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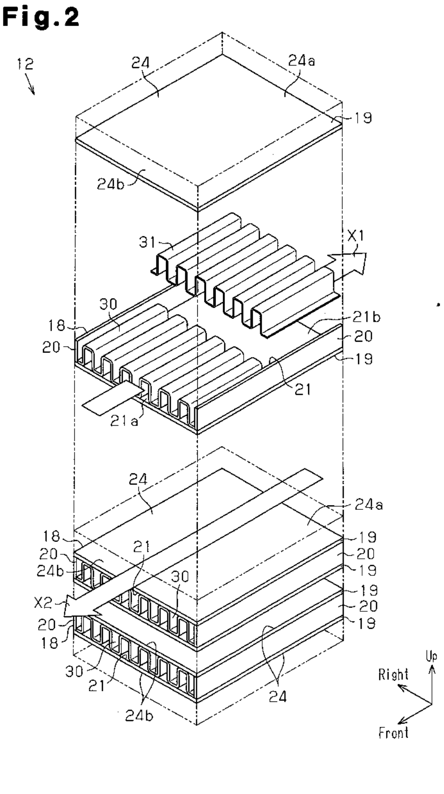
(54) VAPOR COOLING HEAT EXCHANGER

(57) A vapor cooling heat exchanger is provided with: a partition wall (19) for partitioning path (21) for a fluid to be cooled through which a fluid to be cooled flows, and path (24) for a refrigerant through which a refrigerant for cooling the fluid to be cooled flows; and fins which are disposed within path (21) for a fluid to be cooled, and which is thermally connected to the partition wall (19). The fins constitute a first fin (31) and a second fin (30), the local heat flux of which on the partition wall (19) is smaller than the first fin (31). The first fin (31) and the second fin (30) are arranged on the basis of the relationship between the local heat flux on the partition wall (19) and the heat flux limit of the refrigerant. As a consequence, the occurrence of local burn-out on the vapor cooling heat exchanger is suppressed.

Fig.2



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Description

TECHNICAL FIELD

[0001] The present invention relates to an vapor cooling heat exchanger.

BACKGROUND ART

[0002] Typically, a heat exchanger for an vapor cooling apparatus includes a cooling target fluid passage, in which cooling target fluid flows, and a refrigerant passage, in which liquid refrigerant for cooling the cooling target fluid flows. Heat exchange is brought about between the cooling target fluid passage and the refrigerant passage through a partition wall. In the heat exchanger, the liquid refrigerant flowing in the refrigerant passage cools the partition wall, which has been heated by the cooling target fluid, and is thus heated. When the temperature of the heat transmitting surface of the partition wall exceeds the saturation temperature of the liquid refrigerant, nucleate boiling, in which generation and departure of bubbles are repeated, is initiated on the wall surface of the partition wall. The cooling target fluid flowing in the cooling target fluid passage is thus cooled by using the boiling vaporization latent heat produced through the nucleate boiling. One such type of heat exchanger for an vapor cooling apparatus is disclosed in, for example, Patent Document 1.

[0003] Patent Document 1 describes a plate fin type exhaust gas heat exchanger. The exhaust gas heat exchanger is configured by a necessary number of layers each including a fluid passage having a corrugated fin for increasing a heat transmission surface area. The layers are arranged between a pair of tube plates, which are partition walls, having a pair of spacer bars that close opposite sides of the tube plates. In the exhaust gas heat exchanger, high-temperature fluid (cooling target fluid) and low-temperature fluid (liquid refrigerant) enter separate fluid passages through adjacent side surfaces. Heat exchange is thus caused between the high-temperature fluid and the low-temperature fluid through the tube plates and the corrugated fins. Meanwhile, vapor cooling is carried out.

PRIOR ART DOCUMENT

Patent Document

[0004]

Patent Document 1: Japanese Laid-Open Utility Model Publication No. 3-79070

SUMMARY OF THE INVENTION

Problems that the invention is to Solve

[0005] However, in the exhaust gas heat exchanger described in Patent Document 1, heat flux in the fluid passage in which the high-temperature fluid flows locally increases in a contact portion of each tube plate that contacts the corresponding corrugated fin. This promotes boiling of the low-temperature fluid at the position corresponding to the contact portion, where the heat flux locally increases, in the fluid passage in which the low-temperature fluid flows. As a result, film boiling may occur and cover each tube plate with a bubble film, thus causing a burnout. This causes dryness in the fluid passage in which the low-temperature fluid flows at the position corresponding to the contact portion and decreases cooling performance of the heat exchanger.

[0006] Accordingly, it is an objective of the present invention to prevent local burnout in an vapor cooling heat exchanger having a fin arranged in a cooling target fluid passage.

Means for Solving the Problems

[0007] In accordance with one aspect of the present invention, an vapor cooling heat exchanger that includes a partition wall and a fin is provided. The partition wall separates a cooling target fluid passage, in which cooling target fluid flows, from a refrigerant passage, in which refrigerant for cooling the cooling target fluid flows. The fin is arranged in the cooling target fluid passage and thermally connected to the partition wall. The fin includes a first fin and a second fin. The second fin decreases a local heat flux of the partition wall by a greater degree than the first fin does. The first fin and the second fin are arranged based on the relationship between the local heat flux of the partition wall and the critical heat flux of the refrigerant.

[0008] In accordance with one aspect, the thickness of the second fin is greater than the thickness of the first fin.

[0009] In accordance with another aspect, the second fin is arranged in an upstream portion of the cooling target fluid passage in the flow direction of the cooling target fluid where the local heat flux of the partition wall increases.

[0010] In accordance with a further aspect, the second fin is arranged in a zone of the cooling target fluid passage that corresponds to a downstream portion of the refrigerant passage in the flow direction of the refrigerant where the critical heat flux decreases.

[0011] Also, in accordance with another aspect, the cooling target fluid passage and the refrigerant passage are arranged side by side such that the flow direction of the cooling target fluid and the flow direction of the refrigerant cross each other. The second fin is arranged in an upstream portion of the cooling target fluid passage in the flow direction of the cooling target fluid that is a zone in the cooling target fluid passage that corresponds to a downstream portion of the refrigerant passage in the flow direction of the refrigerant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Fig. 1 is a perspective view schematically showing an vapor cooling heat exchanger according to a first embodiment of the present invention;
Fig. 2 is an exploded perspective view showing a heat exchanging portion of the heat exchanger illustrated in Fig. 1;
Fig. 3A is a vertical cross-sectional view showing a second fin;
Fig. 3B is a vertical cross-sectional view showing a first fin;
Fig. 4 is a graph representing the relationship between positions in the flow directions in a cooling target fluid passage and the flow direction in a refrigerant passage and heat flux in the first embodiment;
Fig. 5 is an exploded perspective view showing a portion of a heat exchanging portion of a second embodiment;
Fig. 6 is a graph representing the relationship between positions in the flow direction in a cooling target fluid passage and the flow direction in a refrigerant passage and heat flux in the second embodiment;
Fig. 7 is an exploded perspective view showing a portion of a heat exchanging portion of a third embodiment;
Fig. 8 is a graph representing the relationship between positions in the flow direction in a cooling target fluid passage and heat flux in the third embodiment;
Fig. 9 is an exploded perspective view showing a portion of a heat exchanging portion of another embodiment;
Fig. 10 is a graph representing the relationship between positions in the flow direction in a cooling target fluid passage and the flow direction in a refrigerant passage and heat flux in the embodiment illustrated in Fig. 9;
Fig. 11 is an exploded perspective view showing a portion of a heat exchanging portion of another embodiment; and
Fig. 12 is a graph representing the relationship between positions in the flow direction in a cooling target fluid passage and the flow direction in a refrigerant passage and heat flux in the embodiment illustrated in Fig. 11.

MODES FOR CARRYING OUT THE INVENTION

(First Embodiment)

[0013] An vapor cooling heat exchanger (hereinafter, referred to simply as a heat exchanger) for an EGR (exhaust gas recirculation) gas vapor cooling device (an EGR cooler) used in an EGR apparatus for vehicles will now be described with reference to Figs. 1 to 4. The heat exchanger 11 for the EGR apparatus causes heat exchange between EGR gas serving as cooling target fluid and water (liquid refrigerant) serving as refrigerant, thus boiling some of the water to cool the EGR gas. For the description below, a "forward-rearward direction", an "upward-downward direction", and a "leftward-rightward direction" are defined as represented by the corresponding arrows in Fig. 1, unless otherwise specified.

