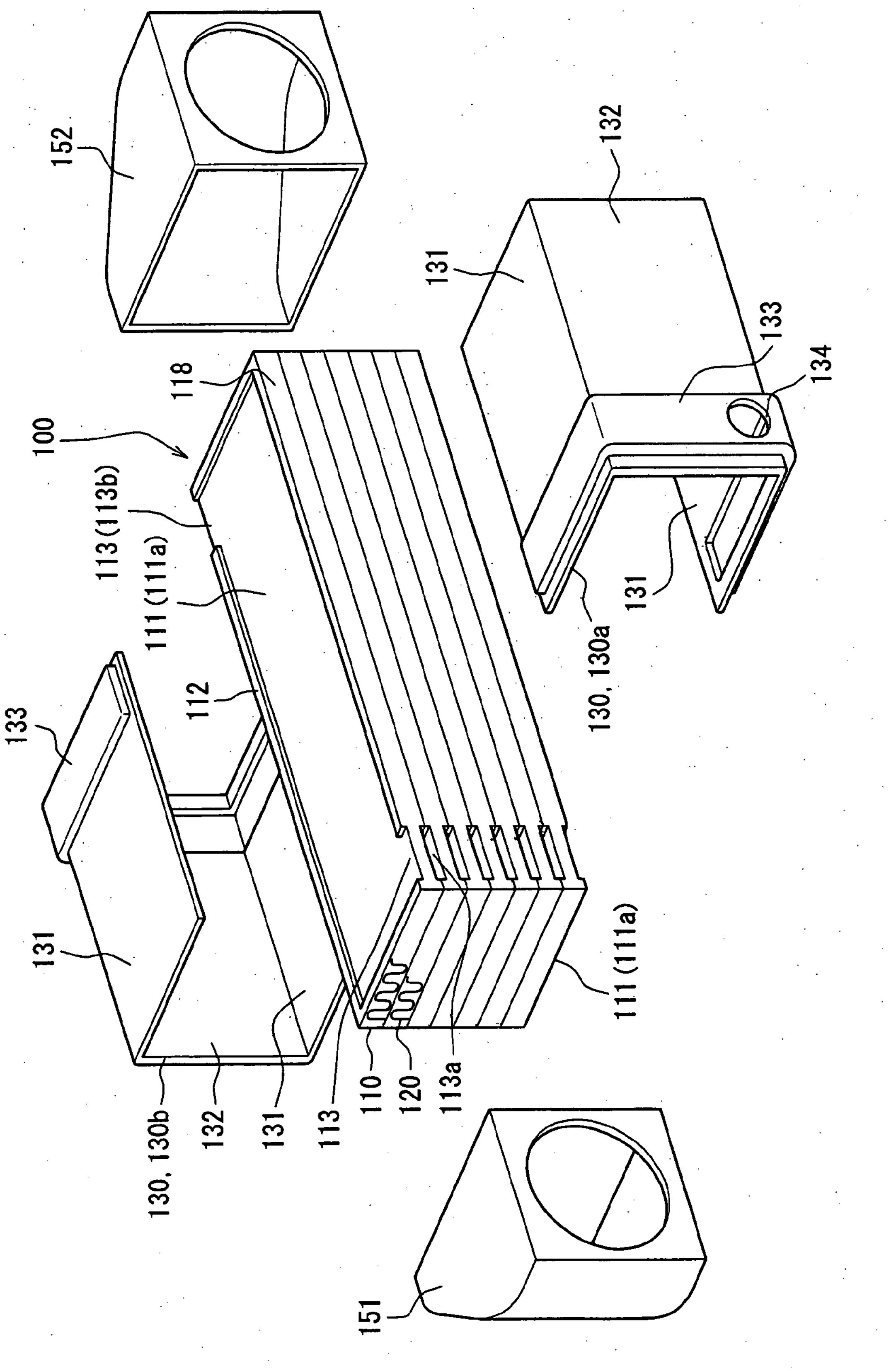


FIG. 4


152
132
131
133
134
100
118
113 (113b)
111 (111a)
112
133
131
130, 130a
131
111 (111a)
113a
120
110
113
131
132
130, 130b
151

