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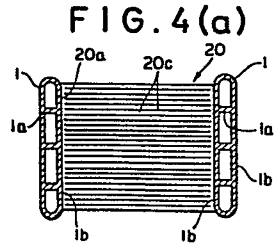
(54) **Heat exchanger.**

(57) A heat exchanger comprising a flat pipe for allowing a heat exchange medium to pass therethrough, flat surfaces of the flat pipe being confronted with each other at an interval and being disposed in parallel, and fins formed by corrugating a strip metal plate, the fins being arranged between the confronted flat surfaces and along their lengthwise direction, characterized in that the strip metal plate is modified structurally in a new manner whereby yield of a fin material, rigidity of the fins and performance of heat transfer are improved, and occurrence of reject articles is reduced.

F I G. 4(a)



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The present invention relates to a heat exchanger.

The heat exchanger is a device for transmitting heat energy from a high-temperature fluid to a low-temperature fluid through a partition wall in order to accomplish heating or cooling. If the heat exchangers are classified structurally, there will be found a pipe type heat exchanger having fins. When a gas is caused to flow outside a heat transfer pipe, a heat transfer rate between the heat transfer pipe and the gas is small, therefore the pipe type heat exchanger having fins is employed in which the fins are fixed on the surfaces of the heat transfer pipe to increase heat fluxes.

As be definite from the foregoing, fitting a variety of fins on the heat transfer pipe is commonly carried out with the intention of improving the heat transfer performance of the heat exchanger, and various configurations of the fins have been suggested. The inventors of the present invention have also proposed, in place of conventional corrugate fins, a high-performance heat exchanger having needle fins (Japanese Utility Model Application Nos. 111005/1981 and 1714/1982).

This suggested heat exchanger equipped with the needle fins is excellent as a condenser in an air conditioner for a car and a house, an evaporator or the like, and its structure is, for example, as shown in FIGS. 1 to 3 attached hereto. That is to say, as a heat transfer pipe, there is used an extruded flat pipe 1 having chambers therein defined by a plurality of partition walls 1a; flat surfaces 1b of the flat pipe 1 are confronted with each other at an interval and disposed in parallel; and a needle fin group 2, which is formed by corrugating a strip metal plate, is disposed between the confronted flat surfaces 1b of the flat pipe 1 in a manner normal to the lengthwise direction of the flat pipe 1. In operation, a heat exchange medium is fed into the flat pipe 1 through union joints 3 at opposite ends thereof, and a fluid such as air is caused to flow thereinto from outside in a direction normal to the lengthwise direction of the flat pipe 1 (i.e., in a direction along straight portions of the corrugate needle fins 2) in order to carry out heat exchange.

The needle fin group 2 can be prepared by forming numerous rectangular punched portions 2b in the strip metal plate (plate width h), slightly leaving opposite width direction end portions 2a thereof, so that the plate is shaped into a ladder-like form. The thus formed needle fin group 2 is corrugated by causing it to meander along the lengthwise direction of the flat pipe at a meander width w, and the opposite width direction end portions of the needle fin group are brazed or caused to adhere to the confronted flat surfaces 1b of the flat pipe 1 by use of a brazing material or an adhesive previously applied on the flat surfaces 1b. In this case, the needle fin group 2 having numerous needle fins 2c is arranged so that each fin pitch parallel to the flow direction of air 4 may be P_L and each fin pitch normal to the flow direction of the air 4 may be P_T.

However, it has been found that the heat exchanger equipped with such needle fins has the following faults:

(1) Since the punched portions 2b are provided in the strip metal plate in order to leave the needle fins 2c, an amount of the plate material corresponding to the punched portions is wasteful, which is undesirable from the viewpoints of resources saving and material cost, and particularly when aluminum is employed as the strip metal plate source, its wastage is serious.

(2) The needle fin group 2 is structurally weak in stiffness in the direction of a plate width (height) h. Therefore, when the application of pressure is carried out to secure the needle fin group on the flat surfaces 1b, the needle fins 2c are prone to curve, so that the fin pitches P_L, P_T would be ununiformed and many reject articles would be manufactured.

(3) Further, with regard to heat transfer performance, since the needle fins 2c are arranged in a straight line

along the direction of the air flow 4, the downstream needle fins 2c get into a boundary layer flow formed by the upstream needle fins 2c. This leads to deterioration in efficiency of the fins.

(4) Furthermore, in the case of the heat exchanger equipped with such fins 2c as mentioned above, the entrance of the air flow 4 into the needle fin group 2 is accomplished through the curved portions of the corrugated plate, i.e. top and bottom portions of the group, and the discharge of the air flow is also done through the same curved portions. Therefore, inflow and outflow of the air 4 are greatly obstructed by the needle fins. As a result, a flow velocity vector 4a of the air 4 at the curved portions of the corrugated plate is small and a flow velocity vector 4b at the straight portions of the corrugated plate is large. Finally, pressure loss at the inlet and outlet sides of the heat exchanger is great, and heat transfer rate is lowered due to the ununiformed flow velocity, which facts lead to the deterioration in heat transfer performance.

(5) Still further, since a sectional shape of the needle fins is rectangular and their edge portions are sharp, a gas which is streaming near the edge portions brings about turbulence. In consequence, pressure loss is large and noise occurs, and additionally the flow

velocity of the gas is reduced due to the pressure loss and heat transfer rate is thus deteriorated. Moreover, since the needle portions 2c are arranged in a straight line along the direction of the air flow 4, contact of the downstream needle portions 2c with the air flow 4 is obstructed by the upstream needle portions 2c. As a result, the air-side heat transfer rate at the downstream needle portions 2c is poor, and it is accordingly impossible to improve the heat transfer rate to an enough extent.

