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(54) **HEAT EXCHANGER**

(75) Inventors: **Young-Ha Jeon**, Daejeon (KR); **Ki-Hong Kim**, Daejeon (KR); **Jung-Jae Lee**, Daejeon (KR)

Correspondence Address:
LOWE HAUPTMAN HAM & BERNER, LLP
1700 DIAGONAL ROAD, SUITE 300
ALEXANDRIA, VA 22314 (US)

(73) Assignee: **HALLA CLIMATE CONTROL CORP.**, Daejeon (KR)

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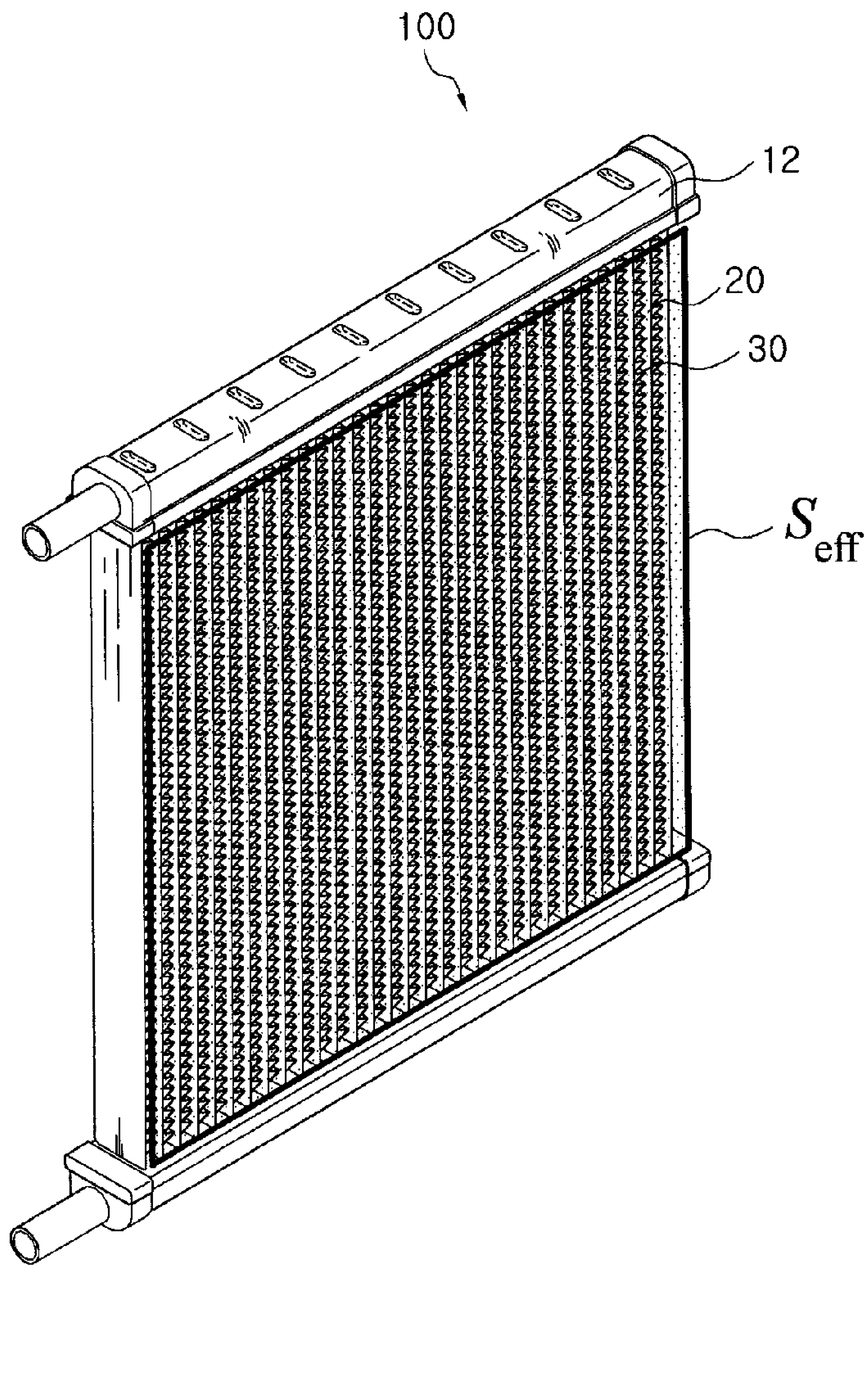
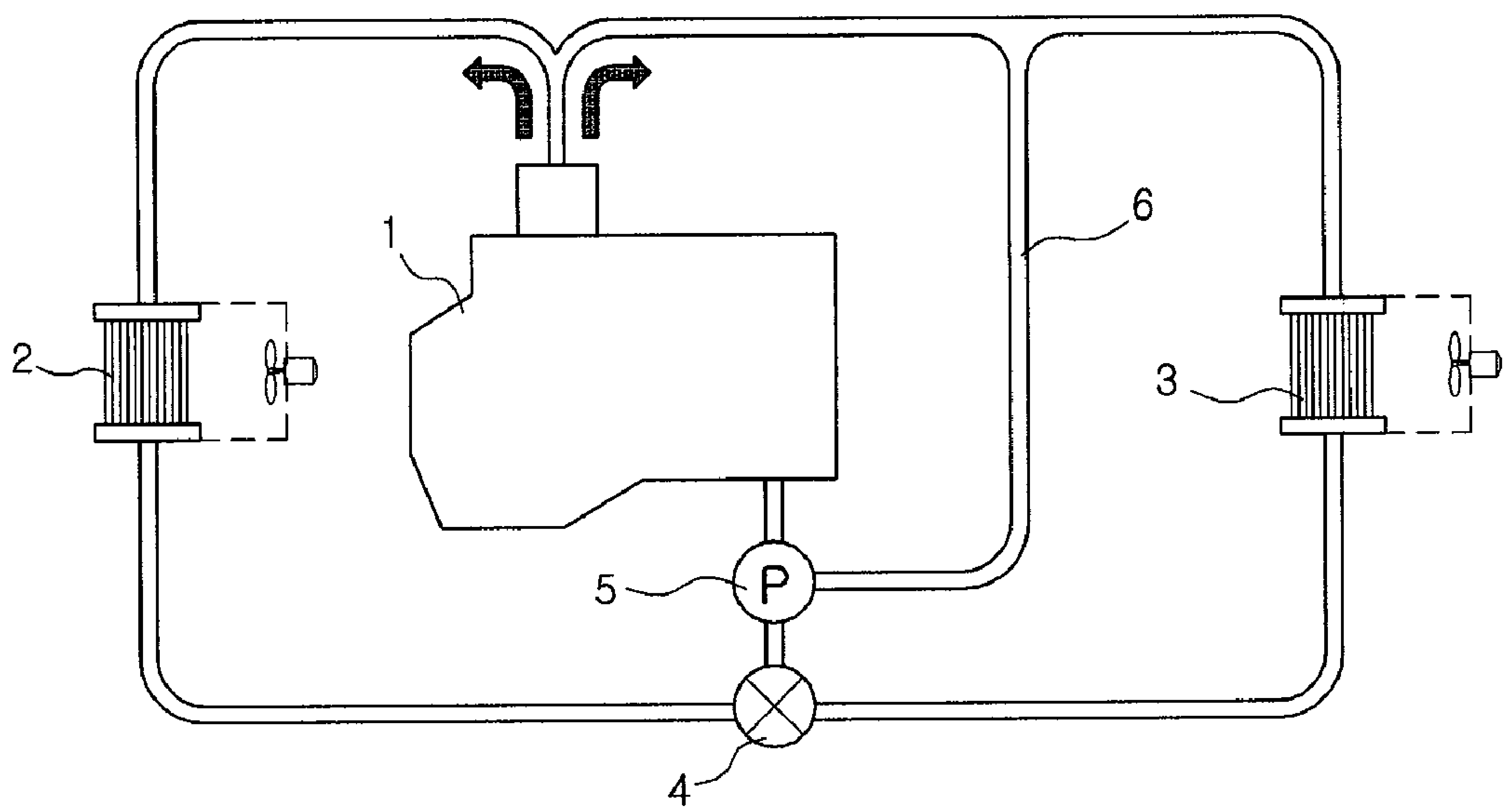
(57) **ABSTRACT**