[0014] As shown in Fig. 1, a heat exchanging portion 12 is received in a substantially rectangular box-like housing 11a, which configures an outer casing for the heat exchanger 11. In the housing 11a, a cooling target fluid inlet portion 14 is arranged forward of the heat exchanging portion 12. A cooling target fluid outlet portion 15 is arranged rearward of the heat exchanging portion 12.

[0015] An inlet pipe 16 for introducing EGR gas into the cooling target fluid inlet portion 14 is connected to the front surface of the housing 11a. An outlet pipe 17 for discharging the EGR gas out from the cooling target fluid outlet portion 15 is connected to the rear surface of the housing 11a. The heat exchanger 11 is used with the inlet pipe 16 connected to the inlet of an EGR passage and the outlet pipe 17 connected to the outlet of the EGR passage.

[0016] First ends 22*a* of a refrigerant inlet pipe 22, which introduces water into the heat exchanging portion 12 of the housing 11 a, are drawn into the housing 11 a through the right surface of the housing 11 a, which is one of the opposite surfaces located between the front and rear surfaces. Also, first ends 23a of a refrigerant outlet pipe 23, which discharge water out from the heat exchanging portion 12, are drawn into the housing 11a through the left surface of the housing 11 a, which is the other one of the opposite surfaces located between the front and rear surfaces.

[0017] With reference to Fig. 2, the heat exchanging portion 12 includes a plurality of (in the first embodiment, three) passage defining bodies 18. Each of the passage defining bodies 18 is configured by a first fin 31 and a second fin 30, which are arranged between two flat partition walls 19. A pair of spacer bars 20 close opposite sides of the partition walls 19. As illustrated in Fig. 1, the heat exchanging portion 12 includes a front wall 13a joined to the front opening ends of the passage defining bodies 18 and a rear wall 13b joined to the rear opening ends of the passage defining bodies 18. The passage defining bodies 18 are joined to the front wall 13a and the rear wall 13b such that the corresponding partition walls 19 of the adjacent pairs of the passage defining bodies 18 are spaced apart at uniform intervals.

[0018] The front opening of each passage defining body 18 is arranged on the side corresponding to the cooling target fluid inlet portion 14 and the rear opening of the passage defining body 18 is located on the side corresponding to the cooling target fluid outlet portion 15. The front wall 13a has elongated holes 13e, which are formed at positions corresponding to the passage defining bodies 18 to allow communication between the interior of the cooling target fluid inlet portion 14 and the front openings of the corresponding passage defining bodies 18. The rear wall 13b has elongated holes (not shown) formed at positions corresponding to the passage defining bodies 18 to allow communication between the interior of the cooling target fluid outlet portion 15 and the rear openings of the corresponding passage defining bodies 18.

[0019] After flowing from the inlet pipe 16 into the cooling target fluid inlet portion 14, EGR gas enters the passage defining bodies 18 from the front openings through the corresponding elongated holes 13e in the front wall 13a. The EGR gas flows out from the rear openings into the cooling target fluid outlet portion 15 through the corresponding elongated holes in the rear wall 13b. The EGR gas is then directed to the outlet of the EGR passage through the outlet pipe 17. As a result, with reference to Fig. 2, the interior of each passage defining body 18 forms a cooling target fluid passage 21, in which EGR gas flows.

[0020] The front opening of each one of the passage defining bodies 18 is the inlet for EGR gas into the corresponding cooling target fluid passage 21. The portion corresponding to the inlet of each passage defining body 18 is an upstream portion 21 a of each of the corresponding cooling target fluid passage 21 in the flow direction of the EGR gas (as represented by arrow X1 in Fig. 2). The rear opening of each passage defining body 18 is the outlet for the EGR gas from the corresponding cooling target fluid passage 21. The portion corresponding to the outlet of each passage defining body 18 is a downstream portion 21 b of each of the corresponding cooling target fluid passage 21 in the flow direction of the EGR gas. In the first embodiment, the "upstream portion 21 a of each cooling target fluid passage 21" refers to a zone close to the inlet with respect to a middle portion in the flow direction in the cooling target fluid passage 21. The "downstream portion 21b of each cooling target fluid passage 21" refers to a zone close to the outlet with respect to the middle portion in the flow direction in the cooling target fluid passage 21.

[0021] In the heat exchanging portion 12, a refrigerant passage 24 is defined between the opposing partition walls 19 of each adjacent pair of the passage defining bodies 18. As shown in Fig. 1, the front opening of each refrigerant passage 24 communicates with the corresponding one of the first ends 23a of the refrigerant outlet pipe 23 through a hole formed in the front wall 13a. The rear opening of the refrigerant passage 24 communicates with the corresponding one of the first ends 22a of the refrigerant inlet pipe 22 through a hole 13c formed in the rear wall 13b. The opposite sides of each refrigerant passage 24 perpendicular to the front wall 13a and the rear wall 13b are closed by the left and right surfaces of the housing 11 a.

[0022] The first ends 23a of the refrigerant outlet pipe 23 face the front openings of the corresponding refrigerant passages 24. The first ends 22a of the refrigerant inlet pipe 22 face the rear openings of the corresponding refrigerant passages 24. A second end of the refrigerant inlet pipe 22 is connected to a first end of a water circulation pipe (not shown) and a second end of the refrigerant outlet pipe 23 is connected to a second end of the circulation pipe. Water is thus introduced into the refrigerant passages 24 through the corresponding first ends 22a of the refrigerant inlet pipe 22. The water is then passed through the refrigerant passages 24 and discharged through the first ends 23a of the refrigerant outlet pipe 23 to return to the circulation pipe.

[0023] The rear opening of each refrigerant passage 24, which faces the corresponding first end 22a of the refrigerant inlet pipe 22, is the inlet into the refrigerant passage 24. The inlet portion of the refrigerant passage 24 is an upstream portion 24a of the refrigerant passage 24 in the water flow direction (represented by arrow X2 in Fig. 2). The front opening of each refrigerant passage 24, which faces the corresponding first end 23a of the refrigerant outlet pipe 23, is the outlet from the refrigerant passage 24. The outlet portion of the refrigerant passage 24 is a downstream portion 24b of the refrigerant passage 24 in the water flow direction. In the first embodiment, the "upstream portion 24a of each refrigerant passage 24" refers to a zone close to the inlet with respect to a middle portion in the flow direction in the refrigerant passage 24. The "downstream portion 24b of each refrigerant passage 24" refers to a zone close to the outlet with respect to the middle portion in the flow direction in the refrigerant passage 24.

[0024] In the heat exchanging portion 12, each cooling target fluid passage 21 and the adjacent refrigerant passage 24 are arranged side by side in the manner described below. Specifically, the inlet of the refrigerant passage 24 is arranged at the positions corresponding to the position of the outlet of the cooling target fluid passage 21 in the direction in which the passage defining bodies 18 are laminated. The position of the outlet of the refrigerant passage 24 corresponds to the position of the inlet of the cooling target fluid passage 21 in the lamination direction of the passage defining bodies 18. As a result, in the heat exchanger 11 of the first embodiment, EGR gas and water form opposite flows, or, in other words, the flow direction of the EGR gas and the flow direction of the water are opposite to each other. Each of the partition walls 19, which form the corresponding passage defining body 18, separates the corresponding cooling target fluid passage 21 from the adjacent refrigerant passage 24.

[0025] Fig. 4 is a graph representing the relationship between the positions in the flow direction in the cooling target fluid passage 21 and the flow direction in the refrigerant passage 24 (the axis of abscissas) and the heat flux (the axis of ordinates). The line formed by a long dash alternating with two short dashes represents the local heat flux in a portion of each partition wall 19 thermally connected to a corresponding conventional fin in a case in which conventional fin having equal thicknesses over the entire zone (from the upstream portion to the downstream portion in the flow direction) of the cooling target fluid passage 21. The broken line represents the critical heat flux of the water.

[0026] Since only a short time has passed after EGR gas reached the cooling target fluid passage 21, the temperature of the EGR gas in the upstream portion 21 a of each cooling target fluid passage 21 is high. The EGR gas is then cooled through heat exchange with the water as the EGR gas proceeds toward the downstream portion 21 b, and the temperature of the EGR gas decreases. Accordingly, as represented by the line formed by a long dash alternating with two short dashes in Fig. 4, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding conventional fin becomes greater toward the upstream portion 21 a of the cooling target fluid passage 21 and smaller toward the downstream portion 21 b of the cooling target fluid passage 21.