An object of the present invention is to provide a heat exchanger which can eliminate conventional drawbacks described above, and can improve yield of a fin material, rigidity of fins and performance of heat transfer and is hard to become a reject article. Such an object of the present invention can be achieved by a heat exchanger comprising a flat pipe for allowing a heat exchange medium to pass therethrough, flat surfaces of the flat pipe being confronted with each other at an interval and being disposed in parallel, and fins formed by corrugating a strip material plate, the fins being arranged between the confronted flat surfaces above and along their lengthwise direction, characterized in that the fins take the configuration of a needle fin group which is prepared by punching out the strip metal plate in the portions corresponding to curved portions of the corrugated plate, leaving its opposite width direction end portions; forming numerous width direction notches in portions corresponding to straight portions of the corrugated plate in order to provide fins therebetween; and causing the respective adjacent fins to alternately oppositely project.

Another object of the present invention is to provide a heat exchanger which can overcome the aforementioned conventional drawbacks and has less pressure loss and high heat transfer performance. Such an object of the present invention can be accomplished by a heat exchanger comprising a flat pipe for allowing a heat exchange medium to pass therethrough, flat surface of the flat pipe being confronted with each other at an interval and being disposed in parallel, and fins formed by corrugating a strip material plate, the fins being arranged between the confronted flat surfaces above and along their lengthwise direction, characterized in that the fins take the configuration of a ladder-like fin group which is formed by punching out the strip metal plate in the portions corresponding to curved portions of the corrugated plate, leaving its opposite width direction end portions; and punching out the strip metal plate in the portions corresponding to straight portions of the corrugated plate in order to form numerous slits therein.

Still another object is to provide a heat exchanger adapted to have great heat transfer rate and to generate less noise. Such an object can be achieved by a heat exchanger comprising a flat pipe for allowing a heat exchange medium to pass therethrough, flat surfaces of the flat pipe being confronted with each other at an interval and being disposed in parallel, and fins formed by corrugating a strip material plate, the fins being arranged between the confronted flat surfaces above and along their lengthwise direction, characterized in that the fins are removed partially to form portions for allowing a fluid to pass therethrough, and outer peripheral surfaces of the fins are made in the state of a smooth curvy surface.

A further object is to provide a heat exchanger which can further improve an air-side heat transfer rate. Such an object of the present invention can be accomplished by a heat exchanger comprising a flat pipe, in cross section, meanderingly arranged so that its flat surfaces may be parallel to each other at a predetermined interval, and a ladder-like needle corrugate fin meanderingly arranged in a space defined by the flat surfaces above so as to be parallel to each other in the width direction of the flat pipe, characterized in that the needle portions of the corrugate fin are shaped into a circular form in cross section, and the respective adjacent needle portions are caused to alternately oppositely project from a standard plane.

FIGS. 1 (a) and 1 (b) to FIGS. 3 (a) and 3 (b) show a heat exchanger having conventional needle fins, FIG. 1 (a) is a front elevational view, FIG. 1 (b) is a cross-sectional view, FIG. 2 is a partial perspective view, FIG. 3 (a) is a partial cross-sectional view, and FIG. 3 (b) is a partial cross-sectional view of the needle fins;

FIGS. 4 (a), (b) and (c) and FIG. 5 show a first embodiment of the heat exchanger according to the present invention, FIG. 4 (a) is a partial cross-sectional view, FIG. 4 (b) is a partial cross-sectional view of the needle fins, FIG. 4 (c) is a partial front elevational view, and FIG. 5 is an enlarged perspective view of the needle fins;

FIG. 6 (a) and (b) and FIG. 7 show a second embodiment of the heat exchanger according to the present invention, FIG. 6 (a) and (b) are partial cross-sectional views, respectively, FIG. 7 is an enlarged perspective view of the fin portions;

FIG. 8 (a), (b) and (c) show a third embodiment of the heat exchanger according to the present invention, FIG. 8 (a) is a partial cross-sectional view, FIG. 8 (b) is a partial cross-sectional view of the needle fins, and FIG. 8 (c) is an enlarged perspective view of the needle fins;

FIG. 9 (a) and (b) and FIG. 10 show a fourth embodiment of the heat exchanger according to the present invention, FIG. 9 (a) is a partial cross-sectional view of the needle fins, FIG. 9 (b) is an enlarged perspective view of the needle fins, FIG. 10 is a diagram showing an air-side heat transfer rate according to the heat exchanger illustrated in FIG. 9 for comparison with that of the heat exchanger in FIG. 8.

Now, the present invention will be described with regard to its first embodiment on the basis of FIGS. 4 to 5:

A heat exchanger of the present invention makes use of an extruded flat pipe 1, by way of a heat transfer pipe, in which partition walls 1a are installed therein in its lengthwise direction, as in a conventional one. The one extruded flat pipe 1 may be caused to meander so that its flat surfaces 1b may be confronted with each other at an interval and disposed in parallel, alternatively many extruded flat pipes 1 may be connected to each other with the interposition of headers. In the spaces defined by the flat surfaces 1b, there is secured a needle fin group 20 in a manner normal to the lengthwise direction of the flat plate 1 by use of a brazing material or adhesive, the needle fin group 20 being formed by corrugating a strip metal plate.

The needle fin group 20 can be formed from the strip metal plate as follows: The strip metal plate having a wall thickness of T and a width of h is employed; the strip metal plate is punched out in the portions corresponding to curved portions R of the corrugated plate, slightly leaving opposite width direction end portions 20a thereof, in order to form punched portions 20b; the strip metal plate is formed with width direction notches in the portions corresponding to straight portions L of the corrugated plate at an interval substantially equal to the wall thickness T in order to form needle fins 20c between the respective notches; and the adjacent needle fins 20c are caused to alternately project in order to obtain a needle fin group 20 as shown enlargedly in FIG. 5. The thus formed needle fin group 20 is corrugated so that a corrugation width and a fin pitch of the straight portions L may be w and P_T, respectively, and the corrugated needle fin group 20 is inserted between the flat surfaces 1b of the flat pipe 1. Then, the fin group is secured on the flat surfaces 1b by the aid of the brazing material or adhesive which is previously affixed on the flat surfaces 1b. In the case of the thus secured needle fin group 20, a fin pitch parallel to the flow direction of air 4 is P_L, a fin pitch, normal to the flow direction of the air 4, of the straight portions L of the corrugated plate is P_T, a fin pitch between the needle fins 20c on the straight line L is Pt, a height of the fins (plate width) is h, and a wave height of the fins (meander width) is w.