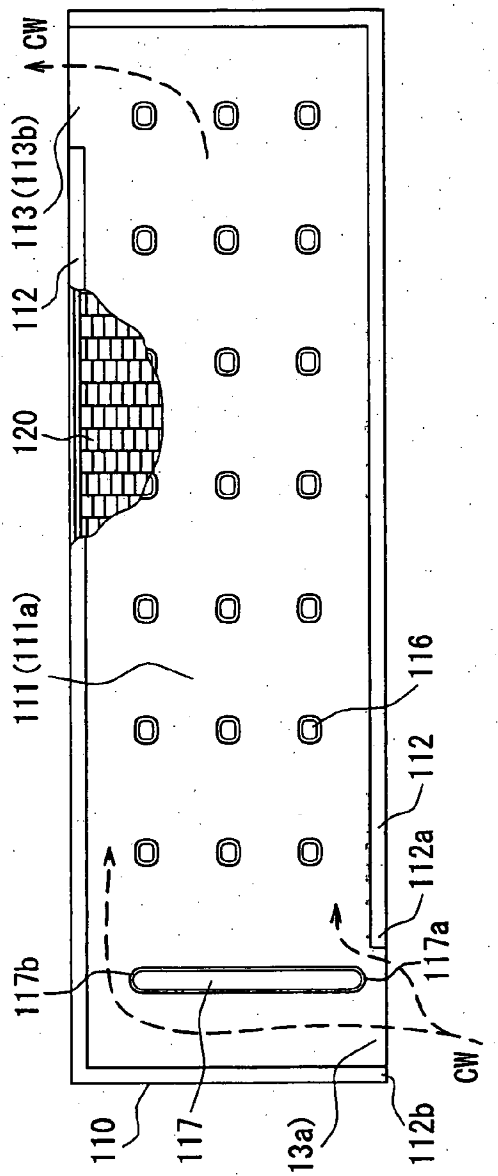



FIG. 5A

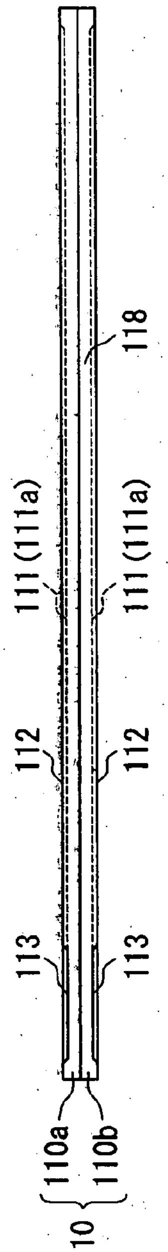



FIG. 5B

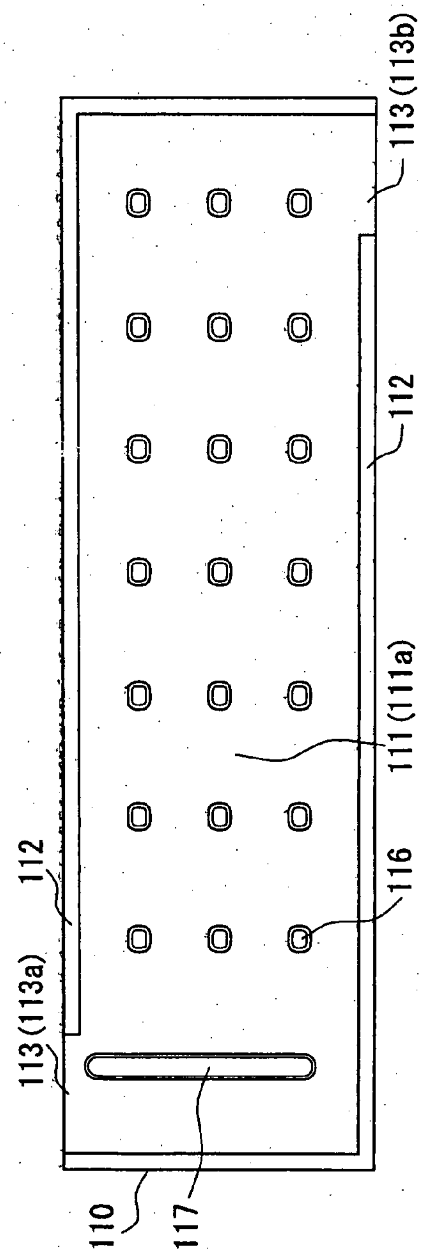
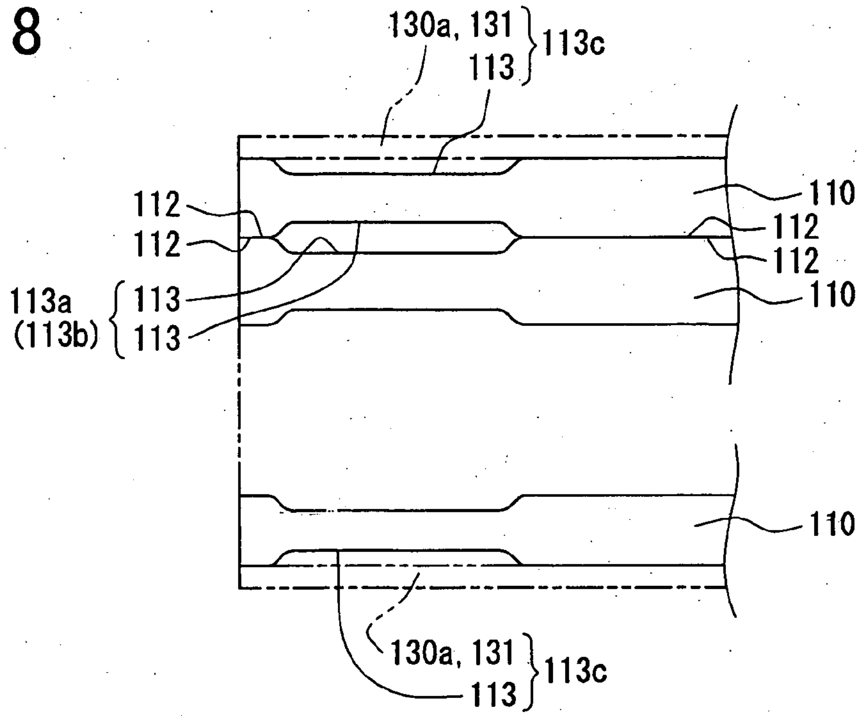



FIG. 5C

FIG. 8


130a, 131
113
113c
110
112
112
112
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113a
(113b)
113
113
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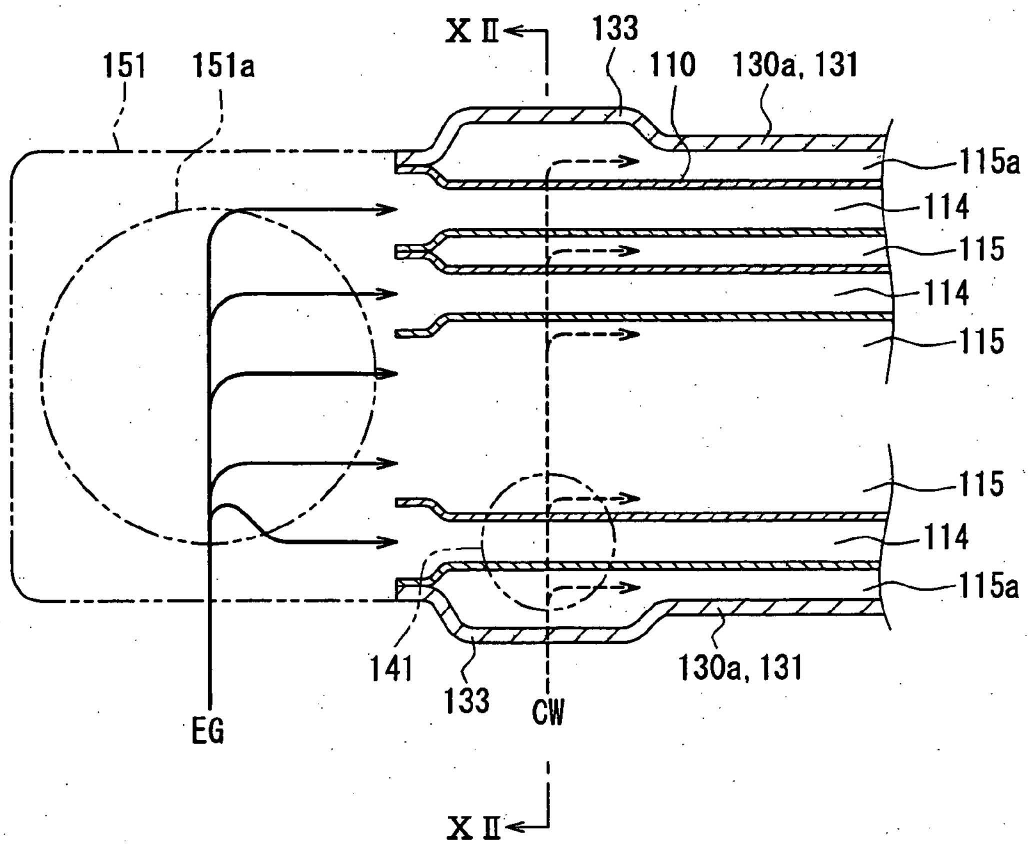
130a, 131
113
113c

FIG. 9


XII
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151a
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130a, 131
115a
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114
115
115
114
115a
141
133
130a, 131
CW
EG
XII