A heat exchanger has plural tubes, an inlet tank, a fin, and an outlet tank. Each tube has a dimple structure for inducing a turbulent flow of heat exchange fluid flowing through each tube, thereby increasing heat exchange performance. The dimples of each tube satisfy the following formula:

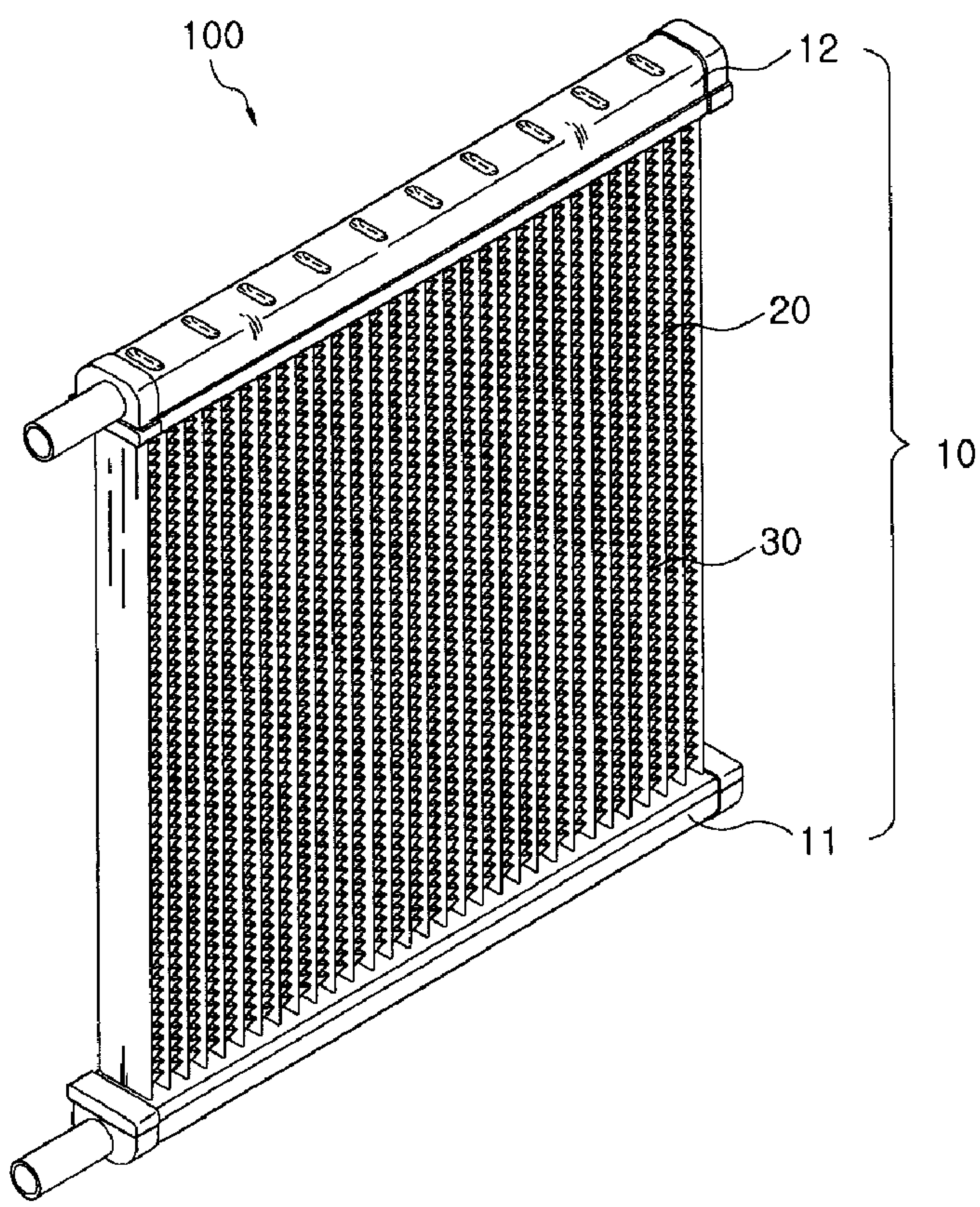
$$8.80 < \frac{\text{the sum } A_{dimple} \text{ of the product of a width } d \text{ and a depth } h \text{ of each dimple}}{\text{a length } L \text{ of the tube} \times \text{a height } H \text{ of the tube}} \times 100 < 13.60$$