With regard to the heat exchanger including the thus formed needle fin group 20, the portions 20b corresponding to the curved portions after completion of corrugation are only punched out in forming the needle fin group 20, therefore the yield of the used material can be improved to a great degree. Further, in the needle fin group 20, the notches are provided and the respective adjacent needle fins 20c are caused to alternately project, therefore the fin rigidity can be improved noticeably. As a result, even if a pressure is applied at the time of securing the needle fin group on the flat surfaces 1b, it will not be deformed. This makes it possible to obtain a stable heat exchanger without any deformation. Furthermore, since being different from the conventional constitution that the punched portions are alternately provided to form the ladder-like structure, the needle fin group of the present invention can increase the fins by the number corresponding to the punched portions. In consequence, a heat transfer area can be enlarged and a heat transfer performance can thus be enhanced. Additionally, when it is attempted to obtain the same performance as in the conventional one, the heat exchanger according to the present invention can be miniaturized. Moreover, since the needle fins are arranged so as to project alternately oppositely, the development of boundary layers can be restrained and the heat transfer performance can thus be improved.

FIGS. 6 and 7 attached hereto show a second embodiment of the present invention.

In this embodiment, as a heat transfer, there is used an extruded flat pipe 1 in which partition walls 1a (which may be disposed along a longer axis, in cross section, of the pipe, though FIG. 1 (b) shows its arrangement along a shorter axis) are installed therein in its lengthwise direction as in the case of the conventional one. The one flat pipe 1 may be caused to meander so that its flat surfaces 1b may be confronted with each other at an interval and disposed in parallel, as shown in FIG. 1, alternatively many flat pipes 1 may be connected to each other with the interposition of headers. In the space defined by the flat surfaces 1b, there is arranged a needle fin group 30 in a securing manner by use of the brazing material or adhesive, the needle fin group 30 being formed by corrugating a strip metal plate and being disposed there in a style normal to the lengthwise direction of the flat pipe 1 or in an inclined style.

When the conventional needle fin group (see FIGS. 3 (a) and 3 (b)) was reviewed in detail, it has been found that the increase in pressure loss and the decrease in heat transfer rate are attributed to the fact the inflow and outflow of the air 4 are obstructed by the needle fins 2c at the curved portions of the corrugated plate, i.e. at the tops and bottoms of the meander. Therefore, the needle fin group 30 of this embodiment is formed as follows: The strip metal thin plate which is a fin material is extensively punched out in the portions corresponding to the curved portions R of the corrugated plate, slightly leaving opposite width direction end portions 30a thereof, in order to form punched portions 30b; and the portions, of the strip metal plate, corresponding to the straight portions L of the corrugated plate are formed with numerous rectangular slits 30c, slightly leaving the opposite width direction end portions 30a thereof, in order to leave ladder-like needle fins 30d which constitute the needle fin group 30. The thus formed group 30 is corrugated by meandering it along the lengthwise direction of the flat surfaces 1b of the flat pipe 1. And, securing the needle fin group 30 on the flat surfaces 1b of the flat pipe 1 as a heat transfer pipe can be carried out by brazing or bonding the opposite width direction end portions of the corrugated needle fin group 30 to the flat surfaces 1b with the aid of the brazing material or adhesive which is previously applied on the flat surfaces, but at this securing operation, the straight portions L of the corrugated plate may be arranged so as to be parallel to the width direction of the flat pipe 1 or to be inclined as much as an angle θ.

In the heat exchanger equipped with such a needle fin group 30, the curved portions R of the corrugated plate have no needle fins 30d, therefore the inflow and outflow of the air 4 can smoothly and uniformly carried out without any obstruction. As a result, the flow velocity vector 4a of the air 4 at the curved portions R is equal to the flow velocity vector 4b of the air 4 at the straight portions L, and thus the pressure loss of the air is reduced and the heat transfer rate is improved. Therefore, when it is contemplated to obtain the same performance as in the conventional one, the heat exchanger according to the present invention can be miniaturized.

FIG. 8 shows a third embodiment of the present invention, and a heat exchanger of this embodiment, as illustrated in FIGS. 8 (a), (b) and (c), comprises a flat pipe 1, in cross section, which is caused to meander so that its flat surfaces 1b may be parallel to each other at an interval, and a corrugate fin 40 meanderingly arranged in a space defined between the flat surfaces 16. As shown in FIGS. 8 (a), (b) and (c), the corrugate fin 40 has needle portions 40b between its opposite end portions 40a, 40a, and each needle portion 40b is shaped into a circular form in cross section. Further, between the respective needle portions 40b, there are provided openings 40c, and at the curved portions 40a' of the corrugate 40, there are formed fin-free portions 40d in order to facilitate the inflow and outflow of the air flow 4. The corrugate fins 40 are arranged in parallel to each other in the width direction of the flat surfaces 16 of the flat pipe 1, and the respective needle portions 40b are in-line arranged (i.e., arranged in a straight line) at a fin pitch P_{TI} in parallel with the width direction of the flat surfaces 16 (i.e., the inflow and outflow direction of the air flow 4), as illustrated in FIG. 8 (b).