[0027] In contrast, the temperature of the water in the upstream portion 24a of each refrigerant passage 24 is low because only a short time has passed since the water entered the refrigerant passage 24. As the water proceeds toward the downstream portion 24b, some of the water is boiled through heat exchange with the EGR gas and transformed into a form mixed with bubbles. The water thus moves in the refrigerant passage 24 toward the outlet of the refrigerant passage 24 in the form mixed with bubbles. As the bubbles flow toward the downstream portion 24b of the refrigerant passage 24, the bubbles may join one another and grow or increase in number.

[0028] As a result, as represented by the broken line in Fig. 4, the critical heat flux of the water becomes smaller from the upstream portion 24a toward the downstream portion 24b in each refrigerant passage 24. Accordingly, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding conventional fin is likely to become greater than or equal to the critical heat flux of the water in the upstream portion 21 a of the corresponding cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the corresponding refrigerant passage 24.

[0029] In the first embodiment, each second fin 30 is arranged in the upstream portion 21 a of the associated cooling target fluid passage 21, which is a zone corresponding to the downstream portion 24b of the refrigerant passage 24. Each second fin 30 extends in a corrugated shape in the direction perpendicular to the flow direction of the EGR gas. With reference to Fig. 3A, the second fin 30 has flat surfaces 30a each contacting a wall surface 19a of the partition wall 19. The height of the second fin 30 is equal to the interval between the two associated partition walls 19. The second fin 30 has corner portions 30b, each of which is formed on one of the opposite sides of the corresponding one of the flat surfaces 30a and has a round shape. Brazing filler R1 is poured into the gap between each of the corner portions 30b and the corresponding one of the partition walls 19 and melted so that the second fin 30 is brazed to the partition wall 19. The second fin 30 and the partition wall 19 are thus thermally connected together and heat is transmissible between the second fin 30 and the partition wall 19.

[0030] Each first fin 31 is arranged in the downstream portion 21 b of the associated cooling target fluid passage 21, which is a zone corresponding to the upstream portion 24a of the refrigerant passage 24. Each first fin 31 extends in a corrugated shape in the direction perpendicular to the flow direction of EGR gas. With reference to Fig. 3B, the first fin 31 has flat surfaces 31 a each contacting the corresponding wall surface 19a of the partition wall 19. The height of the first fin 31 is equal to the interval between the two associated partition walls 19. The first fin 31 has corner portions 31 b, each of which is formed on one of the opposite sides of the corresponding one of the flat surfaces 31 a and has a round shape. Brazing filler R1 is poured into the gap between each corner portion 31 b and the corresponding partition wall 19 and melted so that the first fin 31 is brazed to the partition wall 19. The first fin 31 and the partition wall 19 are thus thermally connected together and heat is transmissible between the first fin 31 and the partition wall 19.

[0031] With reference to Figs. 3A and 3B, the thickness L1 of each second fin 30 is greater than the thickness L2 of each first fin 31. The second fin 30 thus has a greater cross-sectional area than the first fin 31. The second fin 30 and the first fin 31 have substantially equal surface areas. The proportion of the surface area with respect to the cross-sectional area perpendicular to the heat transmitting direction in the second fin 30 is smaller than the corresponding proportion in the first fin 31.

[0032] Operation of the heat exchanger 11, which has the above-described configuration, will hereafter be described with reference to the graph of Fig. 4.

[0033] When the vehicle operates, EGR gas, which is some of the exhaust gas discharged from the internal combustion engine, flows to the inlet of the EGR passage and is directed to the cooling target fluid passage 21 via the cooling target fluid inlet portion 14 and the corresponding elongated holes 13e. The EGR gas then flows from the inlet to the outlet in each of the cooling target fluid passages 21.

[0034] Meanwhile, a non-illustrated pump arranged in the circulation pipe is actuated to forcibly circulate water in the circulation pipe. The water is thus introduced into the refrigerant passages 24 through the refrigerant inlet pipe 22. The water then flows from the inlet to the outlet in each of the refrigerant passages 24.

[0035] In the heat exchanger 11, heat is transmitted from the EGR gas at a high temperature to the water at a low temperature through the partition walls 19, the second fins 30, and the first fins 31. Each second fin 30 is arranged in the upstream portion 21a of the associated cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the refrigerant passage 24, where the local heat flux in the portion of each of the partition walls 19 thermally connected to the corresponding one of the conventional fins is likely to become greater than or equal to the critical heat reflux of the water. The cross-sectional area of the second fin 30 is greater than the cross-sectional area of each first fin 31, which is located in a zone other than the above-described zones. As a result, the heat in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is dispersed in the corresponding cooling target fluid passage 21, compared to the heat in the portion of the partition wall 19 thermally connected to the corresponding first fin 31. This prevents an increase in the local heat flux.

[0036] Since there are a great number of bubbles in the downstream portion 24b of each refrigerant passage 24, the critical heat flux of the water decreases in the downstream portion 24b of the refrigerant passage 24. However, each second fin 30 is arranged in a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b. As a result, even though the critical heat flux of the water is small, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is smaller than the critical heat flux of the water.

[0037] In the graph of Fig. 4, the solid line represents the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 and the corresponding first fin 31.

[0038] As is clear from Fig. 4, by increasing the cross-sectional area of each second fin 30, the local heat flux in the portion of the corresponding partition wall 19 thermally connected to the second fin 30 is reduced. Specifically, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is smaller than the critical heat flux of the water, thus preventing local burnout. The thickness L1 of each second fin 30 must be set to such a value that the local heat flux at the position where the second fin 30 and the corresponding partition wall 19 are thermally connected together is smaller than the critical heat flux of the water.

[0039] As heat exchange occurs between the water and the EGR gas through the partition walls 19, the water boils and evaporates at the wall surfaces 19a of the partition walls 19, thus generating boiling vaporization latent heat. The latent heat is then used to cool the EGR gas flowing in the cooling target fluid passage 21. After having cooled the EGR gas, the water is directed from the outlet of each refrigerant passage 24 into the circulation pipe through the refrigerant outlet pipe 23. The water is then condensed by a non-illustrated refrigerant condensing portion arranged in the circulation pipe and returned to the heat exchanger 11. Meanwhile, the cooled EGR gas is directed from the outlet of each cooling target fluid passage 21 into the outlet of the EGR passage through the outlet pipe 17. The EGR gas is then returned from the outlet of the EGR passage to the intake system of the internal combustion engine.

[0040] The first embodiment has the advantages described below.

(1) In the upstream portion 21a of each cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the refrigerant passage 24, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is likely to increase and the critical heat flux of the water is likely to decrease. Each second fin 30 is thus arranged in the aforementioned zone. Each first fin 31 is arranged in another zone. The thickness L1 of each second fin 30 is greater than the thickness L2 of each first fin 31. This increases the heat transmission area of the portion of each partition wall 19 thermally connected to the corresponding second fin 30, thus decreasing the local heat flux in this portion of the partition wall 19. As a result, the local heat flux in the portion of the partition wall 19 thermally connected to the second fin 30 is prevented from becoming greater or equal to the critical heat flux of the water. Local burnout is thus prevented from occurring.

(2) Heat exchange performance is high in the upstream portion 21 a of each cooling target fluid passage 21. Accordingly, by arranging each second fin 30, which has a thickness greater than the thickness of a conventional fin in the upstream portion 21 a of the cooling target fluid passage 21, the heat transmission area is increased and film boiling is prevented.

(Second Embodiment)

[0041] A heat exchanger for an EGR (exhaust gas recirculation) gas cooling device (an EGR cooler) in an EGR apparatus for vehicles according to a second embodiment of the present invention will now be described with reference to Figs. 5 and 6. The same or like reference numerals are given to components of the second embodiment that are the same as or like corresponding components of the first embodiment. Repeated description of the components is omitted or simplified herein. Fig. 5 shows only a portion of the heat exchanging portion 12 for illustrative purposes.