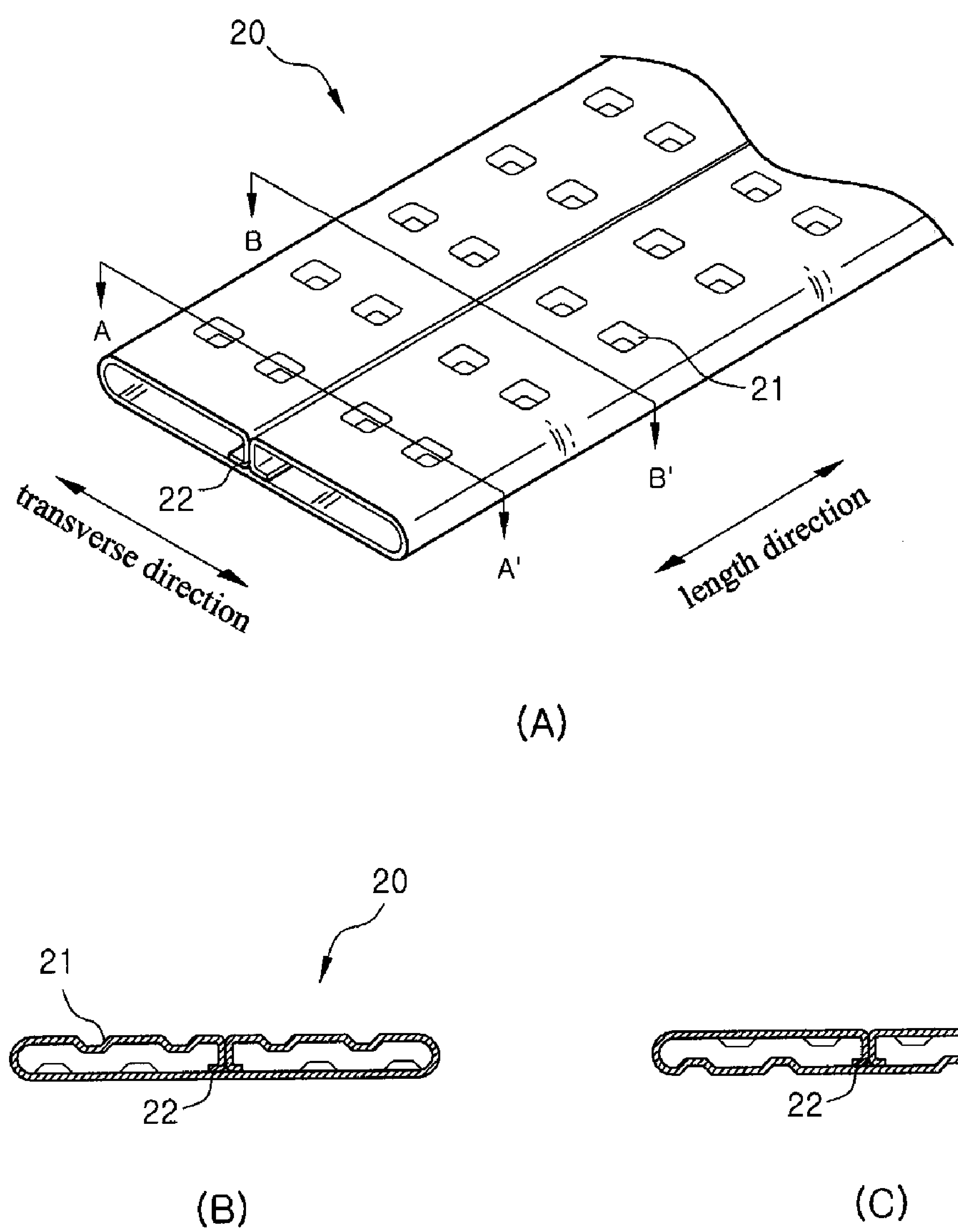
【Figure 1】



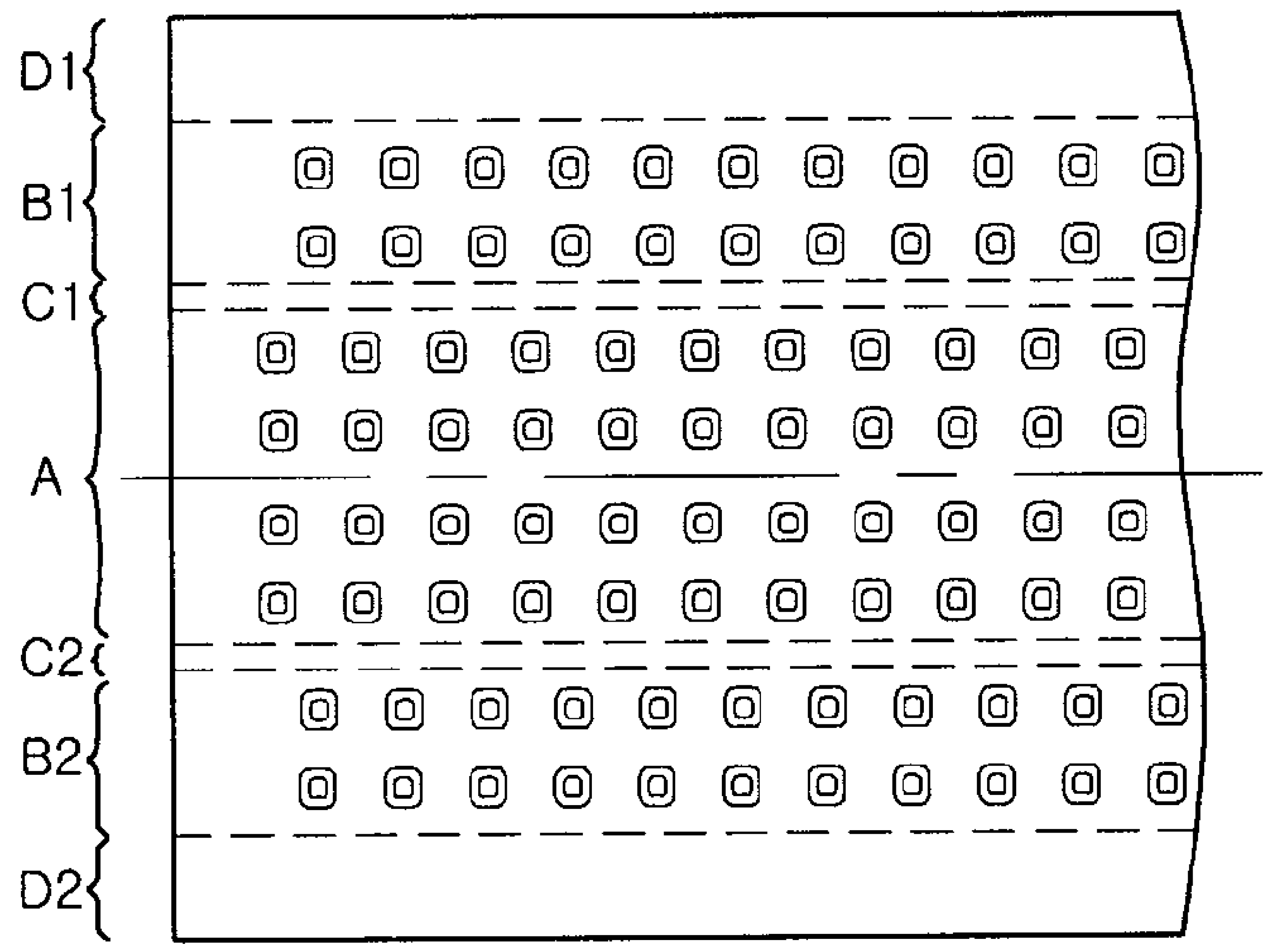
【Figure 2】



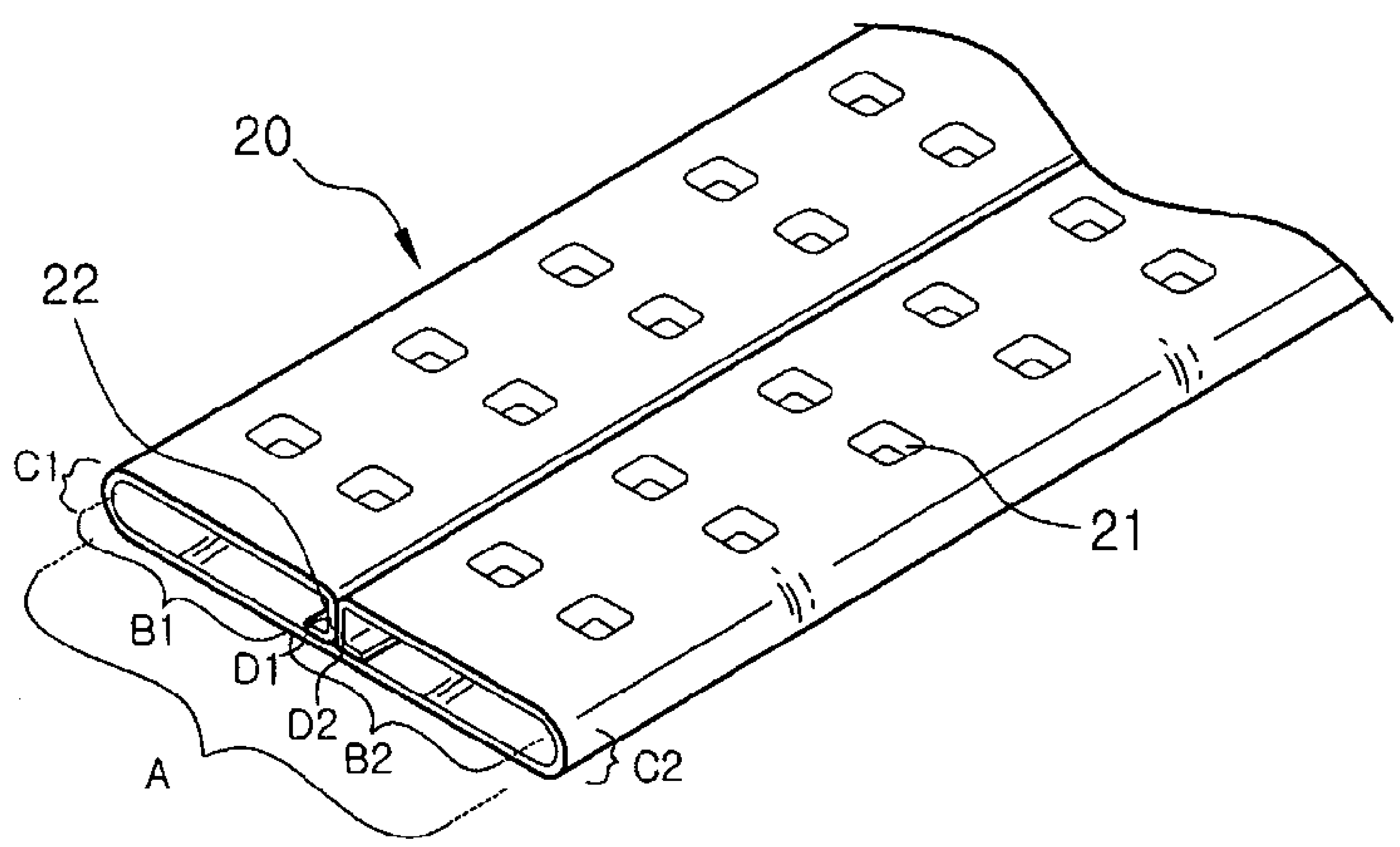