Further, in the above embodiment, the sectional shape of the needles is circular, but it may be elliptic. Furthermore, if edge portions of the needle fin, in addition to the needle portions thereof, are shaped into an elliptic form in cross section, or are finished in the form of smooth curved surface, the pressure loss will be small. Moreover, it is to be noted that a fluid referred to here means a gas or a liquid.

According to the aforementioned heat exchanger, in the corrugate fin, the fin portions near which the fluid passes have their outer peripheral surfaces finished in the form of a smooth curved surface, therefore the pressure loss of the fluid which runs along the members having an increased heat transfer area is small. As a result, the generation of noise is also small and the heat transfer rate between the fluid and the members having the increased heat transfer area is great.

FIG. 9 shows a fourth embodiment of the present invention, and it is directed to a further improved heat exchanger of the third embodiment illustrated in FIG. 8.

This heat exchanger, as shown in FIG. 9 (a), comprises a flat pipe in cross section and a corrugate fin 50 meanderingly arranged in a space defined by the flat surfaces 1b of the flat pipe 1. As shown in FIG. 9 (b), in the case of this corrugate fin 50, needle portions 50b are formed in a ladder-like form between opposite end portions 50a, 50a, and the respective needle portions 50b are shaped into a substantially circular form in cross section. Further, between the respective needle portions 50b, there are formed openings 50c, and at the curved portions 50a' of the end portions 50a, there are formed fin-free portions 50d in order to facilitate the inflow and outflow of the air flow 4. Furthermore, bending portions 50e are formed between the needle portions 50b and the opposite end portions 50a, 50a so that the respective adjacent needle portions 50b, 50b may be caused to alternately oppositely project by a predetermined distance from a plane comprising the opposite end portions 50a, 50a.

The thus prepared corrugate fins 50 are arranged so that they may be in parallel with each other in the width direction of the flat surfaces 1b of the flat pipe 1, and the fin pitch of the needle portions 50b is P_{TS}.

According to the heat exchanger above, the needle portions 50b are caused to alternately project from the plane of the opposite end portions 50a, therefore the downstream needle portions 50b can efficiently be heat exchanged with the air flow 4, which improves the air-side heat transfer rate. In the case of $P_{TS} = 2P_{TI}$ (in the case that the needle portions of the heat exchanger shown in FIG. 8 are caused to project without any processing), an effect on the improvement in α_a kcal/m.°C.hr (air-side heat transfer rate) has been investigated, and obtained results are set forth in FIG. 10. In this drawing, an abscissa axis represents an air flow velocity (Fv <m/sec) and an ordinate axis represents an improvement ratio of the air-side heat transfer rate of the heat exchanger regarding this embodiment with respect to that of the heat exchanger shown in FIG. 8.

According to the results in FIG. 10, it is definite that the heat exchanger of this embodiment is better in the α_a than the one shown in FIG. 8. Further, the improvement ratio of the α_a tends to decrease with the increase in the air flow velocity, but within the range usually employed (Fv < 3 m/sec), it improves as much as 35% or more

Since improving in the air-side heat transfer rate, the aforesaid heat exchanger can be miniaturized and lightened, if it is attempted to have the same performance as in the conventional one. Therefore, when this heat exchanger is applied as an air conditioner for a car, effects such as saving of a car fuel and expansion of a car space can be obtained.

In addition, the ladder-like needle corrugate fin 50 can be formed by in-line punching and circularization in cross section, and its punching pitch is a fin pitch for permitting acquisition of a maximum air-side heat transfer rate α_{aI}. In the case of the corrugate fin of this embodiment, the maximum value of the air-side heat transfer rate α_{aI} can be obtained at a position where the fin pitch P_{TS} is narrower than $2P_{TI}$. For this reason, the fin pitch P_{TS} is to be narrowed, which serves to improve the yield of a used material.

Since the needle portions are circularized in cross section and are caused to project alternately normal to the direction of the air flow as described above, the heat exchanger having such needle portions can obtain noticeable effects of improvement in the air-side heat transfer rate, miniaturization and lightening of the heat exchanger body, betterment in the yield of the material, and the like.

Claims:

(1) A heat exchanger comprising a flat pipe for allowing a heat exchange medium to pass therethrough, flat surfaces of said flat pipe being confronted with each other at an interval and being disposed in parallel, and fins formed by corrugating a strip material plate, said fins being arranged between said confronted flat surfaces above and along their lengthwise direction, characterized in that said fins take the configuration of a needle fin group which is prepared by punching out said strip metal plate in the portions corresponding to curved portions of the currugated plate, leaving its opposite width direction end portions; forming numerous width direction notches in portions corresponding to straight portions of the corrugated plate in order to provide fins there-between; and causing said respective adjacent fins to alternately oppositely project.

(2) A heat exchanger according to claim 1 wherein said width direction motches are spaced at an interval substantially equal to a wall thickness of said strip metal plate.

(3) A heat exchanger comprising a flat pipe for allowing a heat exchange medium to pass therethrough, flat surface of said flat pipe being confronted with each other at an interval and being disposed in parallel, and fins

formed by corrugating a strip material plate, said fins being arranged between the confronted flat surfaces above and along their lengthwise direction, characterized in that said fins take the configuration of a ladder-like fin group which is formed by punching out said strip metal plate in the portions corresponding to curved portions of the corrugated plate, leaving its opposite width direction end portions; and punching out said strip metal plate in the portions corresponding to straight portions of the corrugated plate in order to form numerous slits therein.

(4) A heat exchanger according to claim 3 wherein said straight portions of the corrugated plate are arranged in parallel with the width direction of said flat pipe.

(5) A heat exchanger according to claim 3 wherein said straight portions of the corrugated plate are arranged inclinatorily with respect to the width direction of said flat pipe.