FIG. 10

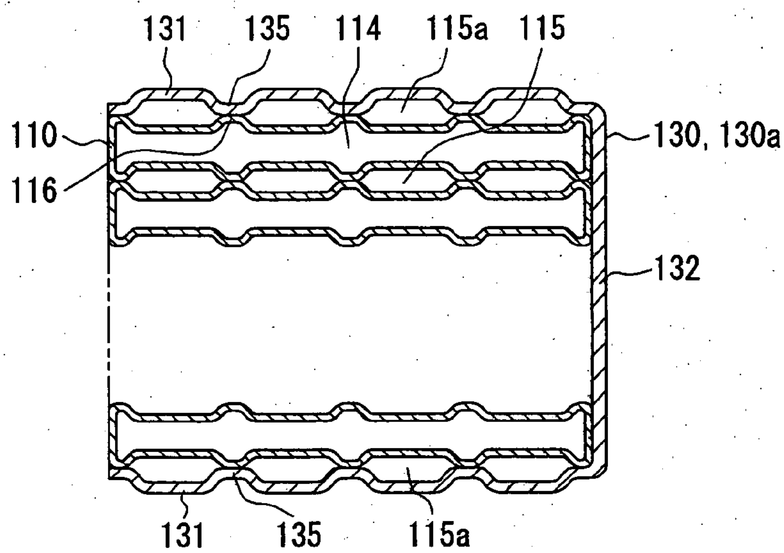



FIG. 11

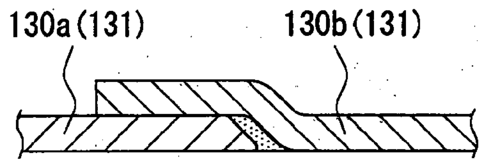



FIG. 12

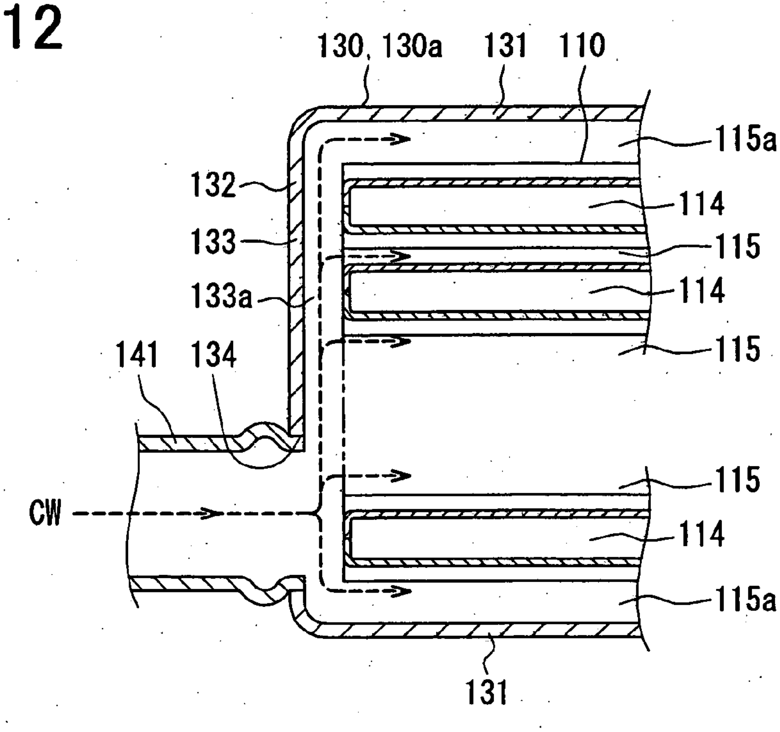
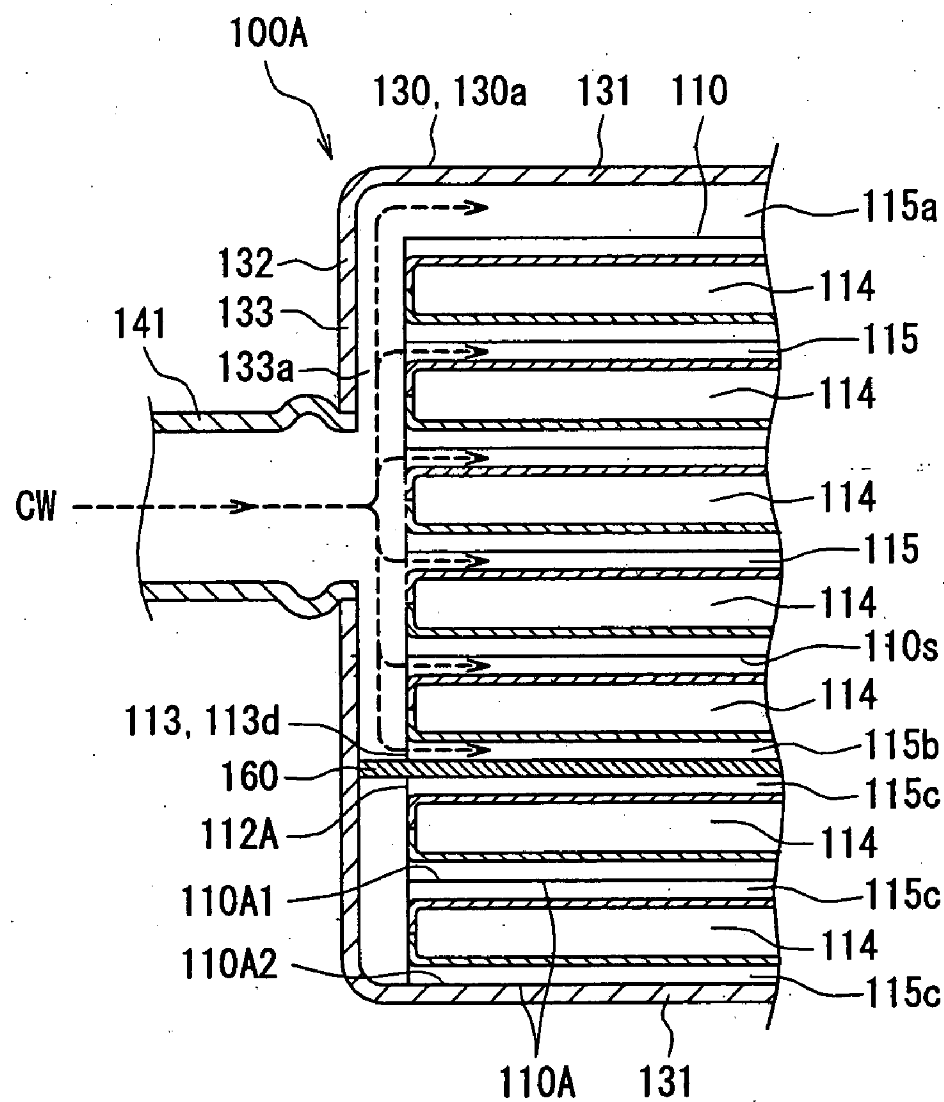


FIG. 13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110
115a
132
133
133a
141
114
115
114
CW
114
115
114
110s
113, 113d
114
115b
160
115c
112A
114
110A1
115c
110A2
114
115c
110A
131

# HEAT EXCHANGER

## CROSS REFERENCE TO RELATED APPLICATION

**[0001]** This application is based on Japanese Patent Application No. 2006-27277 filed on Feb. 3, 2006 and No. 2007-012991 filed on Jan. 23, 2007, the disclosures of which are incorporated herein by reference.

## FIELD OF THE INVENTION

**[0002]** The present invention relates to a heat exchanger, which is for example used in an exhaust gas recirculation system (EGR) for performing heat exchange between an exhaust gas and a cooling water.

## BACKGROUND OF THE INVENTION

**[0003]** Japanese Unexamined Patent Publication No. 2003-106790 (U.S. Pat. No. 6,595,274 B2) discloses an exhaust gas heat exchanger, which is for example used in an exhaust gas recirculation system. The exhaust gas heat exchanger performs heat exchange between a part of an exhaust gas that is discharged from an engine and returned to an air intake side of the engine and a cooling water, thereby to cool the exhaust gas.

**[0004]** In the exhaust gas heat exchanger, stacked tubes are housed in a tank, and bonnets are coupled to longitudinal ends of the tank. Also, core plates are provided at the longitudinal ends of the tank so as to separate the space inside of the tank from spaces of the bonnets. The longitudinal ends of the tubes are inserted to holes of the core plates. Further, a cooling water inlet pipe and a cooling water outlet pipe are coupled to the tank to make communication with the space defined in the tank.

**[0005]** The cooling water entering from the cooling water inlet pipe flows through spaces (water passages) defined outside of the tubes in the tank and flows out of the tank from the cooling water outlet pipe. On the other hand, the exhaust gas is introduced into gas passages defined inside of the tubes from one of the bonnets. The exhaust gas is collected in the other bonnet and discharged to be returned to the engine. Thus, the exhaust gas is cooled by the cooling water while flowing through the tubes.

**[0006]** In the exhaust gas heat exchanger, the core plates are provided to support the tubes such that the spaces for the water passages are provided between the adjacent tubes. Namely, the core plates will not contribute to heat exchanging performance. In manufacturing the exhaust gas heat exchanger, it is necessary to insert the longitudinal ends of the tubes into the holes of the core plates. Thus, steps increase in the manufacturing process, resulting in increase in manufacturing costs.

## SUMMARY OF THE INVENTION

**[0007]** The present invention is made in view of the foregoing matter, and it is an object of the present invention to provide a heat exchanger having a structure capable of providing spaces between adjacent tubes without using a core plate.