[0042] As illustrated in Fig. 5, in the heat exchanging portion 12, the inlets of each cooling target fluid passage 21 is arranged at a position corresponding to the inlet of the refrigerant passage 24 in the lamination direction of the passage defining bodies 18. The position of the outlet of the cooling target fluid passage 21 corresponds to the position of the outlet of the refrigerant passage 24 in the lamination direction of the passage defining body 18. As a result, in the heat exchanger 11 of the second embodiment, EGR gas and water form parallel flows, or, in other words, the flow direction of the EGR gas (represented by arrow X1 in Fig. 5) is parallel to the flow direction of the water (represented by arrow X2 in the drawing).

[0043] Each second fin 30 is arranged in the downstream portion 21b of the associated cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the refrigerant passage 24. Each first fin 31 is arranged in the upstream portion 21 a of the associated cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the upstream portion 24a of the refrigerant passage 24.

[0044] As represented by the line formed by a long dash alternating with two short dashes in the graph of Fig. 6, in a case in which conventional fin is arranged in the entire zone of the cooling target fluid passage 21, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding conventional fin is likely to become greater than or equal to the critical heat flux of the water in the downstream portion 21 b of the corresponding cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the corresponding refrigerant passage 24. However, in the second embodiment, each second fin 30 is arranged in the downstream portion 21b of the associated cooling target fluid passage 21, which is a zone corresponding to the downstream portion 24b of the refrigerant passage 24. Each first fin 31 is arranged in a zone other than the aforementioned zone. As a result, as represented by the solid line in the graph of Fig. 6, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is smaller than the critical heat flux of the water.

[0045] Accordingly, the second embodiment has the same advantage as the advantage (1) of the first embodiment.

(Third Embodiment)

[0046] A heat exchanger for an EGR (exhaust gas recirculation) gas cooling device (an EGR cooler) in an EGR apparatus for vehicles according to a third embodiment of the present invention will now be described with reference to Figs. 7 and 8. Fig. 7 shows only a portion of the heat exchanging portion 12 for illustrative purposes.

[0047] As shown in Fig. 7, the inlet of the refrigerant passage 24 is arranged on one side in the direction perpendicular to the flow direction of EGR gas (represented by arrow X1 in Fig. 7). The outlets of the refrigerant passages 24 are located at the other side in the direction perpendicular to the EGR gas flow direction. Accordingly, in the heat exchanger 11 of the third embodiment, EGR gas and water form perpendicular flows, or, in other words, the flow direction of the EGR gas and the flow direction of the water (represented by arrow X2 in Fig. 7) extend perpendicular to each other. The cooling target fluid passage 21 and the refrigerant passage 24 are thus arranged side by side such that the EGR flow direction and the water flow direction cross each other, or, more specifically, extend perpendicular to each other.

[0048] Each second fin 30 is arranged in the upstream portion 21 a of the associated cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the refrigerant passage 24. As viewed from above, each of the second fins 30 is shaped like a right triangle. Each first fin 31 is arranged in a zone other than the zone corresponding to the second fin 30.

[0049] The graph in Fig. 8 represents the relationship between positions in the flow direction in each cooling target fluid passage 21 and heat flux, as observed along the cross section taken along line A-A in Fig. 7.

[0050] As represented by the line formed by a long dash alternating with two short dashes in the graph of Fig. 8, in a case in which a conventional fin is arranged in the entire zone of the cooling target fluid passage 21, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding conventional fin is likely to become greater or equal to the critical heat flux of the water in the upstream portion 21 a of the corresponding cooling target fluid passage 21, which is a zone corresponding to the downstream portion 24b of the corresponding refrigerant passage 24. However, in the third embodiment, each second fin 30 is arranged in the upstream portion 21 a of the associated cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the refrigerant passage 24. Each first fin 31 is arranged in a zone other than the aforementioned zone. As a result, as represented by the solid line in the graph of Fig. 8, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is smaller than the critical heat flux of the water.

[0051] Accordingly, the third embodiment has the same advantages as the advantages (1) and (2) of the first embodiment.

[0052] The illustrated embodiments may be modified to the forms described below.

[0053] In the second embodiment, each second fin 30 is arranged in the downstream portion 21b of the associated cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the downstream portion 24b of the refrigerant passage 24. Each first fin 31 is arranged in a zone other than the aforementioned zone. However, the present invention is not restricted to this configuration. For example, as illustrated in Fig. 9, each second fin 30 may be located in the upstream portion 21 a of the associated cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the upstream portion 24a of the refrigerant passage 24. Each first fin 31 is arranged in a zone other than the aforementioned zone. As represented by the line formed by a long dash alternating with two short dashes in the graph of Fig. 10, in a case in which a conventional fin is arranged in the entire zone of the cooling target fluid passage 21, the local heat flux in the portion of each partition walls 19 thermally connected to the corresponding one of the conventional fins is likely to become greater than or equal to the critical heat flux of the water in the upstream portion 21 a of the corresponding cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the upstream portion 24a of the corresponding refrigerant passage 24. However, in this modified embodiment, the second fin 30 is arranged in the upstream portion 21 a of the cooling target fluid passage 21, which is a zone in the cooling target fluid passage 21 corresponding to the upstream portion 24a of the refrigerant passage 24. Each first fin 31 is located in a zone other than the aforementioned zone. As a result, as represented by the solid line in the graph of Fig. 10, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is smaller than the critical heat flux of the water.

[0054] In the second embodiment, for example, as illustrated in Fig. 11, each second fin 30 may be arranged in a middle portion of the associated cooling target fluid passage 21 and each first fin 31 may be arranged in a zone in the cooling target fluid passage 21 other than the zone corresponding to the middle portion. As represented by the line formed by a long dash alternating with two short dashes in the graph of Fig. 12, in a case in which a conventional fin is arranged in the entire zone of each cooling target fluid passage 21, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding the conventional fin is likely to become greater than or equal to the critical heat flux of the water in the middle portion of the cooling target fluid passage 21. However, in this modified embodiment, the second fin 30 is located in the middle portion of the cooling target fluid passage 21 and the first fin 31 is arranged in a zone other than the zone corresponding to the middle portion. As a result, as represented by the solid line in the graph of Fig. 12, the local heat flux in the portion of each partition wall 19 thermally connected to the corresponding second fin 30 is smaller than the critical heat flux of the water.

[0055] In the illustrated embodiments, the thickness L1 of each second fin 30 is greater than the thickness L2 of each first fin 31. However, the present invention is not restricted to this configuration. For example, the second fin 30 and the first fin 31 may have the same thickness. In this case, brazing filler R1 is supplied into the gap between each corner portion 30b of the second fin 30 and the corresponding partition wall 19 by an amount greater than the amount of the brazing filler R1 used in the gap between each corner portion 31 b of the first fin 31 and the corresponding partition wall 19. In this manner, the contact area by which the base portion of each second fin 30 is held in contact with the brazing filler R1 is increased.

[0056] In the illustrated embodiments, the height of each second fin 30 may be smaller than the height of each first fin 31. This decreases the surface area of the second fin 30 compared to the surface area of the first fin 31. As a result, compared to a case in which the second fins 30 and the first fins 31 have equal heights, the exposure area by which each second fin 30 is exposed to EGR gas decreases, thus reducing the local heat flux in the portion of the corresponding partition wall 19 thermally connected to the second fin 30.

[0057] In the third embodiment, the shape of each second fin 30 is not restricted to the right triangle as viewed from above. The shape of the second fin 30 is not particularly restricted and may be any suitable shape such as a rectangular shape as viewed from above, as long as the second fin 30 is arranged in correspondence with minimum portion of the upstream portion 21a of the cooling target fluid passage 21, which are minimum portions of the zones corresponding to the downstream portions 24b of the refrigerant passages 24.

[0058] In the heat exchanger 11 of the third embodiment, EGR gas and water form the perpendicular flows, or, in other words, the flow direction of the EGR gas and the flow direction of the water extend perpendicular to each other. However, the flow directions of the EGR gas and the water may simply cross each other, without extending perpendicular to each other.

[0059] In the illustrated embodiments, the second fins 30 and the first fins 31 each have a corrugated shape. However, each second fin 30 and each first fin 31 may be shaped in any other suitable shape.

[0060] In the first embodiment, to introduce water into the heat exchanging portion 12 and direct the water out from the heat exchanging portion 12, the first ends 22a of the refrigerant inlet pipe 22 are passed through the right surface of the housing 11 a and the first ends 23a of the refrigerant outlet pipe 23 extend through the left surface of the housing 11a. However, the configuration for directing the water into and out from the heat exchanging portion is not restricted to this. For example, as described in "Japanese Laid-Open Patent Publication No. 7-159074", the refrigerant inlet pipe 22 may be connected to the top surface of the housing 11a to introduce water into the heat exchanging portion. In this case, the refrigerant outlet pipe 23 is connected to the bottom surface of the housing 11a to direct the water out from the heat exchanging portion.