(6) A heat exchanger comprising a flat pipe for allowing a heat exchange medium to pass therethrough, flat surfaces of said flat pipe being confronted with each other at an interval and being disposed in parallel, and fins formed by corrugating a strip material plate, said fins being arranged between said confronted flat surfaces above and along their lengthwise direction, characterized in that said fins are removed partially to form portions

for allowing a fluid to pass therethrough, and outer peripheral surfaces of said fins are made in the state of a smooth curvy surface.

(7) A heat exchanger according to claim 6 wherein said fins are shaped so as to have a smooth curved surface and a circular form in cross section.

(8) A heat exchanger comprising a flat pipe, in cross section, meanderingly arranged so that its flat surfaces may be parallel to each other at a predetermined interval, and a ladder-like needle corrugate fin meanderingly arranged in a space defined by said flat surfaces above so as to be parallel to each other in the width direction of said flat pipe, characterized in that needle portions of said corrugate fin are shaped into a circular form in cross section, and said respective adjacent needle portions are caused to alternately oppositely project from a standard plane.

FIG. 1(a)
PRIOR ART

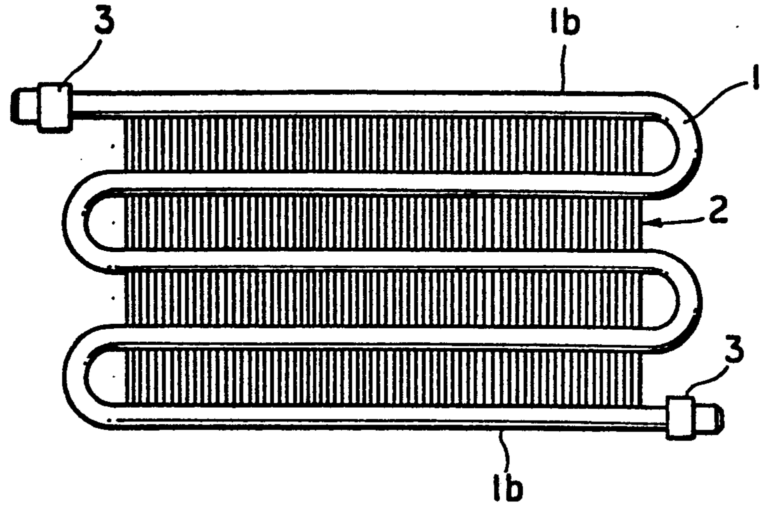


FIG. 1(b)
PRIOR ART

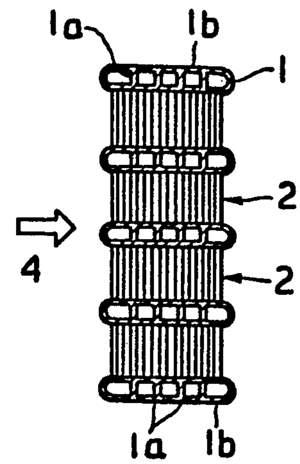


FIG. 2 PRIOR ART

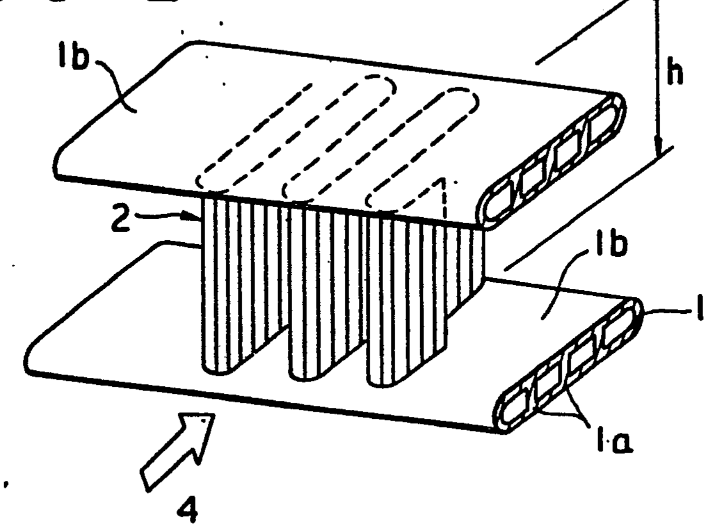


FIG. 3(a)
PRIOR ART

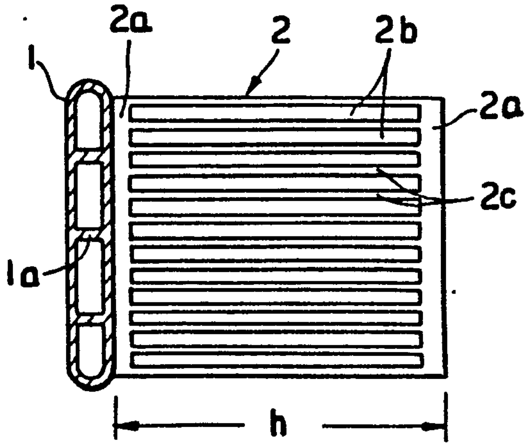


FIG. 3(b) PRIOR ART

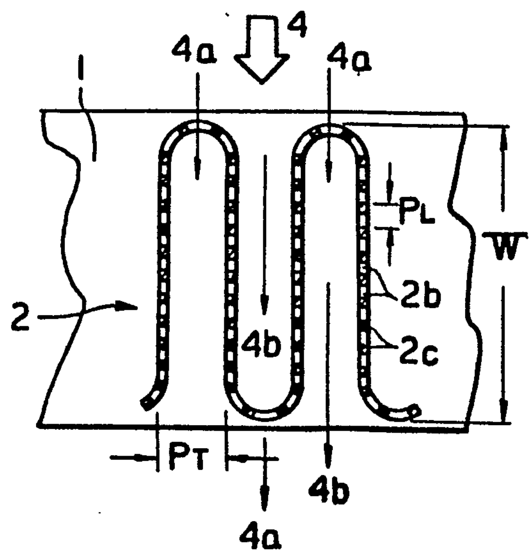


FIG.4(a)