【Figure 3】


20
B
A
21
22
B'
A'
transverse direction
length direction
(A)
20
21
22
(B)
20
22
21
(C)

【Figure 4】

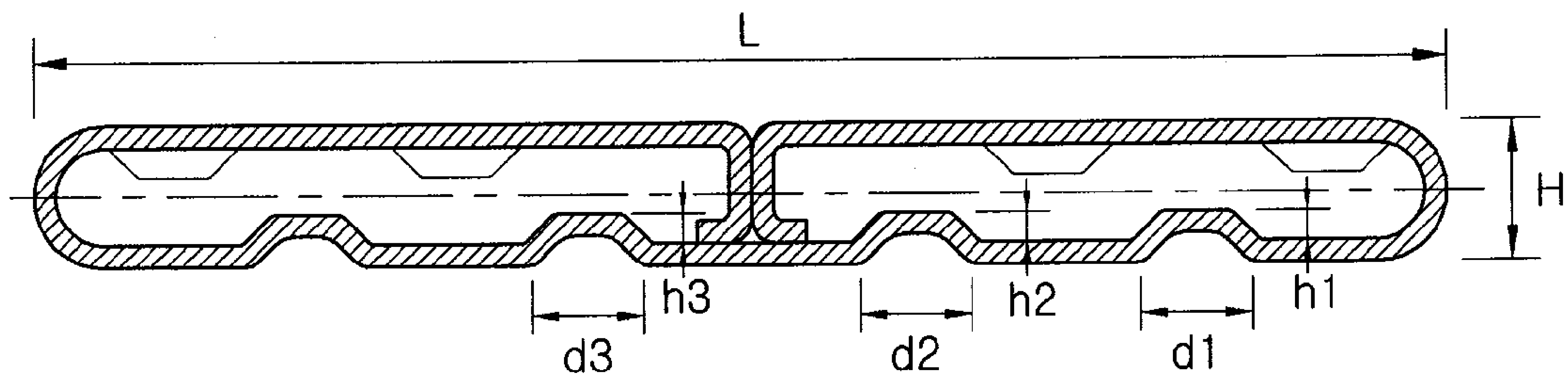


(A)