[0061] In each of the illustrated embodiments, the heat exchanger 11 is embodied as the heat exchanger 11 used in an EGR gas vapor cooling device (an EGR cooler). However, the heat exchanger 11 may be embodied as a heat exchanger employed in a cooler for a device mounted in a vehicle, a refrigerator, or a freezer.

[0062] In each of the illustrated embodiments, the cooling target fluid is EGR gas. However, the cooling target fluid is not restricted to this and may be gas other than the EGR gas or high-temperature liquid.

[0063] The present invention may be employed in a shell-and-tube type vapor cooling heat exchanger.

Claims

1. An vapor cooling heat exchanger comprising:

   a partition wall that separates a cooling target fluid passage, in which cooling target fluid flows, from a refrigerant passage, in which refrigerant for cooling the cooling target fluid flows; and
   a fin that is arranged in the cooling target fluid passage and thermally connected to the partition wall,
   the heat exchanger being **characterized in that** the fin includes a first fin and a second fin, the second fin decreasing a local heat flux of the partition wall by a greater degree than the first fin does, and
   the first fin and the second fin are arranged based on the relationship between the local heat flux of the partition wall and the critical heat flux of the refrigerant.

2. The vapor cooling heat exchanger according to claim 1, **characterized in that** the thickness of the second fin is greater than the thickness of the first fin.

3. The vapor cooling heat exchanger according to claim 1 or 2, **characterized in that** the second fin is arranged in an upstream portion of the cooling target fluid passage in the flow direction of the cooling target fluid where the local heat flux of the partition wall increases.

4. The vapor cooling heat exchanger according to claim 1 or 2, **characterized in that** the second fin is arranged in a zone of the cooling target fluid passage that corresponds to a downstream portion of the refrigerant passage in the flow direction of the refrigerant where the critical heat flux decreases.

5. The vapor cooling heat exchanger according to claim 1 or 2, **characterized in that**
   the cooling target fluid passage and the refrigerant passage are arranged side by side such that the flow direction of the cooling target fluid and the flow direction of the refrigerant cross each other, and
   the second fin is arranged in an upstream portion of the cooling target fluid passage in the flow direction of the cooling target fluid that is a zone in the cooling target fluid passage that corresponds to a downstream portion of the refrigerant passage in the flow direction of the refrigerant.

Amended claims under Art. 19.1 PCT

1. An vapor cooling heat exchanger comprising:

a partition wall that separates a cooling target fluid passage, in which cooling target fluid flows, from a refrigerant passage, in which refrigerant for cooling the cooling target fluid flows; and
a fin that is arranged in the cooling target fluid passage and thermally connected to the partition wall,
the heat exchanger being **characterized in that** the fin includes a first fin and a second fin, the second fin decreasing a local heat flux of the partition wall by a greater degree than the first fin does, and
the first fin and the second fin are arranged based on the relationship between the local heat flux of the partition wall and the critical heat flux of the refrigerant.

2. The vapor cooling heat exchanger according to claim 1, **characterized in that** the thickness of the second fin is greater than the thickness of the first fin.

3. The vapor cooling heat exchanger according to claim 1 or 2, **characterized in that** the second fin is arranged in an upstream portion of the cooling target fluid passage in the flow direction of the cooling target fluid where the local heat flux of the partition wall increases.

4. The vapor cooling heat exchanger according to claim 1 or 2, **characterized in that** the second fin is arranged in a zone of the cooling target fluid passage that corresponds to a downstream portion of the refrigerant passage in the flow direction of the refrigerant where the critical heat flux decreases.

5. The vapor cooling heat exchanger according to claim 1 or 2, **characterized in that**
the cooling target fluid passage and the refrigerant passage are arranged side by side such that the flow direction of the cooling target fluid and the flow direction of the refrigerant cross each other, and
the second fin is arranged in an upstream portion of the cooling target fluid passage in the flow direction of the cooling target fluid that is a zone in the cooling target fluid passage that corresponds to a downstream portion of the refrigerant passage in the flow direction of the refrigerant.

6. (added) The vapor cooling heat exchanger according to claim 1, **characterized in that** the second fin and the first fin have substantially equal surface areas.

Fig.1

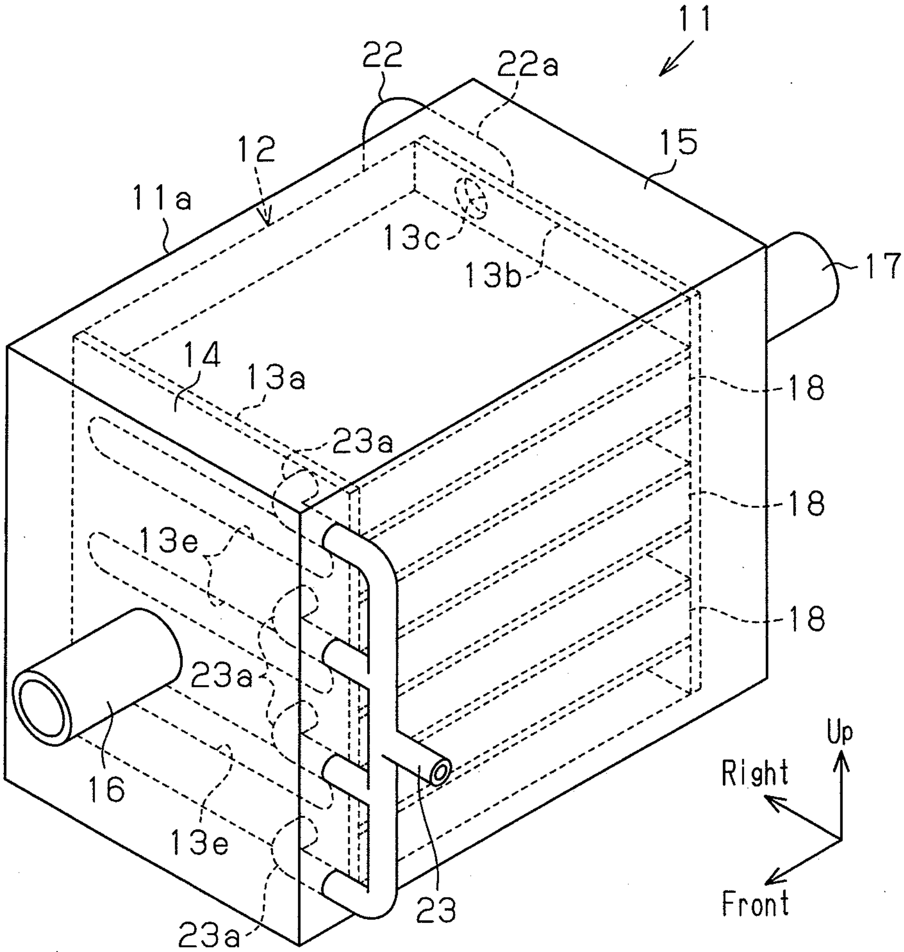
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Fig.2