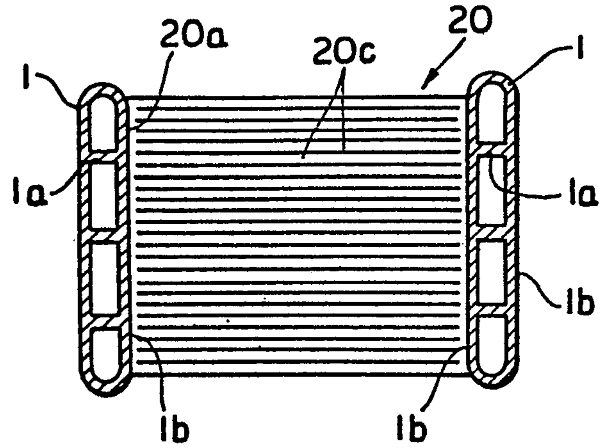


FIG.4(b)

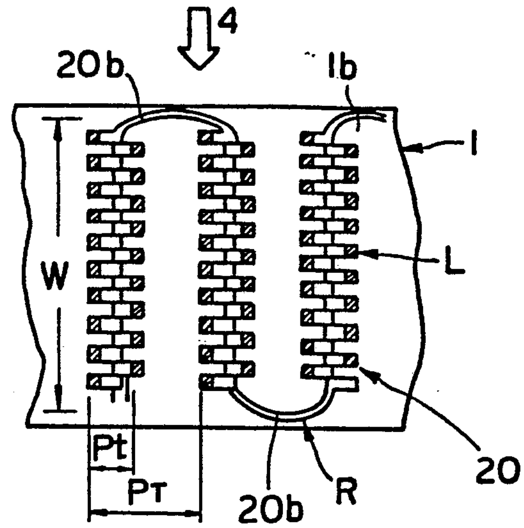


FIG.4(c)

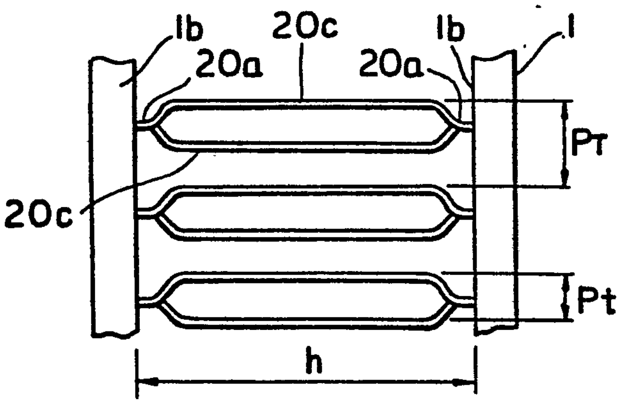


FIG.5

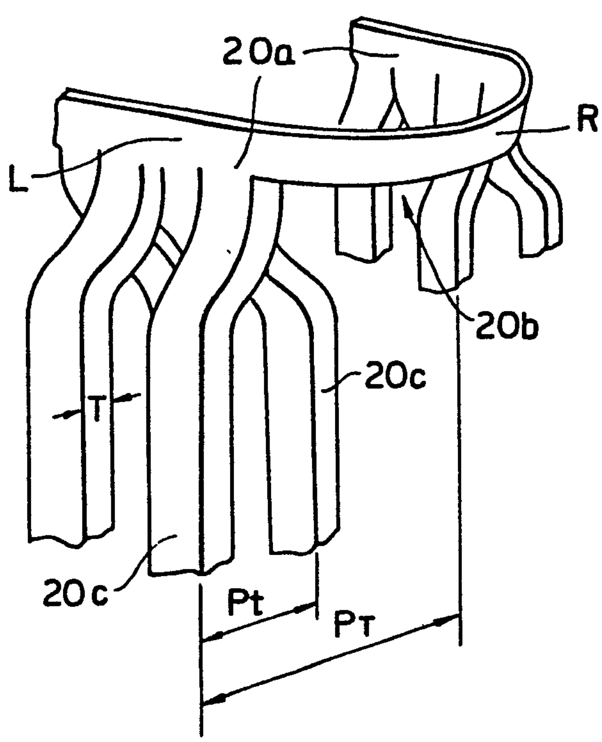


FIG.6(a)

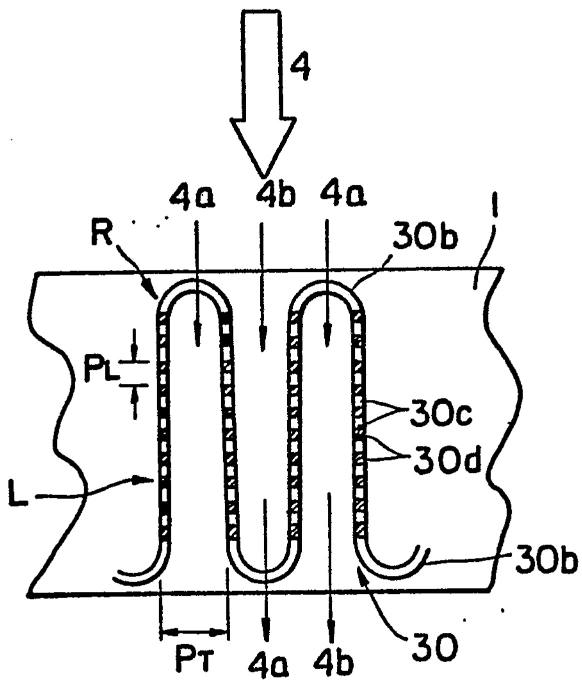


FIG.6(b)