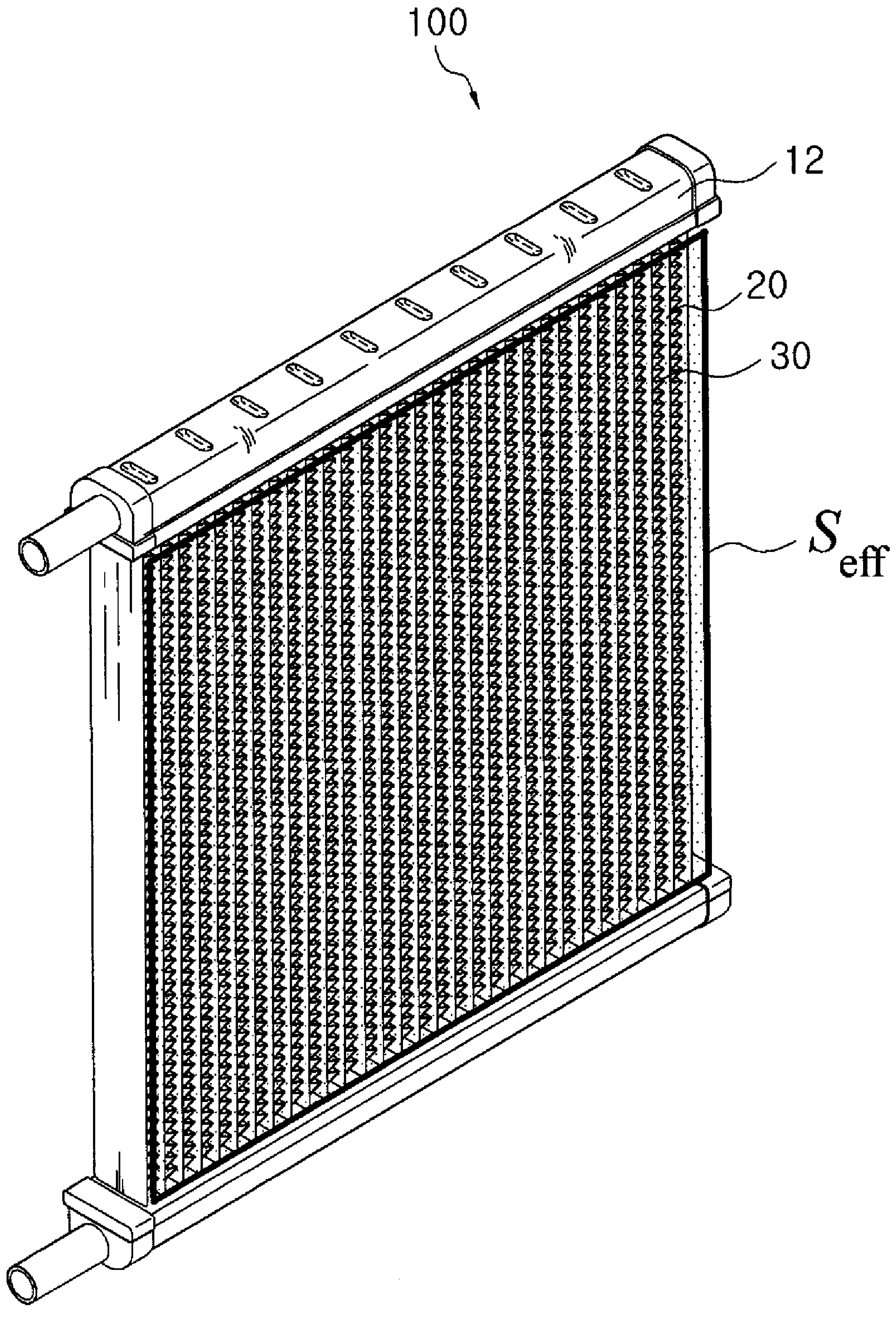


(B)