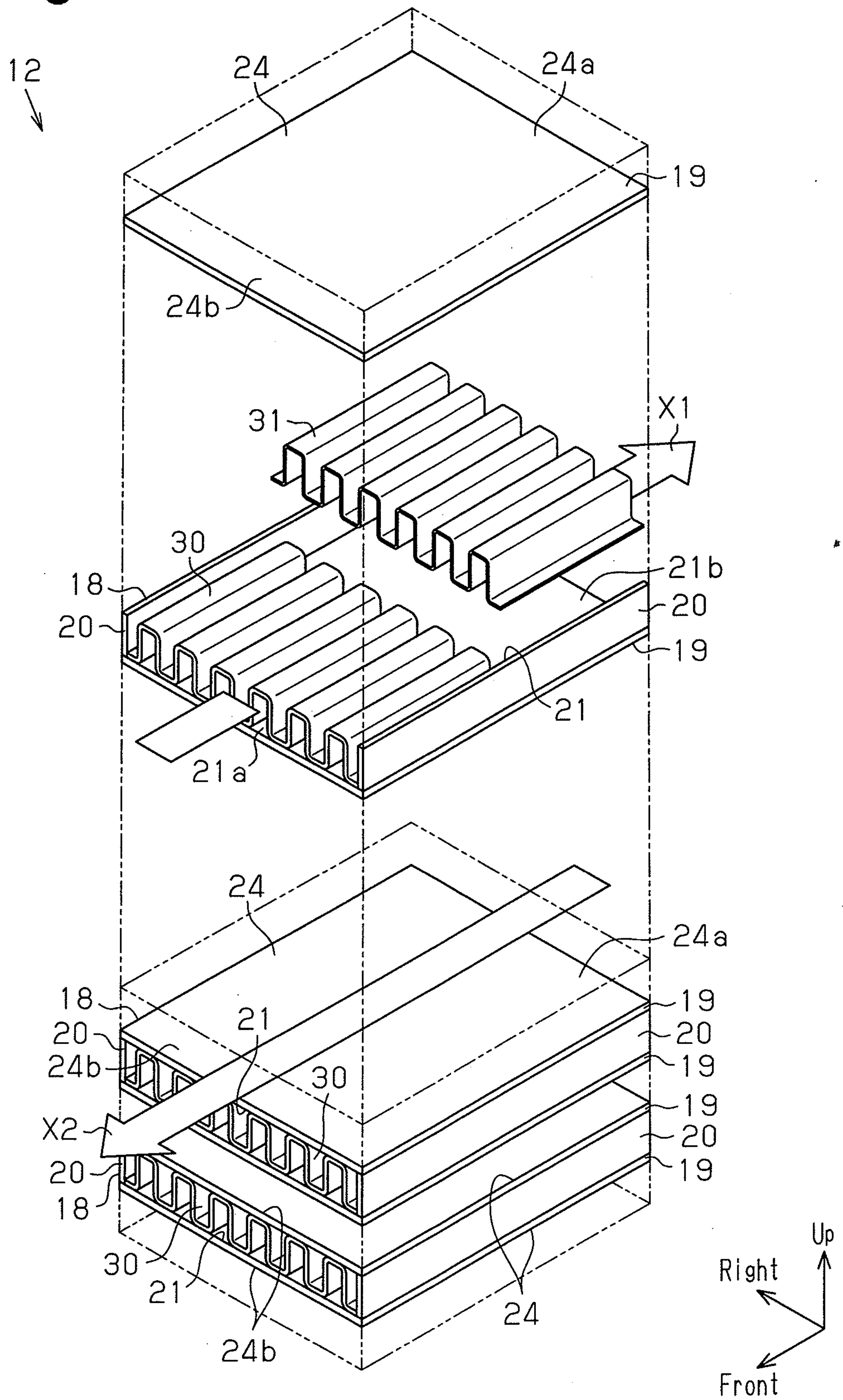
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Fig.3A

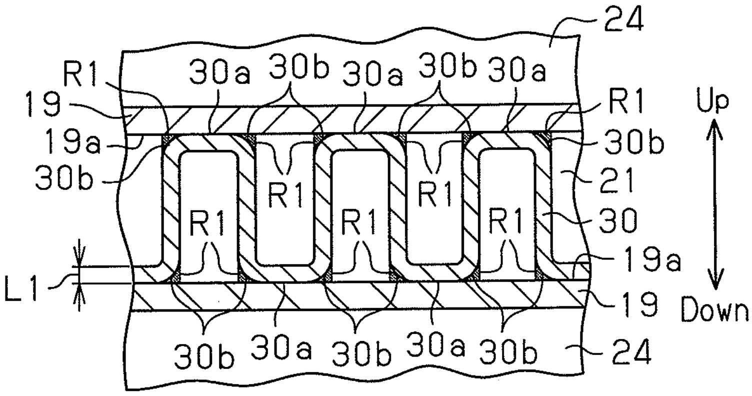

Fig.3B

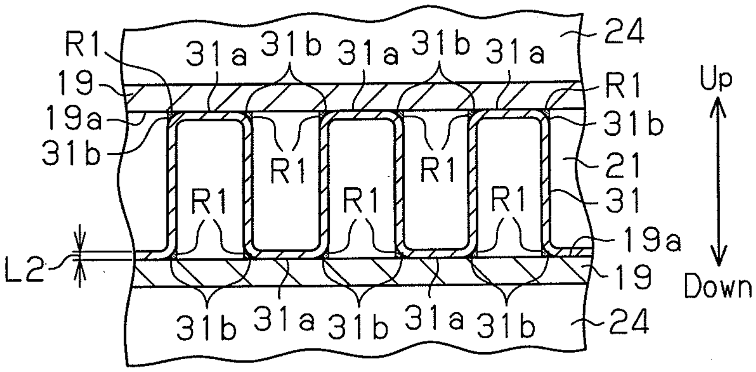

Fig.4

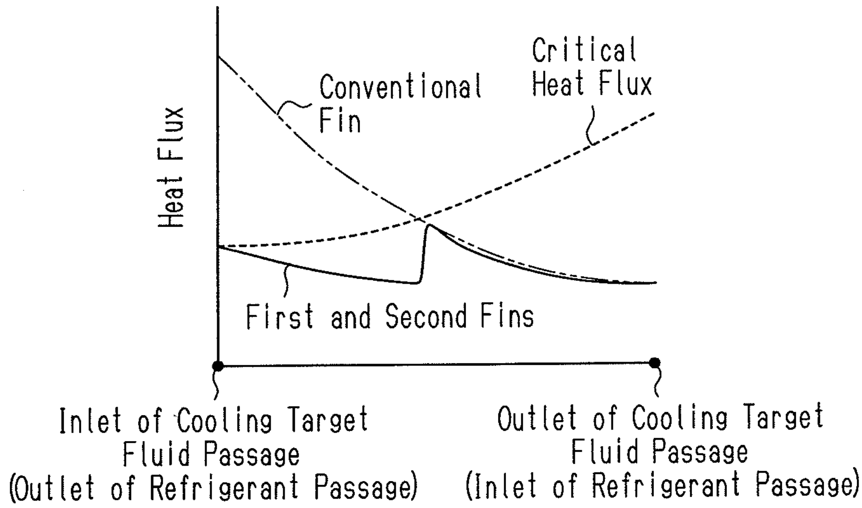

Fig.5

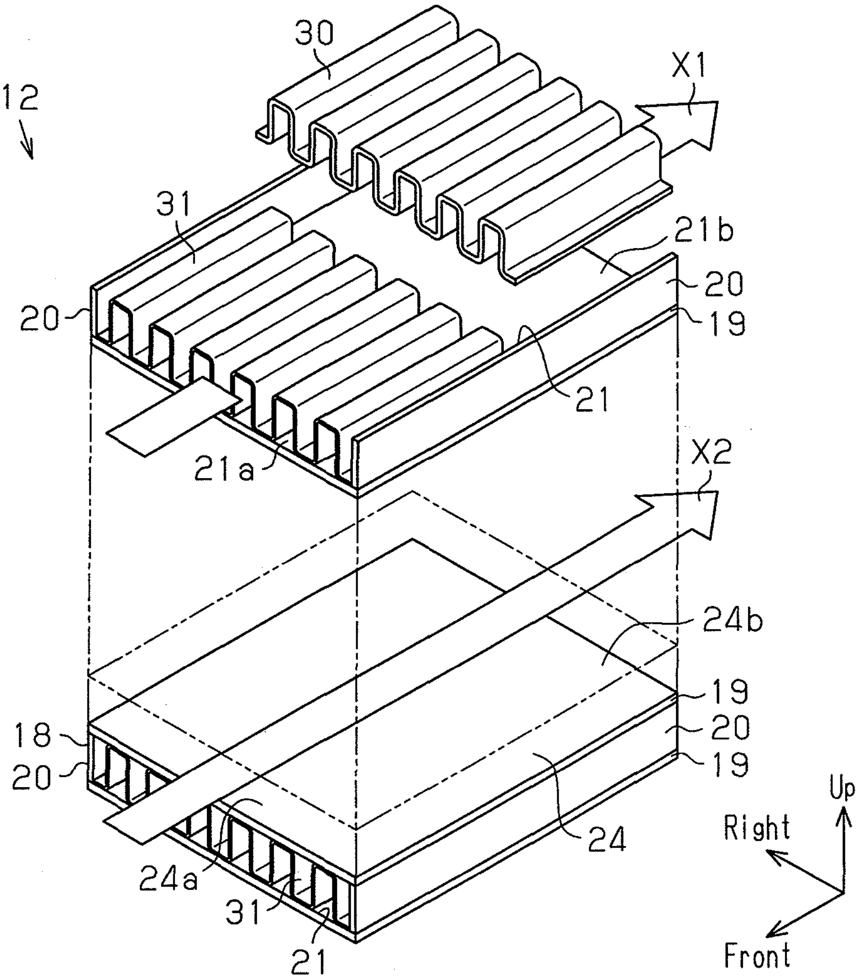
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Fig.6