**[0008]** According to an aspect of the present invention, a heat exchanger has a plurality of tubes, an inlet part and an outlet part. Each of the tubes defines a first fluid passage therein through which a first fluid flows. Each tube has a first main wall and a second main wall, and at least one of the first main wall and the second main wall has a projection projecting outside of the tube and along its peripheral end. A first recess and a second recess are formed on the projection at predetermined positions. The tubes are stacked such that the first main walls and the second main walls are opposed to each other and spaces are provided between the adjacent tubes by the projections. The spaces define second fluid passages through which a second fluid flows. Also, first openings are defined by the first recesses and second openings are defined by the second recesses. The inlet part is disposed in communication with the first openings for introducing the second fluid into the second fluid passages. The outlet part is disposed in communication with the second openings for discharging the second fluid from the second fluid passages.

**[0009]** In this construction, the spaces for the second fluid passages are provided between the adjacent tubes by the projections, without using core plates. Therefore, steps of manufacturing the heat exchanger reduces.

**[0010]** The inlet part is for example constructed of an inlet portion for introducing the second fluid and a distributing portion for distributing the second fluid flowing from the inlet portion into the second fluid passages. The outlet part is for example constructed of a collecting portion for collecting the second fluid having passed through the second fluid passages therein and an outlet portion for discharging the second fluid from the collecting portion.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** Other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings, in which like parts are designated by like reference numbers and in which:

**[0012]** FIG. **1** is a schematic plan view of an EGR gas cooler according to a first embodiment of the present invention;

**[0013]** FIG. **2** is a schematic side view of the EGR gas cooler according to the first embodiment;

**[0014]** FIG. **3** is a schematic side view of the EGR gas cooler when viewed along an arrow Al in FIG. **2**;

**[0015]** FIG. **4** is an exploded perspective view of the EGR gas cooler according to the first embodiment;

**[0016]** FIG. **5**A is a top view of a tube of the EGR gas cooler according to the first embodiment;

**[0017]** FIG. **5**B is a side view of the tube according to the first embodiment;

**[0018]** FIG. **5**C is a bottom view of the tube according to the first embodiment;

**[0019]** FIG. **6** is a schematic cross-sectional view of a part of the tube as an example according to the first embodiment;

**[0020]** FIG. **7** is a schematic cross-sectional view of a part of the tube as another example according to the first embodiment;

**[0021]** FIG. **8** is a schematic side view of a stack of tubes of the EGR gas cooler according to the first embodiment;

**[0022]** FIG. **9** is a schematic cross-sectional view of the EGR gas cooler taken along a line IX-IX in FIG. **1**;

**[0023]** FIG. **10** is a cross-sectional view of the EGR gas cooler taken along a line X-X in FIG. **2**;

**[0024]** FIG. **11** is a schematic cross-sectional view of a joining portion between a first tank member and a second tank member of the EGR gas cooler according to the first embodiment;

**[0025]** FIG. **12** is a schematic cross-sectional view of the EGR gas cooler taken along a line XII-XII in FIG. **9**; and

**[0026]** FIG. **13** is a schematic cross-sectional view of an EGR gas cooler according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENT

**[0027]** A first embodiment will be described with reference to FIGS. **1** to **12**. A heat exchanger shown in FIG. **1** is for example used as an EGR gas cooler for an exhaust gas recirculation system (EGR) of a diesel engine.

**[0028]** As shown in FIGS. **1** to **4**, an EGR gas cooler **100** performs heat exchange between an exhaust gas (first fluid) to be returned to an engine of a vehicle and an engine cooling water (second fluid), thereby cooling the exhaust gas. In the drawings, arrows CW denote flows of the cooling water, and arrows EG denote flows of the exhaust gas.

**[0029]** Components of the EGR gas cooler **100** are made of materials, such as stainless, having sufficient strength and sufficient resistance to corrosion. The respective components are joined by such as brazing or welding.

**[0030]** The EGR gas cooler **100** has a stack of tubes **110**, a water tank **130**, a first gas tank **151**, and a second gas tank **152**. As shown in FIGS. **5**A to **9**, each tube **110** has a substantially flat tubular shape and defines a gas passage (first fluid passage) **114** therein through which the exhaust gas flows. The tube **110** has a substantially rectangular-shaped cross-section.

**[0031]** For example, each tube **110** is constructed of a first tube plate (first tube member) **110***a* and a second tube plate (second tube member) **110***b*. Each of the first and second tube plates **110***a*, **110***b* is shaped from a flat plate member such as by pressing or rolling to have a substantially U-shaped cross-section. Specifically, the tube plate **110***a*, **110***b* has a main wall and side walls on opposite sides of the main wall.

**[0032]** As shown in FIG. **6**, the first and second tube plates **110***a*, **110***b* are joined such that the respective side walls partly overlap with each other. FIG. **6** shows an example in which the side walls overlap at a substantially middle portion of a side of the tube **110**. FIG. **7** shows another example in which the side walls overlap at a position close to the main wall of the second tube plate **110***b*. The main wall of each tube plate **110***a*, **110***b* provides a tube main wall (opposed wall) **111**. The joined side walls of the tube plate **110***a*, **110***b* provide tube side walls **118**.

**[0033]** The tube **110** has an inner fin **120** therein. The inner fin **120** is for example a corrugated fin and formed from a thin plate member by pressing. For example, the inner fin **120** is interposed between the first and second tube plates **110***a*, **110***b* and joined such as by brazing. As such, the inner fin **120** is joined to inner surfaces of the tube main walls **111**.

**[0034]** The tubes **110** are stacked such that the tube main walls **111** are opposed to each other, as shown in FIGS. **4**, **8** and **9**. The gas passages **114** are formed within the tubes **110**. On the other hand, water passages (second fluid passages) **115** through which the cooling water flows are provided by spaces defined between the adjacent tubes **110**. The main walls **111** of the outermost tubes **110**, which are disposed on outermost layers of the stack of the tubes **110**, provide outermost tube walls **111***a*.

**[0035]** Each of the tube **110** has projections **112** and recesses **113** on its both main walls **111**, as shown in FIGS. **5**A to **5**C. Here, all tubes **110** have the same structure. Thus, the outermost tubes **110** also have the projections **112** and the recesses **113** on the outermost tube walls **111***a*, as shown in FIG. **4**.

**[0036]** The projection **112** projects outwardly from the tube main wall **111**. The projection **112** is for example formed by pressing. The projection **112** is formed along a peripheral end of the tube main wall **111** like a continuous dam.

**[0037]** The recesses **113** are recessed from a top end of the projection **112** toward the tube main wall **111**. Each recess **113** has a predetermined length in a longitudinal direction of the tube main wall **111**. The dimension of the recess **113** is for example equal to the dimension (height) of the projection **112** in a direction perpendicular to the tube main wall **111**. In other words, the projection **112** is not formed at a part corresponding to the recess **113**.

**[0038]** Here, two recesses **113** are formed on each tube main wall **111**. Also, the recesses **113** are located on diagonal positions and along longitudinal sides of the tube main wall **111**.

**[0039]** Further, the tube **110** has first raised portions **116** on both tube main walls **111** thereof. The first raised portions **116** are arranged at predetermined intervals over the tube main wall **111**. Each raised portion **116** projects outwardly from the tube main wall **111** in a form of tube and has the same dimension (height) as the projection **112** in a direction perpendicular to the tube main wall **111**.

**[0040]** The tube **110** further has second raised portions **117** on both tube main walls **111** thereof as flow-adjusting portions for adjusting or arranging the flow of the cooling water. Each second raised portion **117** is located adjacent to one of the recesses **113** (left recess in FIGS. **5**A and **5**C, hereafter, referred to as a first recess **113**), which is located upstream of the other recess **113** with respect to the flow of the cooling water.

**[0041]** The second raised portion **117** extends parallel to a short side of the tube main wall **111**, i.e., extends perpendicular to a longitudinal direction of the tube **110**. The second raised portion **117** has the same height as the projection **112**. Further, the second raised portion **117** is located closer to a first end **112***a* of a first portion of the projection **112** than a second end **112***b* of the projection **112** with respect to the longitudinal direction of the tube main wall **111**. The first portion extends along the longitudinal side of the tube main wall **111**, and the second portion extends along the short side of the tube main wall **111**.