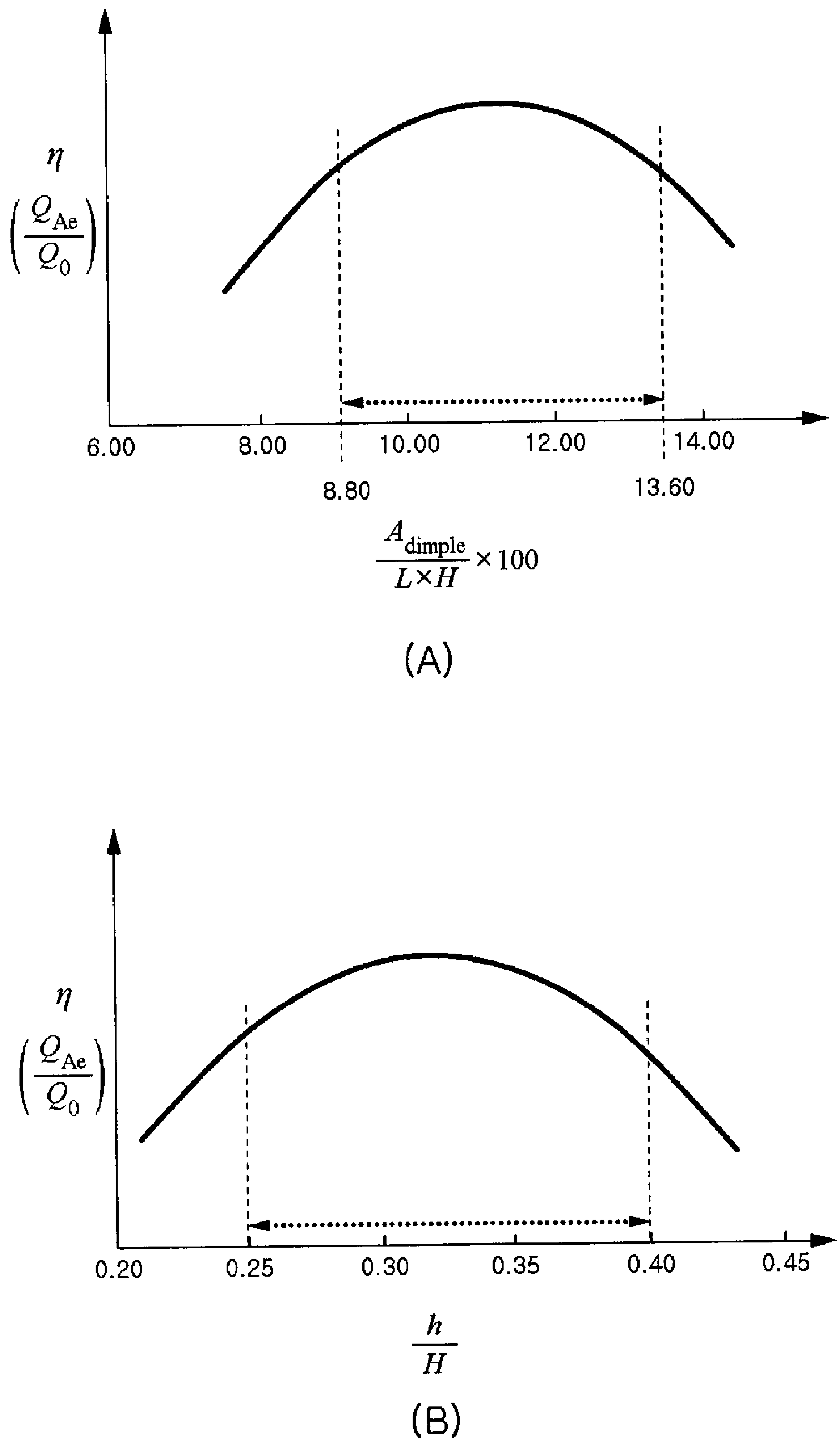
【Figure 5】



【Figure 6】



【Figure 7】



η
$\left(\frac{Q_{Ae}}{Q_0}\right)$
6.00
8.00
10.00
12.00
14.00
8.80
13.60
$\frac{A_{dimple}}{L \times H} \times 100$
(A)
η
$\left(\frac{Q_{Ae}}{Q_0}\right)$
0.20
0.25
0.30
0.35
0.40
0.45
$\frac{h}{H}$
(B)

HEAT EXCHANGER

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger, more particularly, to a heat exchanger with a tube having a dimple structure by which a turbulent flow is generated in the tube, thereby increasing a heat exchanging performance.

BACKGROUND ART

[0002] FIG. **1** is a view showing a general cooling and heating system of a vehicle. In a vehicle engine **1**, high temperature and high pressure gas is ignited and burned. Therefore, if leaving the vehicle engine **1** as it is, it will be overheated and a metallic material used in constructing the engine **1** is melted and thus a cylinder, a piston and the like may be damaged seriously. To prevent such damage, as shown in FIG. **1**, a water jacket (not shown) in which cooling water is stored is formed around the cylinder of the vehicle engine **1** and the cooling water is circulated through a radiator **2** or a heater core **3** by a water pump **5** so as to cool the engine **1**. The cooling water may be not passed through the heater core **3**, but directly returned to the water jacket through a bypass circuit **6** according to the purpose of heating and cooling. At this time, a thermostat **4** is provided in a passage for the cooling water so as to function as a control device for preventing the overheating of the engine **1** by controlling an opening/closing degree of the passage on the basis of a temperature of the cooling water.

[0003] The radiator **2** is a kind of heat exchanger for radiating heat of the cooling water which is heated by heat of the engine **1** while being circulated in the engine **1**. The radiator **2** is disposed in an engine room of the vehicle and provided with a cooling fan at a center portion thereof so as to cool a radiator core. Further, the heater core **3** is a part of an air conditioner of the vehicle and also functions as the kind of heat exchanger for supplying warm air to an inside of the vehicle using the high temperature cooling water which absorbs the heat generated from the engine **1** while being circulated in the engine **1**. In the heater core **3**, the high temperature cooling water which is heated by the heat of the engine **1** is passed through a fin and a tube of the heater core **3** so as to transfer the heat to air supplied from the outside, thereby providing the warm air to the inside of the vehicle.

[0004] In order to properly heat the inside of the vehicle, a heat exchange performance of the heater core should be increased. However, in case that the heat exchanger is installed in the vehicle, it is difficult to change a basic structure of the heat exchanger, like a size or a position of an inlet/outlet port for a heat exchange medium due to problems of connection with other parts as well as limitation of an inner space of the engine room. In order to increase an amount of radiant heat without change of the basic structure of the heat exchanger, typically, a design for increasing a cross-sectional area of the tube in which the heat exchange is substantially performed and thus increasing a flow rate in the tube is employed. However, if the cross-sectional area of the tube is increased, a laminar flow is generated at a low flow rate condition, and thus there is a problem that the amount of radiant heat is reduced. Japanese Laid-Open Publication No. 1996-136176 (hereinafter, called as "cited reference") had planed to improve the heat radiation performance by numerically limiting the tube and fin. In the cited reference, the laminar flow area is always maintained at a running speed of 60 Km/h or less so as to reduce a wide difference of the heating performance between when the vehicle is running at 60 Km/h or more and when the vehicle is in an idling state, thereby improving the heating performance. However, since the laminar flow is generated at the low flow rate condition, as described above, the heat exchange performance is deteriorated.

DISCLOSURE

Technical Problem

[0005] An object of the present invention is to provide a heat exchanger in which a turbulent flow is generated early at the low flow rate condition, thereby securing an optimum heat exchange performance.

[0006] Another object of the present invention is to provide an optimum design range for each element constructing a heat exchanger tube so as to satisfy the optimum heat exchange performance.

Technical Solution

[0007] In order to achieve the above objects, there is provided a heat exchanger comprising a plurality of tubes **20** which are arranged in parallel at regular distances to be parallel with a ventilation direction and through which a heat exchange medium is flowed; an inlet tank **11** in which the heat exchange medium is introduced and then distributed to the plurality of tubes **20**; a fin **30** which is interposed between the tubes **13** so as to increase a contact surface with air passing between the tubes **20**; and an outlet tank **12** in which the heat exchange medium flowed through the tubes **20** is collected and then discharged, wherein a dimple **21** is formed in each of the tubes **20** so as to be protruded to an inside of the tube **20**, and when a total sectional area $A_{dimiple}$ of the dimples **21** is expressed as sum of the product of a width d and a depth h of each dimple **21** and a sectional area of the tube **20** is expressed as the product of a length L and a height H of the tube **20**, a following formula is satisfied:

$$8.80 < \frac{\text{the sum } A_{dimple} \text{ of the product of a width } d \text{ and a depth } h \text{ of each dimple}}{\text{a length } L \text{ of the tube} \times \text{a height } H \text{ of the tube}} \times 100 < 13.60$$

[0008] Preferably, the depth h of the dimple **21** and the height H of the tube **20** satisfy a following formula:

$$0.25 < \frac{\text{a depth } h \text{ of the dimple}}{\text{a height } H \text{ of the tube}} < 0.4$$

[0009] Preferably, the plurality of dimples which are arranged in a transverse direction so as to form a row are formed at upper and lower surfaces of the tube **20**, and the upper dimple row and the lower dimple row of the tube **20** are alternately arranged along the length of the tube **20**.

[0010] Preferably, the dimples **21** of the upper dimple row and lower dimple row are also arranged alternately along the width of the tube **20** so that the dimples **21** of the upper dimple row and lower dimple row are not coincided with each other, and one of the dimples **21** of the lower dimple row is disposed between two adjacent dimples **21** of the upper dimple row, and one of the dimples **21** of the upper dimple row is also disposed between two adjacent dimples **21** of the lower dimple row.