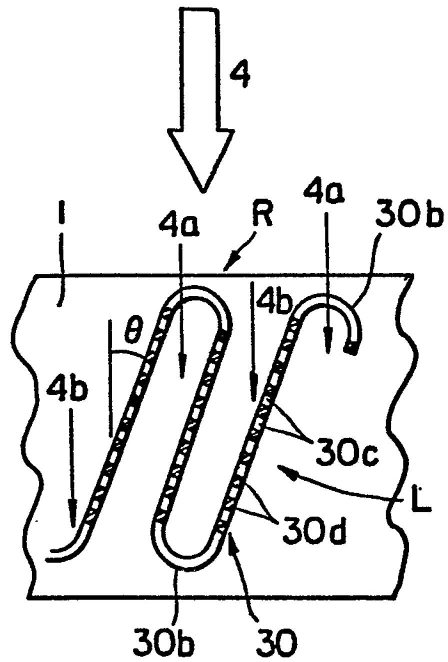


FIG.7

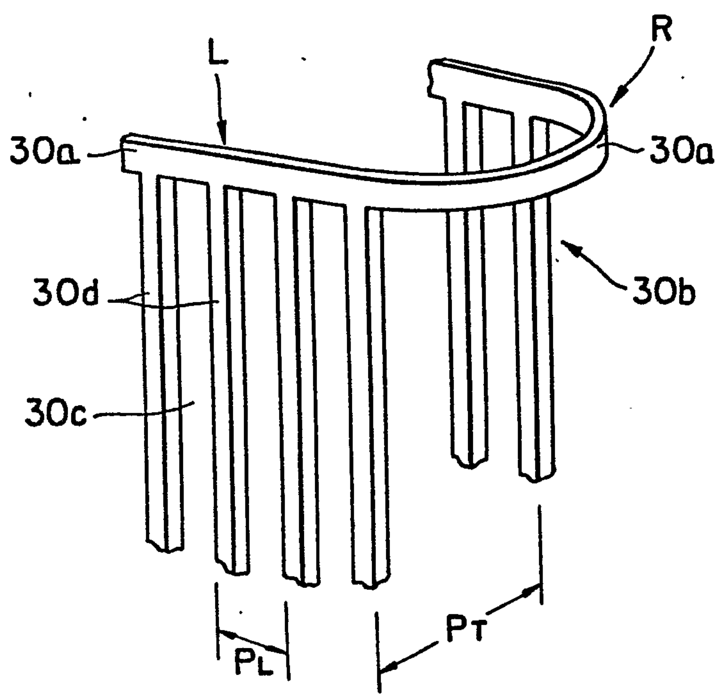


FIG.8(a)

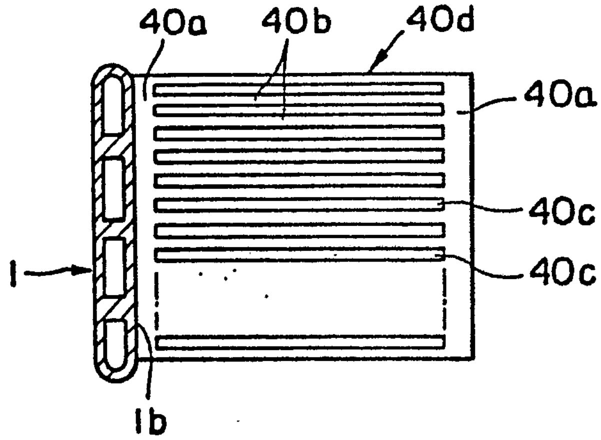


FIG.8(b)

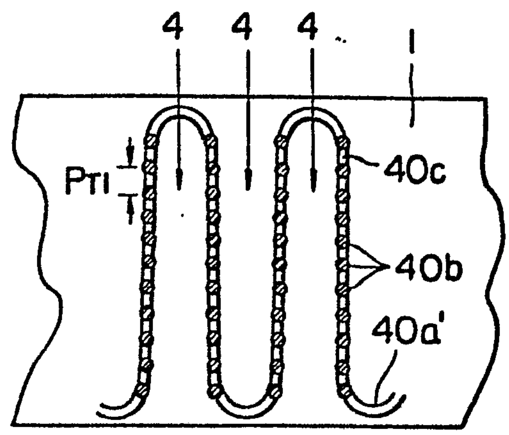


FIG.8(c)

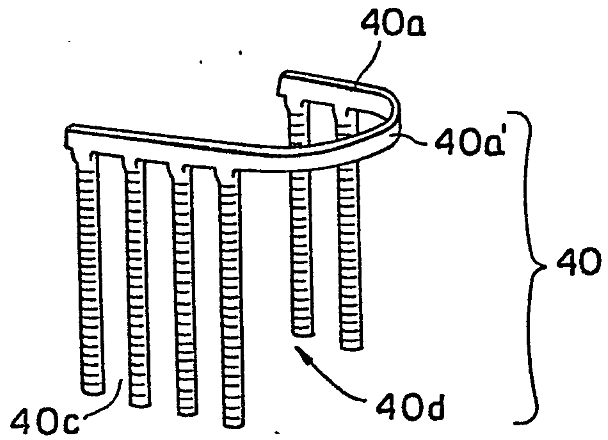


FIG.9(a)

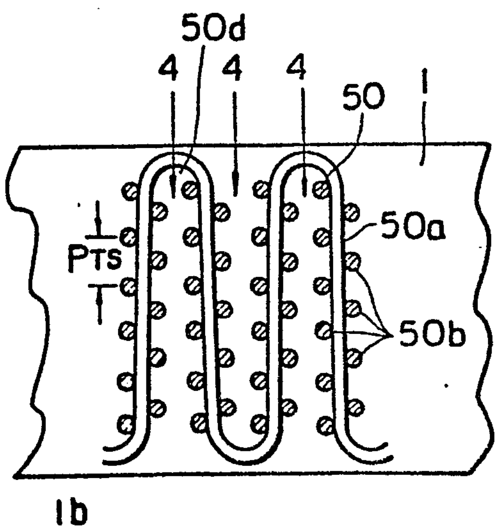


FIG.9(b)