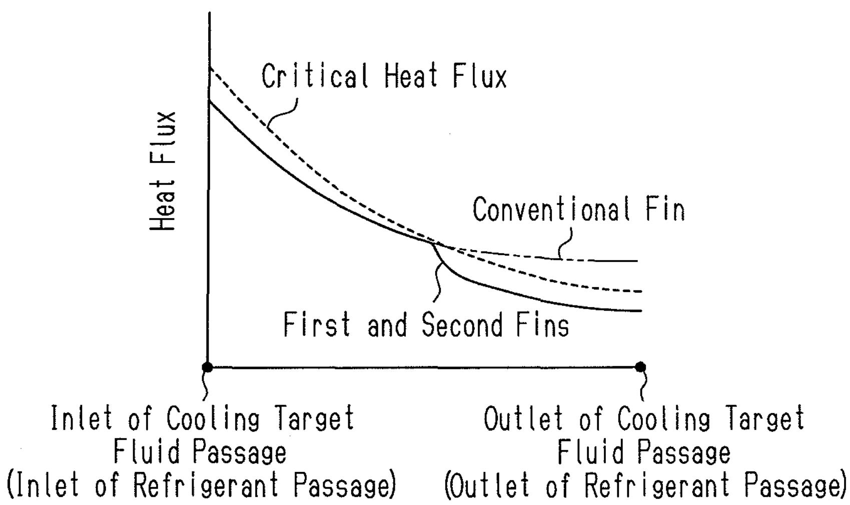
Critical Heat Flux
Heat Flux
Conventional Fin
First and Second Fins
Inlet of Cooling Target
Fluid Passage
(Inlet of Refrigerant Passage)
Outlet of Cooling Target
Fluid Passage
(Outlet of Refrigerant Passage)

Fig.7

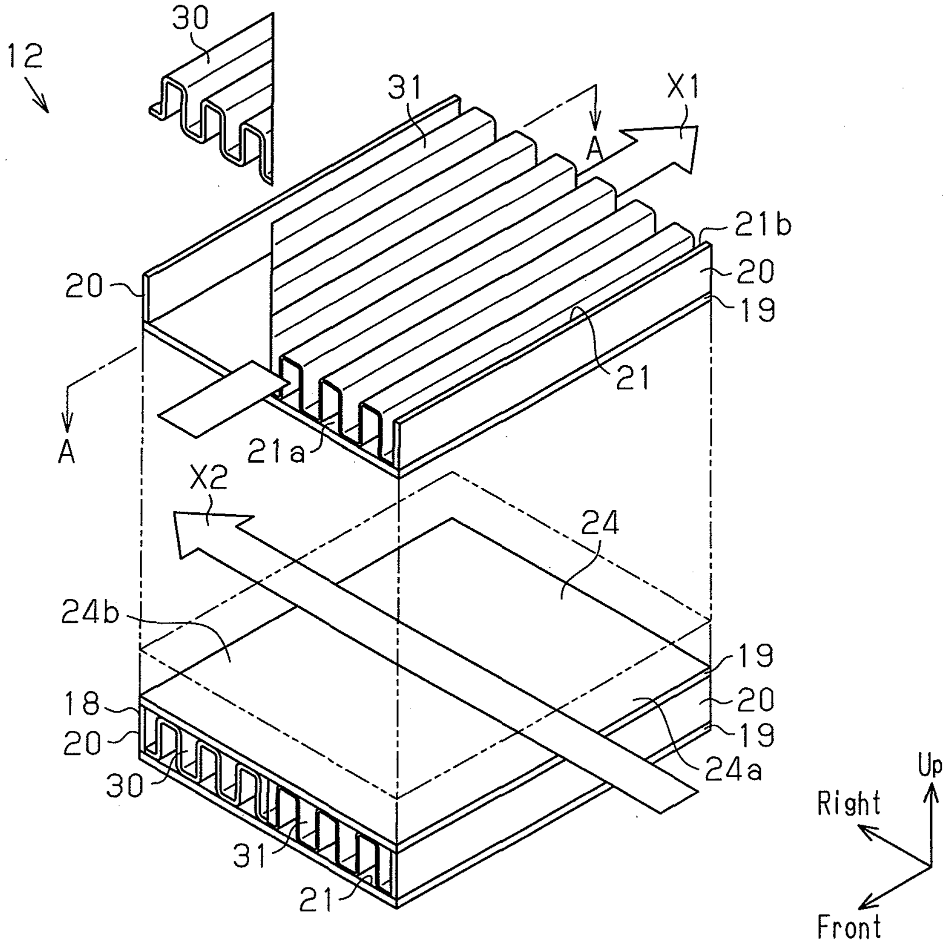
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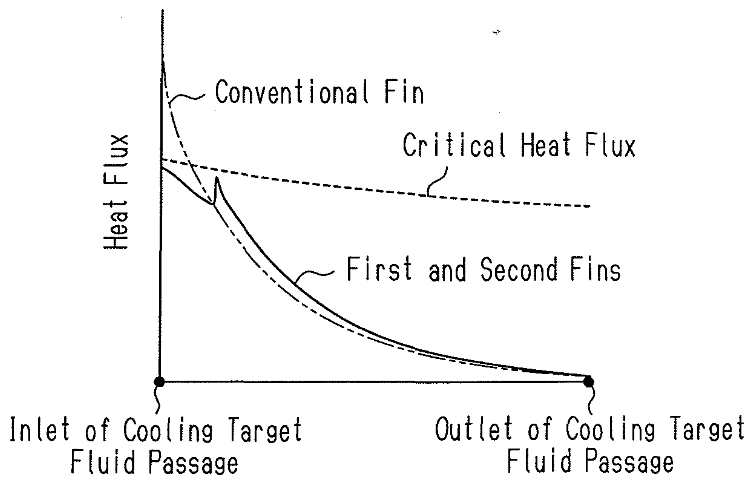
Fig.8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Conventional Fin
Critical Heat Flux
First and Second Fins
Inlet of Cooling Target Fluid Passage
Outlet of Cooling Target Fluid Passage