[0011] Preferably, the number of dimples **21** of the upper dimple row of the tube **20** is the same as the number of dimples **21** of the lower dimple row of the tube **20**.

ADVANTAGEOUS EFFECTS

[0012] According to the present invention, since a turbulent flow is generated early even when a flow rate condition of the heat exchange medium in the heat exchanger tube is unfavorable, it is possible to increase the heat exchange performance and also optimize the heat exchange performance at all of the flow rate conditions. Furthermore, it is possible to easily design a shape and a dimension of the dimple for the optimal heat exchange performance by regulating a flowing property of the fluid, thereby saving labor, cost, time and the like.

DESCRIPTION OF DRAWINGS

[0013] The above and other objects, features and advantages of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

[0014] FIG. **1** is a view showing a general cooling and heating system of a vehicle.

[0015] FIG. **2** is a perspective view of a heat exchanger.

[0016] FIG. **3** is a perspective view and cross-sectional views of a tube having a dimple structure.

[0017] FIG. **4** is a view showing a fabricating method of the tube having the dimple structure according to an embodiment of the present invention.

[0018] FIG. **5** is a view showing dimensions of the dimple and tube.

[0019] FIG. **6** is a view showing an effective area of the heat exchanger.

[0020] FIG. **7** is a graph showing a heat exchange performance per effective area with respect to each factor.

DETAILED DESCRIPTION OF MAIN ELEMENTS

[0021]

100: heat exchanger	10: tank
11: inlet tank	12: outlet tank
20: tube	30: fin
21: dimple	22: partition wall

Best Mode

[0022] Hereinafter, the embodiments of the present invention will be described in detail with reference to accompanying drawings.

[0023] FIG. **2** is a perspective view of a heat exchanger **100**. A heat exchange medium is flown in the heat exchanger **100**, and the heat exchanger **100** includes a plurality of tubes **20** which are arranged in parallel at regular distances to be parallel with a ventilation direction, and tanks **10** which are respectively coupled to both ends of the tubes **20**. The tanks **10** are divided into an inlet tank **11** in which the heat exchange medium is introduced and then distributed to the plurality of tubes **20** and an outlet tank **12** in which the heat exchange medium moved through the tubes **20** is collected and then discharged. Fins **30** are provided between the tubes **20** so as to increase a contact surface area with air flowing between the tubes **20**. As described above, the heat exchange medium is introduced through an inlet port of the inlet tank **11**, collected in the outlet tank **12** through the tubes **20** and then discharged through an outlet port of the outlet tank **12**. While the heat exchange medium is flowed through the tubes **20**, heat exchange is occurred between the heat exchange medium received in the tubes **20** and the external air through the tubes **20** and the fins **30** interposed between the tubes **20**.

[0024] Hereinafter, the heat exchange phenomenon occurred in the heat exchanger will be described briefly. First of all, the heat exchange is occurred by convection between the heat exchange medium in the tubes **20** and inner surfaces of the tubes **20**, and the heat is transferred from the inner surfaces of the tubes **20** to outer surfaces of the tubes **20** and the fins **30**. Finally, the heat exchange is occurred between the outer surfaces of the tubes **20** and the fins **30** and the external air by the convection. As described above, the heat exchange phenomenon occurred in the heat exchanger depends on the convective heat exchange, and a heat exchange amount also depends on the contact surface area and flow rate. Particularly, the heat exchange between the heat exchange medium and the tubes **20** is performed more smoothly when the heat exchange medium is under a turbulent flow condition. Therefore, it will be easily understood that the heat exchange performance is increased if the turbulent flow of the heat exchange medium is forcibly generated in the tubes **20**.

[0025] FIG. **3** is a perspective view and cross-sectional views of a tube having a dimple structure. In the tube **20**, there are formed a dimple **21** which is protruded into the tube **20** and a partition wall **22** which partitions the inside of the tube **20** along a length of the tube **20**. As described above, the dimple **21** functions to form the turbulent flow of the heat exchange medium received in the tube **20**. FIG. **3***b* is a cross-sectional view of the tube **20** taken along a line A-A' of FIG. **3***a*, and FIG. **3***c* is a cross-sectional view of the tube **20** taken along a line B-B'. At upper and lower surfaces of the tube **20**, there are formed the plurality of dimples which are arranged in a transverse direction so as to form a row. The upper dimple row and the lower dimple row are alternately arranged along the length of the tube **20**. Further, the dimples **21** of the upper dimple row and lower dimple row are also arranged alternately as shown in FIGS. **3***b* and **3***c*. In other words, one of the dimples **21** of the lower dimple row is disposed between two adjacent dimples **21** of the upper dimple row, and one of the dimples **21** of the upper dimple row is also disposed between two adjacent dimples **21** of the lower dimple row so that the dimples **21** of the upper dimple row and lower dimple row are not coincided with each other. Preferably, the number of dimples **21** of the upper dimple row is the same as the number of dimples **21** of the lower dimple row. The turbulent flow can be generated more smoothly by such structure.

[0026] FIG. **4** is a view showing a fabricating method of the tube having the dimple structure and the partition wall according to an embodiment of the present invention. As shown in FIG. **4***a*, the dimples **21** are formed in a material (e.g., metal plate) of the tube by a pressing process or other process. Referring to FIGS. **4***a* and **4***b*, A part becomes the lower surface of the tube **20**, C**1** and C**2** parts are bent to form side surfaces thereof, B**1** and B**2** parts become the upper surface thereof, and D**1** and D**2** are bent at a boarder line between B1 and B2 so as to be protruded into the inside of the tube **20** and thus form the partition wall **22**. If the tube **20** is fabricated by the bending process, the upper surface A and the lower surface B1 and B2 are opposite to each other. Therefore, when forming the dimples in the material of the tube **20**, all of the dimples **21** are formed to be protruded in the same direction and thus directed to the inside of the tube **20**. Of course, the tube **20** having the dimples **21** or the dimples **21** and partition wall **22** may be formed by other method.

[0027] FIG. **5** is a view showing dimensions of the dimple and tube. Assuming that a width of the tube **20** is L, a height is H, a width of the dimple **21** is d_i and a height is h_i, the sum of sectional areas of the dimples **21** with respect to a section of a specific position in the tube **20** having the plurality of dimples **21** is expressed as follows:

$$A_{dimple} = \sum_{i=1}^{N} d_i \cdot h_i$$ [Formula 1]

[0028] wherein $A_{dimiple}$ is an approximate sectional area value of the total dimples **21**, N is the number of dimples **21** per sectional area, and d_i and h_i are a width and a depth of the i-th dimple **21**, respectively.