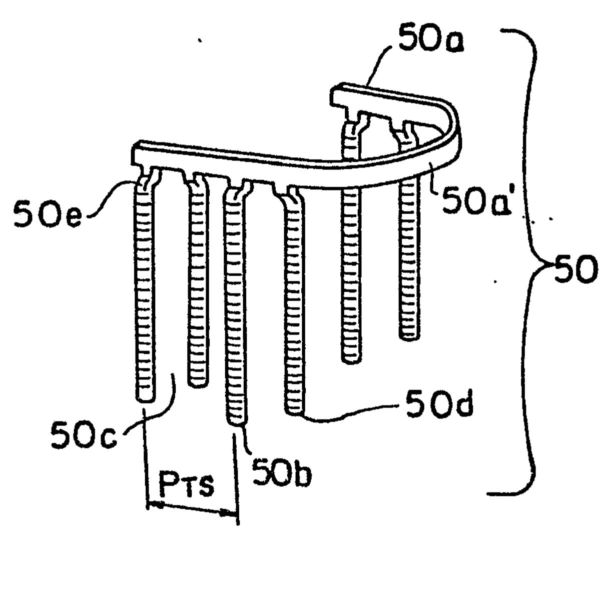
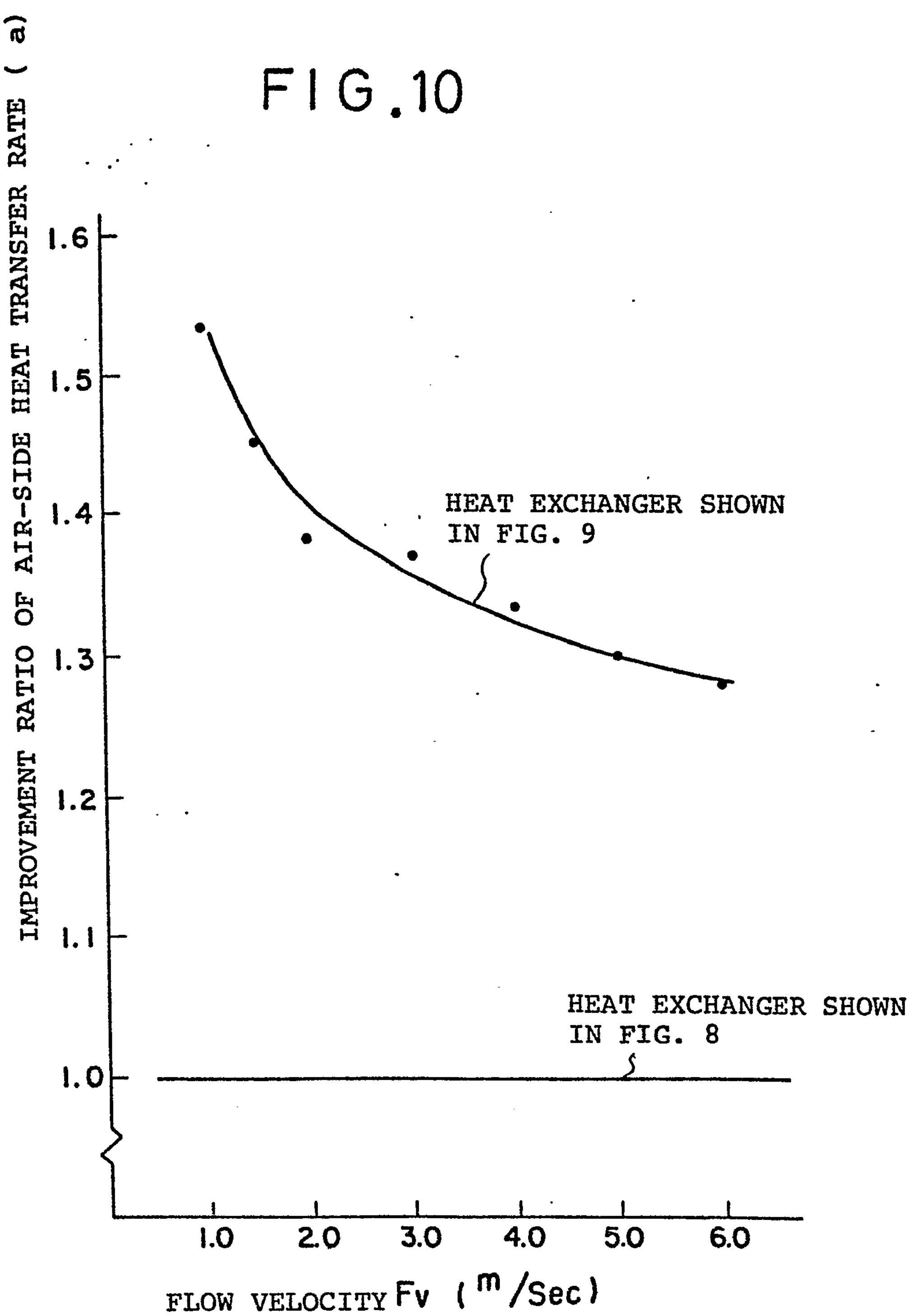


FIG.10


IMPROVEMENT RATIO OF AIR-SIDE HEAT TRANSFER RATE (a)
1.6
1.5
1.4
1.3
1.2
1.1
1.0
HEAT EXCHANGER SHOWN IN FIG. 9
HEAT EXCHANGER SHOWN IN FIG. 8
1.0
2.0
3.0
4.0
5.0
6.0
FLOW VELOCITY Fv (m /Sec)