**[0042]** Furthermore, the second raised portion **117** is located such that a distance between its first end (upstream end) **117***a* and the longitudinal side of the tube main wall **111** is smaller than a distance between its second end (downstream end) **117***b* and the opposite longitudinal side of the tube main wall **111**, with respect to a direction perpendicular to the longitudinal direction of the tube **110**.

**[0043]** As shown in FIG. **8**, the tubes **110** having the above structure are stacked such that the respective projections **112** are opposed and in contact with each other. As such, the tubes **110** are joined to each other at the projections **112**. In this case, the first raised portions **116** and the second raised portion **117** have the same height as the projection **112**. Thus, the adjacent tubes **110** are also in contact with and are joined at the first raised portions **116** and the second raised portion **117**. Further, the inner fins **120** are joined to the inner surfaces of the tubes **110**. Accordingly, the strength of the stack of the tubes **110** improves.

[0044] In the stack of the tubes **110**, spaces are provided between the adjacent tubes since the projections **112** are formed on the tube main walls **111**. Each space is surrounded by the projections **112**. As such, the cooling water passage **115** is defined by this space except for the first raised portions **116** and the second raised portions **117**, as shown in FIGS. **9** and **12**.

[0045] Further, openings **113***a* are provided by the recesses **113** of the adjacent tubes **110**. Here, the openings **113***a* provided by the first recesses **113**, which are adjacent to the second raised portions **117**, define inlet opening **113***a* for introducing the cooling water into the cooling water passages **115**. The openings **113***b* provided by the second recesses **113** (right recesses **113** in FIG. **5**B), which are further from the second raised portion **117**, define outlet openings **113***b* for discharging the cooling water from the cooling water passages **115**.

[0046] The water tank **130** includes a first tank member **130***a* and a second tank member **130***b*, which are arranged in the longitudinal direction of the tubes **110**. The first tank member **130***a* is disposed adjacent to the inlet openings **113***a* of the stack of the tubes **110**, and the second tank member **130***b* is disposed adjacent to the outlet openings **113***b* of the stack of the tubes **110**.

[0047] Each of the first and second tank members **130***a*, **130***b* has a substantially U-shape and includes outer walls **131** and a connecting wall **132** between the outer walls **131**. The outer walls **131** are parallel to each other. The first and second tank members **130***a*, **130***b* are formed from plate members by bending, for example.

[0048] The first and second tank members **130***a*, **130***b* are coupled to the stack of the tubes **110** so as to substantially surround the stack of the tubes **110**. Thus, the outer walls **131** are opposed to the outermost tube walls **111***a* and the connecting walls **132** are opposed to the tube side walls **118**.

[0049] In this case, since the inlet openings **113***a* and the outlet openings **113***b* are located on diagonal positions of the stack of the tubes **110**, the first and second tank members **130***a*, **130***b* are coupled from opposite sides of the stack of the tubes **110**. Specifically, the connecting portion **132** of the first tank member **130***a* are opposed to the inlet openings **113***a*, and the connecting portion **132** of the second tank member **130***b* are opposed to the outlet openings **113***b*.

[0050] Further, as shown in FIG. **11**, the first and second tank members **130***a*, **130***b* are engaged with each other at ends thereof such that the outer walls **131** thereof share a plane. Thus, the first and second tank members **130***a*, **130***b* are engaged at a substantially middle position of the stack of the tubes **110** in the longitudinal direction of the tubes **110**. For example, the ends of the first and second tank members **130***a*, **130***b* overlap with each other.

[0051] Although the first and second tank members **130***a*, **130***b* are coupled to the stack of the tubes **110** in opposite directions, these have the same shape. Thus, the specific shape of the first and second tank members **130***a*, **130***b* is described hereafter about the first tank member **130***a* as an example.

[0052] As shown in FIGS. **1**, **2** and **10**, a peripheral end of each outer wall **131** is in contact with and joined to the projection **112** of the outermost tube wall **111***a*. A main portion of each outer wall **131**, other than the peripheral end, is raised from the peripheral end in an outward direction of the U-shaped tank member **130***a*. Further, first recesses **135**, a second recess **136**, and reinforcement ribs **137** are formed on the raised main portion of each outer wall **131**.

[0053] The first recesses **135** are recessed from the raised main portion so as to be in contact with and joined to the first raised portions **116** of the outermost tube wall **111***a*. The second recess **136** is recessed from the raised main portion so as to be in contact with and joined to the second raised portion **117** of the outermost tube wall **111***a*, as the flow-adjusting portion. The reinforcement ribs **137** are located between the first recesses **135** and project from the raised main wall, as shown in FIG. **2**.

[0054] As shown in FIGS. **9** and **10**, a space is provided between one outer wall **131** and the outermost tube wall **111***a*. The space is surrounded by the peripheral end of the outer wall **131** and the projection **112** of the outermost tube wall **111***a*. Thus, similar to the cooling water passages **115**, an end water passage **115***a* is defined by this space except for the first raised portions **116**, the first recesses **135** and the second raised portion **117** and the second recess **136**.

[0055] Further, as shown in FIG. **8**, an end opening **113***c* is formed between the outer wall **131** and the first recess **113** of the outermost tube **110** for introducing the cooling water into the end water passage **115***a*. Likewise, the end opening **113***c* is formed between the outer wall **131** and the second recess **113** of the outermost tube **110** for discharging the cooling water from the end water passage **115***a*.

[0056] The connecting wall **132** of the first tank member **130***a* is in contact with and joined to the side walls **118** on which the inlet openings **113***a*, **113***c* are formed. Likewise, the connecting wall **132** of the second tank member **130***b* is in contact with and joined to the side walls **118** on which the outlet openings **113***a*, **113***c* are formed.

[0057] The first tank member **130***a* is also formed with a bulge **133**. The bulge **133** expands in an outward direction of the first tank member **130***a* and extends over the outer walls **131** and the connecting wall **132**. In the connecting wall **132**, the bulge **133** is opposed to the inlet openings **131***a*, **131***c* so as to cover or encases the inlet openings **131***a*, **131***c*, and a clearance **133***a* is defined between an inner surface of the bulge **133** and the inlet openings **113***a*, **113***c* of the tubes **110**, as shown in FIG. **12**. The clearance **133***a* is in communication with the water passages **115**, **115***a* thorough the inlet openings **113***a*, **113***c*. Further, the end water passages **115***a* are partly expanded by the bulge **133** formed on the outer walls **131**, as shown in FIG. **9**.

[0058] As shown in FIGS. **4** and **12**, a pipe hole **134** is formed on the bulge **133**. A water inlet pipe (pipe member) **141** is coupled to the inlet hole **134**. Thus, the water passages **115**, **115***a* are in communication with an outside of the EGR gas cooler **100** through the inlet openings **113***a*, **113***c*, the clearance **133***a*, the pipe hole **134** and the water inlet pipe **141**. Thus, an inlet part is provided by the water inlet pipe **141** and the bulge **133** (clearance **133***a*) of the first tank member **130***a*. The water inlet pipe **141** corresponds to an inlet portion for introducing the cooling water into the clearance **133***a* of the bulge **133**, and the bulge **133** (clearance **133***a*) corresponds to a distribution portion for distributing the cooling water into the water passages **115**, **115***a*.

[0059] Likewise, a water outlet pipe (pipe member) **142** is coupled to the bulge **133** of the second tank member **130***b*. The water passages **115**, **115***a* are also in communication with the outside through the outlet openings **113***b*, **113***c*, the clearance **113***a*, the pipe hole **134** and the water outlet pipe **142**. Thus, an outlet part is provided by the water outlet pipe

142 and the bulge 133 (clearance 133*a*) of the second tank member 130*b*. The bulge 133*a* (clearance 133*a*) corresponds to a collecting portion for collecting the cooling water discharged from the water passages 115, 115*a* and the water outlet pipe 142 corresponds to an outlet portion for discharging the cooling water from the collecting portion to the outside.