[0029] In the tube having the dimple structure, the dimensions of the dimple and tube which directly affect to the heat exchange performance and thus has a specific correlation with each other is expressed as follows:

$$\frac{A_{dimple}}{L \times H}, \frac{h}{H}$$ [Formula 2]

[0030] Since the actual heat exchange is performed between the heat exchange medium in the tube **20** and the external air while the external air passes between the tubes **20**, the heat exchange is substantially performed at the surface area of the tube **20** and the fin **30** perpendicular to a flowing direction of the external air.

[0031] This surface area is the effective surface area S_{ff} as shown in FIG. **6**. In order to express the heat exchange performance regardless of a size of the heat exchanger, a valuation of the heat exchange performance is obtained by only the effective surface area S_{ff}. Assuming that the heat exchange amount which is substantially generated is Q, the heat exchange amount Q_{Ae} per effective surface area is expressed as follows:

$$Q_{Ae} = \frac{Q}{S_{eff}}$$ [Formula 3]

[0032] Since the present invention provides a dimension relationship between the tube **20** and the dimple **21** capable of maximizing the heat exchange performance per effective surface area, the heat exchange performance per effective surface area is estimated on the basis of the heat exchange amount Q_0 per effective surface area which is a requirement in a vehicle. The heat exchange performance η per effective surface area is expressed as follows:

$$\eta = \frac{Q_{Ae}}{Q_0}$$ [Formula 4]

[0033] FIG. **7** is a graph showing a heat exchange performance per effective area with respect to each factor, wherein FIG. **7a** shows a change of η with respect to $A_{dimiple}$/L×H and FIG. **7b** shows a change of η with respect to h/H. A large $A_{dimiple}$ value means that many dimples are formed per sectional area of the tube **20**. The more the dimples are formed, the more the turbulent flow is generated. However, if the dimples are formed excessively and thus the $A_{dimiple}$ value approaches the sectional area (L×H) of the tube, a sectional area of the passage for the heat exchange medium is too small and thus the heat exchange medium can not flow smoothly therethrough. As described above, in case that a resistance is increased, a heat exchange coefficient is reduced, thereby reducing the heat exchange performance. Therefore, it will be understood that the $A_{dimiple}$ value should be established at a proper ratio with respect to the sectional area (L×H) of the tube. FIG. **7a** shows that such tendency is actually confirmed by experiment. Referring to FIG. **7a**, when the value of $A_{dimiple}$/(L×H) is 8.80~13.60, the heat exchange performance η per effective surface area is optimized. Therefore, from this it is possible to deduce the relationship between the dimensions of the tube and dimple per sectional area so as to optimize the heat exchange performance η per effective surface area.

[0034] FIG. **7b** shows the change of the heat exchange performance η with respect to the relationship between the depth h and height H of the dimple. According as the ration of h/H is increased (i.e., the depth of the dimple is increased relatively), the heat exchange performance is gradually increased and then reduced from a peak point. Referring to FIG. **7b**, when the value of h/H is 0.25~0.4, the heat exchange performance η per effective surface area is optimized. On the basis of the graphs of FIGS. **7a** and **7b**, it is possible to design an optimal width and depth of the dimple with respect to a width and height of a certain tube so as to optimize the heat exchange performance η per effective surface area.

[0035] Those skilled in the art will appreciate that the conceptions and specific embodiments disclosed in the foregoing description may be readily utilized as a basis for modifying or designing other embodiments for carrying out the same purposes of the present invention. Those skilled in the art will also appreciate that such equivalent embodiments do not depart from the spirit and scope of the invention as set forth in the appended claims.

INDUSTRIAL APPLICABILITY

[0036] According to the present invention, since a turbulent flow is generated early even when a flow rate condition of the heat exchange medium in the heat exchanger tube is unfavorable, it is possible to increase the heat exchange performance and also optimize the heat exchange performance at all of the flow rate conditions. Furthermore, it is possible to easily design a shape and a dimension of the dimple for the optimal heat exchange performance by regulating a flowing property of the fluid, thereby saving labor, cost, time and the like.

1. A heat exchanger, comprising:

a plurality of tubes **20** arranged in parallel at regular distances so they in the same direction as a ventilation direction through which a heat exchange medium is adapted to flow;

an inlet tank in which the heat exchange medium is adapted to be introduced and then distributed to the plurality of tubes;

a fin interposed between the tubes so as to increase contact surface with air passing between the tubes; and

an outlet tank in which the heat exchange medium flowing through the tubes is adapted to be collected and then discharged,

each of the tubes including a dimple protruding from an inside surface of the tube, and when the total sectional area A_{dimple} of the dimples of each tube is expressed as the sum of the product of the width d and depth h of each dimple and the cross sectional area of each tube is expressed as the product of a length L and height H of each tube, the following formula is satisfied:

$$8.80 < \frac{\text{the sum } A_{dimple} \text{ of the product of a width } d \text{ and a depth } h \text{ of each dimple}}{\text{a length } L \text{ of the tube} \times \text{a height } H \text{ of the tube}} \times 100 < 13.60$$

2. The heat exchanger according to claim **1**, wherein the depth h of each dimple and the height H of each tube satisfy the following formula:

$$0.25 < \frac{\text{a depth } h \text{ of the dimple}}{\text{a height } H \text{ of the tube}} < 0.4$$

3. The heat exchanger according to claim **2**, wherein a plurality of the dimples are arranged in a transverse direction to form rows on upper and lower surfaces of each tube, the upper dimple row and the lower dimple row of each tube **20** being alternately arranged along the length of each tube.

4. The heat exchanger according to claim **3**, wherein the dimples of the upper dimple row and lower dimple row are also arranged alternately along the width of the tube so that the dimples of the upper dimple row and lower dimple row are not aligned with each other, and one of the dimples of the lower dimple row being disposed between two adjacent dimples of the upper dimple row, and one of the dimples of the upper dimple row being also disposed between two adjacent dimples of the lower dimple row.

5. The heat exchanger according to claim **3**, wherein the number of dimples of the upper dimple row of each tube is the same as the number of dimples of the lower dimple row of each tube.

6. The heat exchanger according to claim **1**, wherein a plurality of the dimples are arranged in a transverse direction to form rows on upper and lower surfaces of each tube, and the upper dimple row and the lower dimple row of each tube being alternately arranged along the length of each tube.

7. The heat exchanger according to claim **6**, wherein the dimples of the upper dimple row and lower dimple row are also arranged alternately along the width of the tube so that the dimples of the upper dimple row and lower dimple row are not aligned with each other, and one of the dimples of the lower dimple row being disposed between two adjacent dimples of the upper dimple row, and one of the dimples of the upper dimple row being also disposed between two adjacent dimples of the lower dimple row.

8. The heat exchanger according to claim **7**, wherein the number of dimples of the upper dimple row of each tube is the same as the number of dimples of the lower dimple row of each tube.

* * * * *