Fig.9

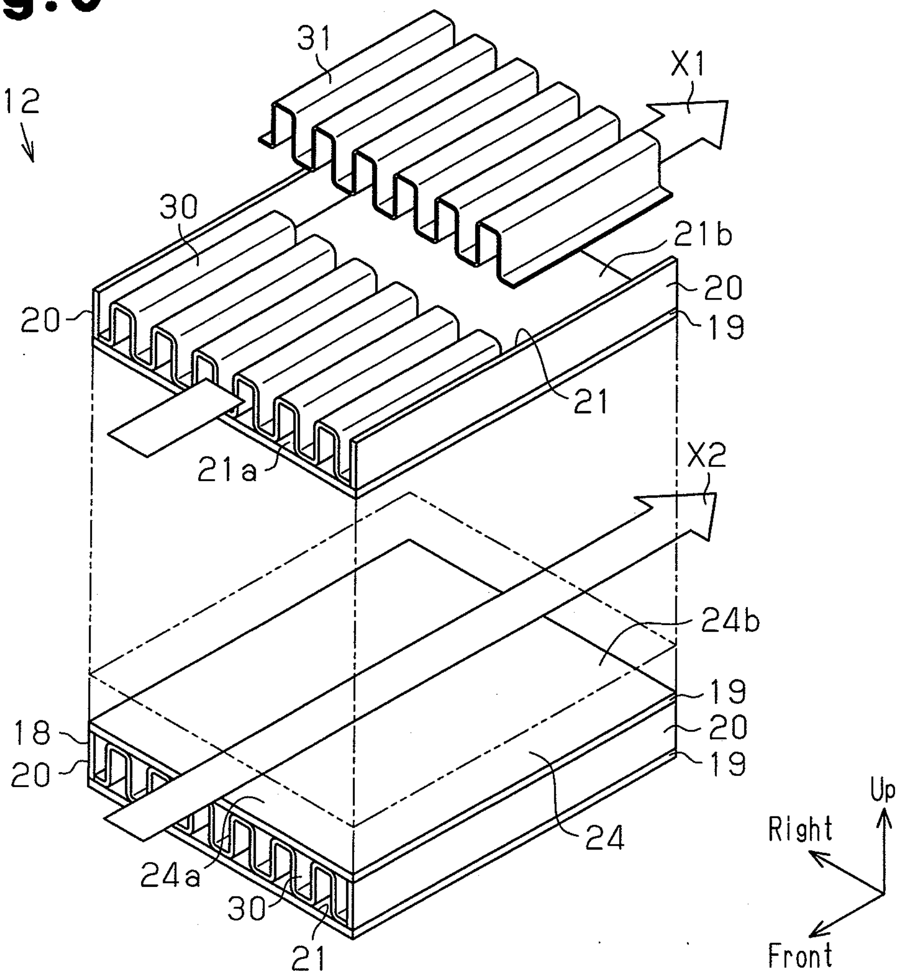

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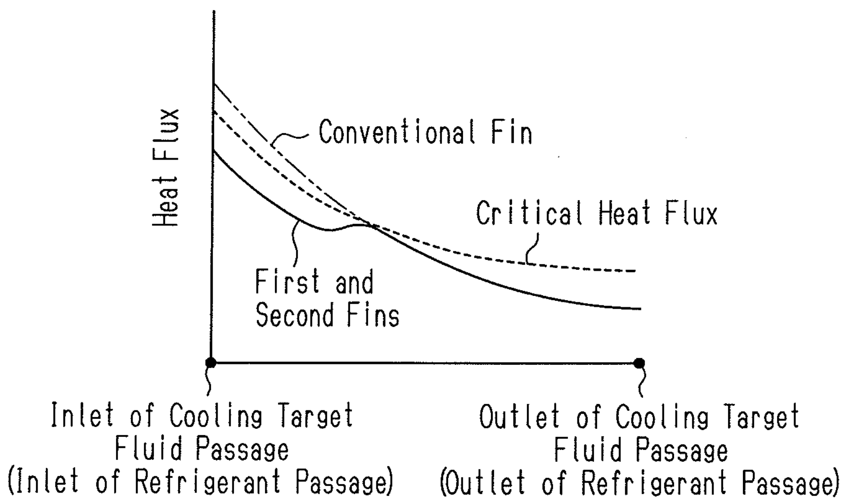
Fig.10



Heat Flux
Conventional Fin
Critical Heat Flux
First and
Second Fins
Inlet of Cooling Target
Fluid Passage
(Inlet of Refrigerant Passage)
Outlet of Cooling Target
Fluid Passage
(Outlet of Refrigerant Passage)

Fig.11

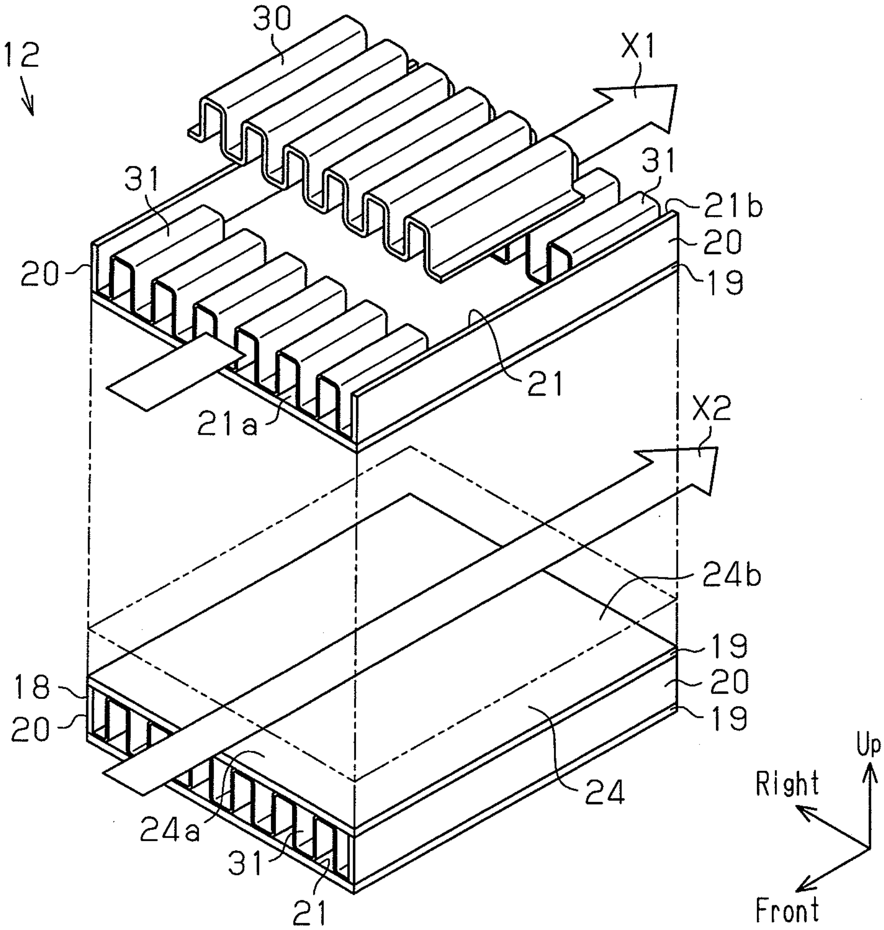

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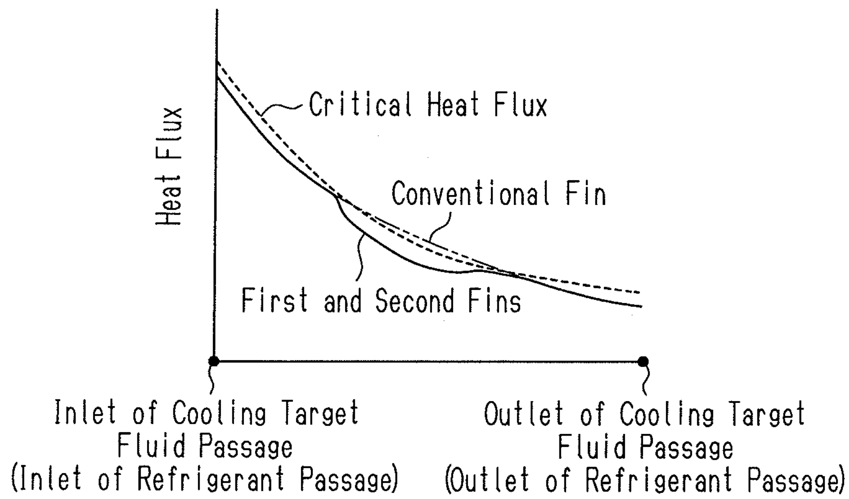
Fig.12


Heat Flux
Critical Heat Flux
Conventional Fin
First and Second Fins
Inlet of Cooling Target Fluid Passage (Inlet of Refrigerant Passage)
Outlet of Cooling Target Fluid Passage (Outlet of Refrigerant Passage)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069677

A. CLASSIFICATION OF SUBJECT MATTER
F28D9/02(2006.01)i, *F28F3/08*(2006.01)i, *F28F13/02*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28D9/02, F28F3/08, F28F13/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 134490/1989(Laid-open No. 79070/1991) (Sumitomo Precision Products Co., Ltd.), 12 August 1991 (12.08.1991), entire text; all drawings (particularly, fig. 1, 2) (Family: none)	1-4
Y	JP 2009-192177 A (Toyota Industries Corp.), 27 August 2009 (27.08.2009), entire text; all drawings (Family: none)	1-4

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search 01 December, 2010 (01.12.10)	Date of mailing of the international search report 14 December, 2010 (14.12.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2010/069677

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 60-238688 A (Mitsubishi Electric Corp.), 27 November 1985 (27.11.1985), entire text; all drawings (particularly, fig. 10, 13, 14) & US 4616695 A & EP 161396 A2 & DE 3565174 D & CA 1268755 A & KR 10-1989-0003897 B1	4 5

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Patent documents cited in the description

- JP 3079070 A **[0004]**
- JP 7159074 A **[0060]**