**[0060]** The first gas tank 151 and the second gas tank 152 are coupled to the longitudinal end of the stack of the tubes 110. For example, the first gas tank 151 is coupled to the first end adjacent to the inlet part, and the second gas tank 152 is coupled to the second end adjacent to the outlet part.

**[0061]** The first gas tank 151 has a cup shape for defining a tank space therein. The first gas tank 151 is coupled such that its end defining an opening is in contact with and joined to the peripheral portions of the first ends of the stacked tubes 110 and the end of the first tank member 130*a*. Thus, the tank space of the first gas tank 151 is in communication with the gas passages 114 defined inside of the tubes 110.

**[0062]** Further, a gas inlet pipe 151 a is coupled to a side wall of the first gas tank 151 to be in communication with the tank space. For example, the gas inlet pipe 151*a* and the water inlet pipe 141 are disposed on the same side of the EGR gas cooler 100. The gas inlet pipe 151*a* has a flange 151*b* to be coupled to the exhaust gas recirculation system. As such, the gas passages 141 are in communication with the exhaust gas recirculation system through the first gas tank 151 and the gas inlet pipe 151*a*.

**[0063]** The second gas tank 152 has the shape similar to the first gas tank 151. The second gas tank 152 is coupled such that its end defining an opening is in contact with and joined to the peripheral portions of the second ends of the stacked tubes 110 and the end of the second tank member 130*b*. Thus, a tank space defined in the second gas tank 152 is in communication with the gas passages 114.

**[0064]** Further, a gas outlet pipe 152*a* is coupled to a side wall of the second gas tank 152. For example, the gas outlet pipe 152*a* is disposed on the same side as the gas inlet pipe 151*a* and the water inlet pipe 141. The gas outlet pipe 152*a* has a flange 152*b* at its end. Thus, the exhaust gas having passed through the gas passages 114 is discharged from the EGR gas cooler 100 through the second gas tank 152 and the gas outlet pipe 152*a*.

**[0065]** In this EGR gas cooler 100, as shown by the arrows EG in FIG. 1, a part of the exhaust gas discharged from the engine flows in the gas passages 114 from the inlet gas pipe 151*a*, the first gas tank 151. The exhaust gas having passed through the gas passages 114 is discharged through the second gas tank 152 and the gas outlet pipe 152*a* and returned to the engine.

**[0066]** On the other hand, as shown by the arrows CW in FIG. 1, the engine cooling water flows in the water passages 115, 115*a* from the inlet part provided by the water inlet pipe 141, the clearance 133*a* and the inlet openings 113*a*, 113*c*. The cooling water having passed through the water passages 115, 115*a* are discharged from the inlet part provided by the outlet openings 113*b*, 113*c*, the clearance 133*a*, and the water outlet pipe 142.

**[0067]** As such, the heat exchange is performed between the exhaust gas flowing through the gas passages 114 and the cooling water flowing through the water passages 115, 115*a*. As a result, the exhaust gas is cooled.

**[0068]** In a general heat exchanger, tube holes are formed on core plates at predetermined intervals and ends of the tubes are inserted to tube holes of the core plates. That is, the tubes are held with predetermined spaces by the core plates so as to provide passages between the adjacent tubes.

**[0069]** In the EGR gas cooler 100, the projections 112 and the recesses 113 are formed on the tube main walls 111. Thus, the water passages 115 are defined by the spaces provided between the tube main walls 111 of the adjacent tubes 110, and the inlet and outlet openings 113*a*, 113*b*, 113*c* are provided by the recesses 113.

**[0070]** Accordingly, the gas passages 114 and the water passages 115 are separated without requiring core plates. That is, the water passages 115 are provided without using the core plates. Also, since the core plates are not required, a step of inserting the ends of the tubes into the holes of the core plates is not necessary in manufacturing the EGR gas cooler 100. Therefore, manufacturing cots of the EGR gas cooler 100 reduce.

**[0071]** In this embodiment, the dimension of the recesses 113 is equal to the height of the projections 112. Therefore, the size of the inlet and outlet openings 113*a*, 113*b* is increased. Thus, resistance of the cooling water to flow in and out of the water passages 115 reduces.

**[0072]** Also, the inlet openings 113*a* and the outlet openings 113*b* are located on diagonal positions of the tube main walls 111. Therefore, a region where the cooling water easily stagnate is reduced. Namely, it is less likely that the cooling water will stagnate in the water passage 115. Accordingly, heat exchange efficiency improves.

**[0073]** Further, the second raised portions 117 are formed on the tube main walls 111 as the flow-adjusting portions. Therefore, the cooling water entering from the inlet openings 113*a*, 113*c* can be directed toward the second ends 117*b* of the second raised portions 117 to flow further inside of the tubes 110, as shown by a dashed arrow CW1 in FIG. 5A. As such, the cooling water can be substantially uniformly introduced over the water passages 115. Namely, the heat exchange is performed by effectively using the tube main walls 111. Accordingly, the heat exchange efficiency improves.

**[0074]** In a case that the cooling water stagnates in the water passage 115 at a position corresponding to a portion where the high temperature exhaust gas flows, heat exchange is excessively performed, resulting in boiling of the cooling water. In the embodiment, however, the second raised portion 117 is formed at an upstream side of each tube main wall 111 with respect to the flow of the exhaust gas. Therefore, it is less likely that the cooling water will boil due to the excess heat exchange.

**[0075]** In the embodiment, each tube 110 is constructed by joining the first and second tube plates 110*a*, 110*b*. The first and second tube plates 110*a*, 110*b* are formed such as by bending, pressing, rolling and the like. Therefore, the tubes 110 are produced easily and with reduced costs, as compared with a case in which a tube is formed by shaping a cylindrical tube member into a flat tubular shape.

**[0076]** In addition, since the inner fins 120 are provided in the gas passages 114 of the tubes 110, turbulence effect is provided to the flow of the exhaust gas. As such, the heat exchange efficiency further improves.

**[0077]** The projections 112 and the recesses 113 are also formed on the outermost tube walls 111*a* of the outermost tubes 110, and the outer walls 131 of the tank members 130*a*, 130*b* are joined to the projections 112 of the outermost tube walls 111*a*. Therefore, the end water passages 115*a* with the end inlet and outlet openings **113***c* are formed between the outermost tube walls **111***a* and the outer walls **131**. As such, since the heat exchange area increases, the heat exchange efficiency improves.

**[0078]** In each tank members **130***a*, **130***b*, the outer walls **131** are connected through the connecting wall **132**. Namely, the outer walls **131** are integrally formed into the tank member **130***a*, **130***b*. Therefore, the tank member **130***a*, **130***b* is easily coupled to the stack of the tubes **110** by inserting the stack of the tubes **110** into the space defined between the outer walls **131**.

**[0079]** The connecting walls **132** of the first and second tank members **130***a*, **130***b* are opposed to and joined to the side walls **118** of the tubes **110**. The bulges **133** are formed on the connecting walls **132** at positions corresponding to the inlet and outlet openings **113***a*, **113***b*, **113***c* such that the clearances **133***a* are provided between the inner surfaces of the bulges **133** and the inlet and outlet openings **113***a*, **113***b*, **113***c*. Further, the water inlet pipe **141** and the water outlet pipe **142** are coupled to the pipe holes **134** formed on the bulges **133**.

**[0080]** As such, the inlet part and the outlet part are provided by the bulges **133** and the water inlet and outlet pipes **141**, **142**. Namely, The inlet part and the outlet part are formed with simple structure. With this configuration, expansion loss or reduction loss while the cooling water flows into and out of the water passages **115**, **115***a* reduces. That is, because pressure loss of the flow of the cooling water reduces, the heat exchange efficiency improves.

## Second Embodiment

**[0081]** A second embodiment will be described with reference to FIG. **13**. In the second embodiment, a EGR gas cooler **100**A has bypass tubes **110**A and a partition wall **160** in addition to the structure of the EGR gas cooler **100** of the first embodiment. In FIG. **13**, the water inlet part is exemplary shown because a water inlet part and a water outlet part have the similar structure.

**[0082]** The bypass tubes **110**A are stacked on one side (lower side in FIG. **13**) of the stack of the tubes **110**. The bypass tubes **110**A define the gas passages **114** through which the exhaust gas flows, similar to the tubes **110**. The partition wall **160** is interposed between the tube **110** and the bypass tube **110**A. The partition wall **160** is for example made of stainless and has a rectangular shape. The stack of the tubes **110**, partition wall **160** and bypass tubes **110**A is disposed in the water tank **130**.

**[0083]** Similar to the first embodiment, the water tank **130** includes the first tank member **130***a* and the second tank member **130***b*. The stack of the tubes **110**, partition wall **160** and the bypass tubes **110**A are located between the outer walls **131** of the tank members **130***a*, **130***b*.

**[0084]** An end tube **110***s*, which is one of the tubes **110** and is opposed to the partition wall **160**, has a projection **112**, similar to the other tubes **110**. Thus, the end tube **110***s* is in contact with and joined to the partition wall **160** at the projection **112**. An end water passage **115***b* is formed between the tube main wall **111** of the end tube **110***s* and the partition wall **160**.

**[0085]** Further, the recesses **113** are formed on the end tube **110***s*. Thus, an inlet opening **113***d* is provided between the recess **113** of the end tube **110***s* and the partition wall **160**. The end water passage **115***b* is in communication with the clearance **133***a* through the inlet opening **113***d*.

**[0086]** In the example of FIG. **13**, the EGR gas cooler **100**A has two bypass tubes **110**A. Similar to the tubes **110**, each of the bypass tubes **110**A is constructed of a first tube plate and a second tube plate. The bypass tubes **110**A define the gas passages **114** therein through which the exhaust gas flows. Although not illustrated, reinforcement plates are interposed between the first and second tube plates and joined to inner walls of the first and second tube plates. Each reinforcement plate has a crank shape in its cross-section with a pitch greater than that of the inner fin **120** of the first embodiment.

**[0087]** The bypass tubes **110**A are formed with projections **112**A, similar to the projections **112** of the tubes **110**. Thus, the bypass tubes **110**A are stacked such that the projections **112**A are opposed to and joined to each other. Further, spaces are provided between the adjacent bypass tubes **110**A as thermal insulation spaces.

**[0088]** A first end bypass tube **110A1**, which is one of the bypass tubes **110**A and is opposed to the partition wall **160**, is joined to the partition wall **160** at the projection **112**A thereof. Thus, the thermal insulation space **115***c* is also provided between the partition wall **160** and the tube main wall of the first end bypass tube **110A1**.

**[0089]** A second end bypass tube **110A2**, which is one of the bypass tubes **110**A and is opposed to the outer wall **131**, is joined to the outer wall **131** through the projection **112**A thereof. Thus, the thermal insulation space **115***c* is also provided between the tube main wall of the second end bypass tube **110A2** and the outer wall **131**.

**[0090]** A portion of the partition wall **160**, which corresponds to the bulge **133**, extends across the clearance **113***a*. The end of the portion of the partition wall **160** is in contact with and joined to an inner wall of the bulge **133**. Therefore, the thermal insulation spaces **115***c* defined outside of the bypass tubes **110**A are separated from the water passages **115**, **115***a*, **115***b* defined outside of the tubes **110** and the clearance **113***a* by the partition wall **160**. As such, the cooling water is not allowed to enter the thermal insulation spaces **115***c*.

**[0091]** In the EGR gas cooler **100**A, the bypass tubes **110**A are provided to allow the part of the exhaust gas to flow therein. On the other hand, since the cooling water is not introduced into the bypass tubes **110**A, heat exchange with the cooling water is reduced in the bypass tubes **110**A.

**[0092]** For example, a valve device is provided in the first gas tank **151** to control the volume of the exhaust gas to be introduced into the bypass tubes **110**A. The valve device can be controlled to permit the exhaust gas to both of the tubes **110** and the bypass tubes **110**A or only to the tubes **110**. Because the volume ratio of the exhaust gas into the tubes **110** to the exhaust gas into the bypass tubes **110**A can be controlled, a temperature of the exhaust gas is controlled.

**[0093]** Since the thermal insulation space **115***c* is provided between the first end bypass tube **110A1** and the partition wall **160**, heat exchange between the exhaust gas flowing in the first end bypass tube **110A1** and the cooling water flowing in the end water passage **115***b* is reduced. On the other hand, since the end water passage **115***b* is provided between the partition wall **160** and the end tube **110***s*, cooling effect of the exhaust gas in the end tube **110***s* improves. Accordingly, heat exchange efficiency improves.

**[0094]** In the second embodiment, the bypass tubes **110**A only have the projections **112** for providing thermal insulation spaces **115***c*. That is, the recesses **113** are not formed on the bypass tubes **110**A. However, the bypass tubes **110**A may have the recesses **113**. Namely, the bypass tubes **110**A can be constructed by using the tubes **110**.

**[0095]** In the above description, the ERG gas cooler **100**A has two bypass tubes **110**A. However, the number of the bypass tubes **110**A is not particularly limited to two. The number of the bypass tubes **110**A can be changed in accordance with the required degree of change of the exhaust gas temperature.

**[0096]** Also, the reinforcement plates are provided and joined in the bypass tubes **110**A. Instead of the reinforcement plates, recesses recessed from the tube main walls **111** toward the inside of the bypass tubes **110**A can be formed, and the recesses of the opposed tube main walls are joined to each other inside of the bypass tubes **110**A.

Other Embodiments

**[0097]** The shape and/or dimension of the recesses **113** can be modified. In the above embodiments, the dimension of the recesses **113** is equal to the height of the projections **112**. However, the dimension of the recesses **113** may reduced depending on resistance of the cooling water to pass through the inlet openings **113***a*, **113***c* and the outlet openings **113***b*, **113***c*. Alternatively, the dimension of the recesses **113** may be larger than the height of the projections **112**.

**[0098]** The positions of the recesses **113** can be modified. Instead of the diagonal positions, the recesses **113** may be formed on the same longitudinal side of the tubes **110**. In this case, the water inlet pipe **141** and the water outlet pipe **142** are coupled to the same side of the stack of the tubes **110**. Therefore, it is not necessary that the water tank **130** is constructed of two tank members **130***a*, **130***b*. Namely, the water tank **130** can be constructed of a single tank member.

**[0099]** In the above embodiments, the second raised portions **117** are formed parallel to the short side of the tubes **110**. However, the second raised portions **117** may be modified in accordance with flow conditions of the cooling water. For example, the second raised portion **117** can be inclined relative to the short side of the tube **110** such that a distance between the longitudinal end of the tube **110** and the second raised portion **117** gradually increases with a distance from the inlet opening **113***a*. Alternatively, the second raised portion **117** may have a curved shape. Further, each of the flow-adjusting portion may be provided by a plurality of second raised portion **117**. That is, the second raised portion **117** may be divided into plural portions. Furthermore, the second raised portions **117** may be eliminated.

**[0100]** Further, it is not always necessary that each tube **110** is constructed of the first and second tube plates **110***a*, **110***b*. For example, the tube **110** can be formed by a single pipe member.

**[0101]** In the above embodiments, the projections **112** are formed on both tube main walls **111** of each tube **110**, **110**A. However, the projections **112** may be formed on only one of the tube main walls of the tube **110**, **110**A. In this case, the tubes **110**, **110**A may be stacked such that the tube main wall **111** on which the projection **112** is formed is opposed to the tube main wall **111** of the adjacent tube **110**, **110**A on which the projection **112** is not formed. Also in this case, the spaces are provided between the adjacent tubes **110**, **110**A.

**[0102]** Also, the inner fins **120** may be eliminated in accordance with required heat exchange efficiency. Further, one of or both of the outer walls **131** of the water tank **130** may be eliminated in accordance with the required heat exchange efficiency of the exhaust gas.

**[0103]** Also, it is not always necessary that the water tank **130** has the bulges **133**. For example, the pipe hole **134** can be enlarged over an area where the inlet openings **113***a* or the outlet openings **113***b* are formed, and a bore size of the end of the pipes **141**, **142** can be increased so as to correspond to the size of the pipe hole **134**. In this case, the bulge **133** can be eliminated. Thus, the end of the pipe **141***a* corresponds to the distributing portion of the inlet part and the end of the pipe **142** corresponds to the collecting portion of the outlet part.

**[0104]** Further, use of the present invention is not limited to the EGR gas cooler, but can be employed to any other heat exchangers. For example, the heat exchanger **100** can be used as an exhaust gas recovery heat exchanger that performs heat exchange between the exhaust gas, which is discharged to air, and the cooling water, thereby to heat the cooling water.

**[0105]** Also, the material of the components of the heat exchanger is not limited to stainless steel. The components can be made of other materials such as aluminum alloy, or copper alloy depending on conditions in use.

**[0106]** The example embodiments of the present invention are described above. However, the present invention is not limited to the above example embodiments, but may be implemented in other ways without departing from the spirit of the invention.

What is claimed is:

**1**. A heat exchanger for performing heat exchange between a first fluid and a second fluid, comprising:

a plurality of tubes, each of the tubes defining a first fluid passage therein through which the first fluid flows and having a first main wall and a second main wall, wherein at least one of the first main wall and the second main wall has a projection along its peripheral end, a first recess and a second recess, the projection projects outside of the tube, the first and second recesses are recessed from an end of the projection at predetermined positions, wherein the tubes are stacked such that the first main walls and the second main walls are opposed to each other, second fluid passages through which the second fluid flows are defined by spaces provided between opposed first and second main walls of the adjacent tubes and surrounded by the projections, first openings communicating with the second fluid passages are defined by the first recesses, and second openings communicating with the second fluid passages are defined by the second recesses;

a second fluid inlet part disposed in communication with the first openings for introducing the second fluid into the second fluid passages; and

a second fluid outlet part disposed in communication with the second openings for discharging the second fluid from the second fluid passages.

**2**. The heat exchanger according to claim **1**, wherein

the second fluid inlet part includes an inlet portion for introducing the second fluid and a distributing portion disposed downstream of the inlet portion with respect to a flow of the second fluid for distributing the second fluid flowing from the inlet portion into the second fluid passages, and

the second fluid outlet part includes a collecting portion for collecting the second fluid having passed through the second fluid passages therein and an outlet portion for discharging the second fluid from the collecting portion.

**3**. The heat exchanger according to claim **1**, wherein

both of the first and second main walls have the projections, the first recess and the second recess, and

the tubes are stacked such that the projections of the adjacent two tubes are opposed to and in contact with each other, the first recesses of the adjacent two tubes are opposed to each other to define the first opening and the second recesses of the adjacent two tubes are opposed to each other to define the second opening.

**4**. The heat exchanger according to claim **1**, wherein each of the first and second recesses has a dimension equal to a dimension of the projection with respect to a direction perpendicular to the first and second main walls.

**5**. The heat exchanger according to claim **1**, wherein

the first and second main walls have a substantially rectangular shape, and

the first and second recesses are located along longitudinal sides of the rectangular shape and on diagonal positions.

**6**. The heat exchanger according to claim **1**, wherein

each of the tubes has a flow-adjusting portion on at least one of the first main wall and the second main wall at a position corresponding to an upstream location respect to a flow of the first fluid flowing in the first fluid passage, and

the flow-adjusting portion is configured such that the second fluid is spread throughout the second fluid passage.

**7**. The heat exchanger according to claim **1**, wherein

each of the tubes is constructed of a first tube member and a second tube member, and

the first main wall and the second main wall are included in the first and second tube members, respectively.

**8**. The heat exchanger according to claim **1**, wherein each of the tubes has an inner fin in the first fluid passage.

**9**. The heat exchanger according to claim **2**, further comprising:

a side wall member attached to longitudinal sides of the plurality of tubes, wherein

the side wall member has a bulge at a position corresponding to the first openings,

the bulge provides a clearance therein and encases the first openings,

the distributing portion is defined by the bulge, and

the inlet portion has a pipe shape and is in communication with the clearance provided by the bulge.

**10**. The heat exchanger according to claim **2**, further comprising:

a side wall member attached to longitudinal sides of the plurality of tubes, wherein

the side wall member has a bulge at a position corresponding to the second openings,

the bulge provides a clearance therein and encases the second openings,

the collecting portion is defined by the bulge, and

the outlet portion has a pipe shape and is in communication with the clearance provided by the bulge.

**11**. The heat exchanger according to claim **9**, wherein

the plurality of tubes includes an outermost tube stacked at an outermost side, the outermost tube provides an outermost tube wall,

the outermost tube wall has an end projection along its peripheral end, a first end recess and a second end recess recessed from an end of the end projection, the heat exchanger further comprising:

an outer wall member disposed along the outermost tube wall such that an end passage is defined by a space provided between the outer wall member and the outermost tube wall and surrounded by the end projection, wherein

the end passage is in communication with the second fluid inlet part and the second fluid outlet part through the first end recess and the second end recess, respectively.

**12**. The heat exchanger according to claim **11**, further comprising:

a tank having a connecting wall and outer walls extending from opposite sides of the connecting wall, wherein

the tank is coupled to the plurality of tubes such that the outer walls are disposed along outermost tubes that are stacked at outermost sides, wherein

the outer wall member is included in at least one of the outer walls of the tank, and the side wall member is included in the connecting wall of the tank.

**13**. The heat exchanger according to claim **12**, wherein the bulge extends over the outer walls of the tank.

**14**. The heat exchanger according to claim **1**, further comprising:

at least one bypass tube defining a first fluid passage therein through which the first fluid flows and a thermal insulation area on its outer periphery, the bypass tube disposed in parallel to the plurality of tubes; and

a partition wall disposed between the tubes and the bypass tube to separate the thermal insulation area from an area where the second fluid flows.

**15**. The heat exchanger according to claim **14**, wherein

the bypass tube has a main wall opposed to the partition wall,

the main wall of the bypass tube has a projection that projects toward the partition wall on its peripheral end and contacts the partition wall such that at least a part of the thermal insulation area is defined by a space provided between the main wall of the bypass tube and the partition wall and surrounded by the projection of the bypass tube.

**16**. The heat exchanger according to claim **14**, wherein

one of the plurality of tubes, which is opposed to the partition wall, provides an opposed main wall opposed to the partition wall,

the opposed main wall has the projection, the first recess and the second recess, the projection projects toward the partition wall and is in contact with the partition wall such that a space is provided between the opposed main wall of the tube and the partition wall and surrounded by the projection of the tube, and

the space is in communication with the second fluid inlet part and the second fluid outlet part through the first recess and the second recess of the opposed main wall, respectively.

**17**. The heat exchanger according to claim **1**, further comprising:

a first fluid inlet tank defining a first tank space and having an opening, the first fluid inlet tank coupled to the tubes such that first ends of the tubes are disposed in the opening of the first fluid inlet tank and the first tank space is directly in communication with the first fluid passages defined inside of the tubes,

a first fluid outlet tank defining a second tank space and having an opening, the first fluid outlet tank coupled to the tubes such that second ends of the tubes are disposed in the opening of the first fluid outlet tank and the second tank space is directly in communication with the first fluid passages defined inside of the tubes.

* * * * *