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(54) HEAT EXCHANGER

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(57) **ABSTRACT**

Outsides of flat tubes through which a first fluid flows are formed with wave-shaped surfaces, and fins form meandering passages for a second fluid. While the second fluid is flowing along the fins, it is made turbulent by striking the wave-shaped surfaces of the flat tubes due to the meandering passages. The turbulent flow contacts the outside surfaces of the flat tubes and the front and rear surfaces of the fins, so heat conduction is promoted without the formation of thick boundary layers at these surfaces. Therefore, the heat exchange efficiency is remarkably improved between the first fluid such as warm water flowing through the insides of the flat tubes and the second fluid such as air flowing at the outsides.

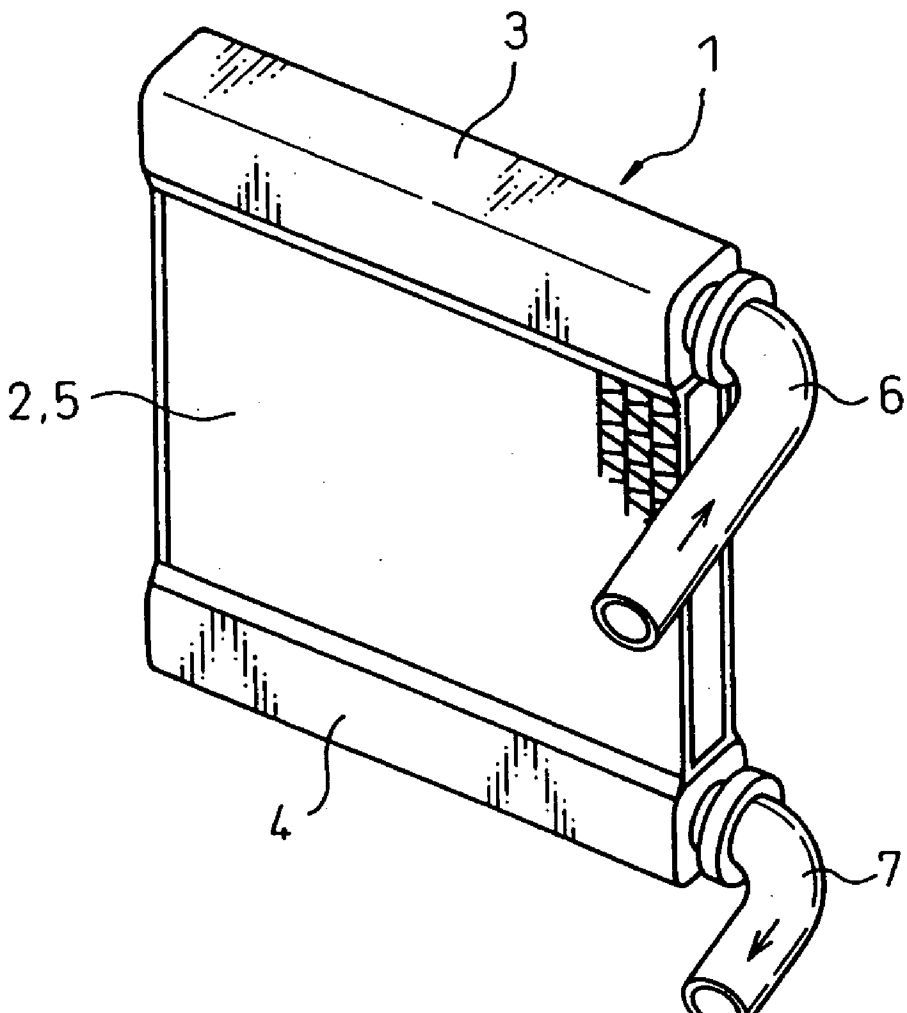

Fig.1

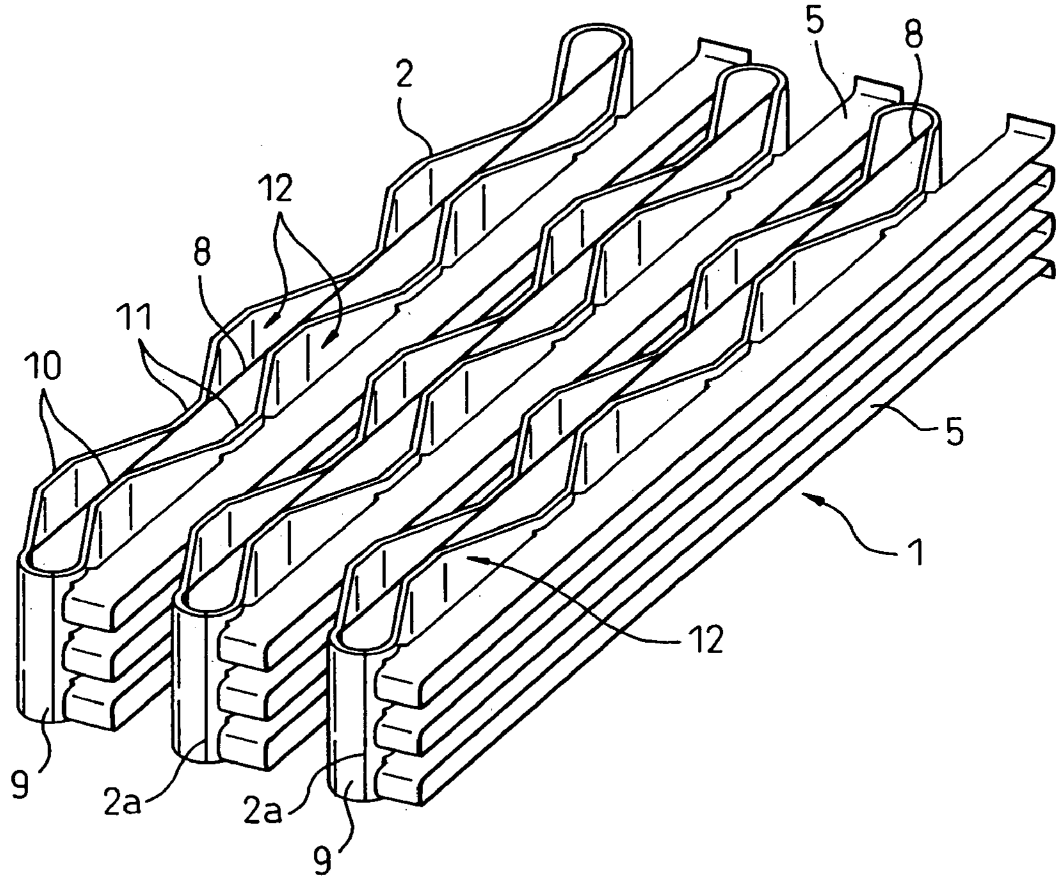

Fig.2

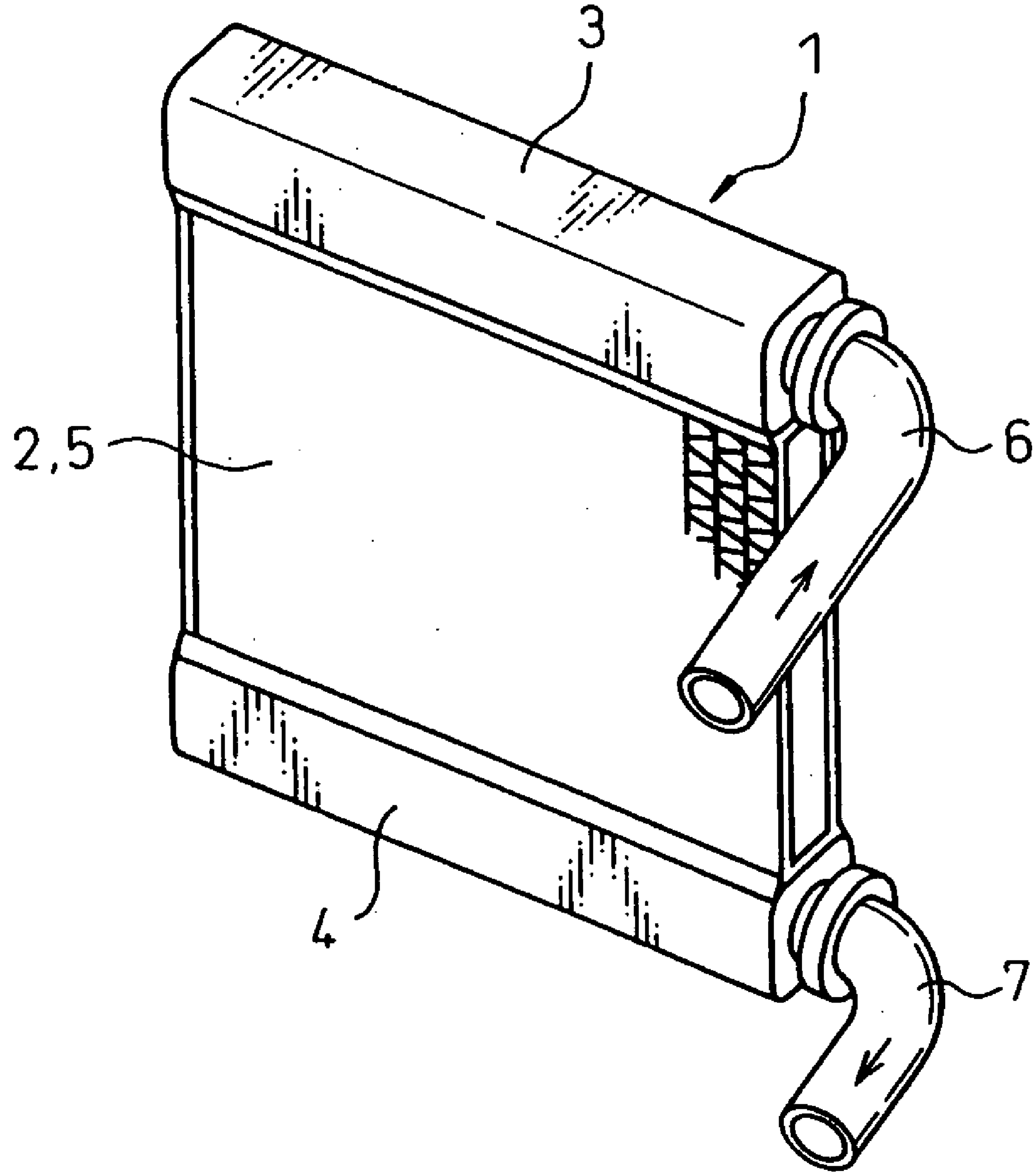

Fig.3

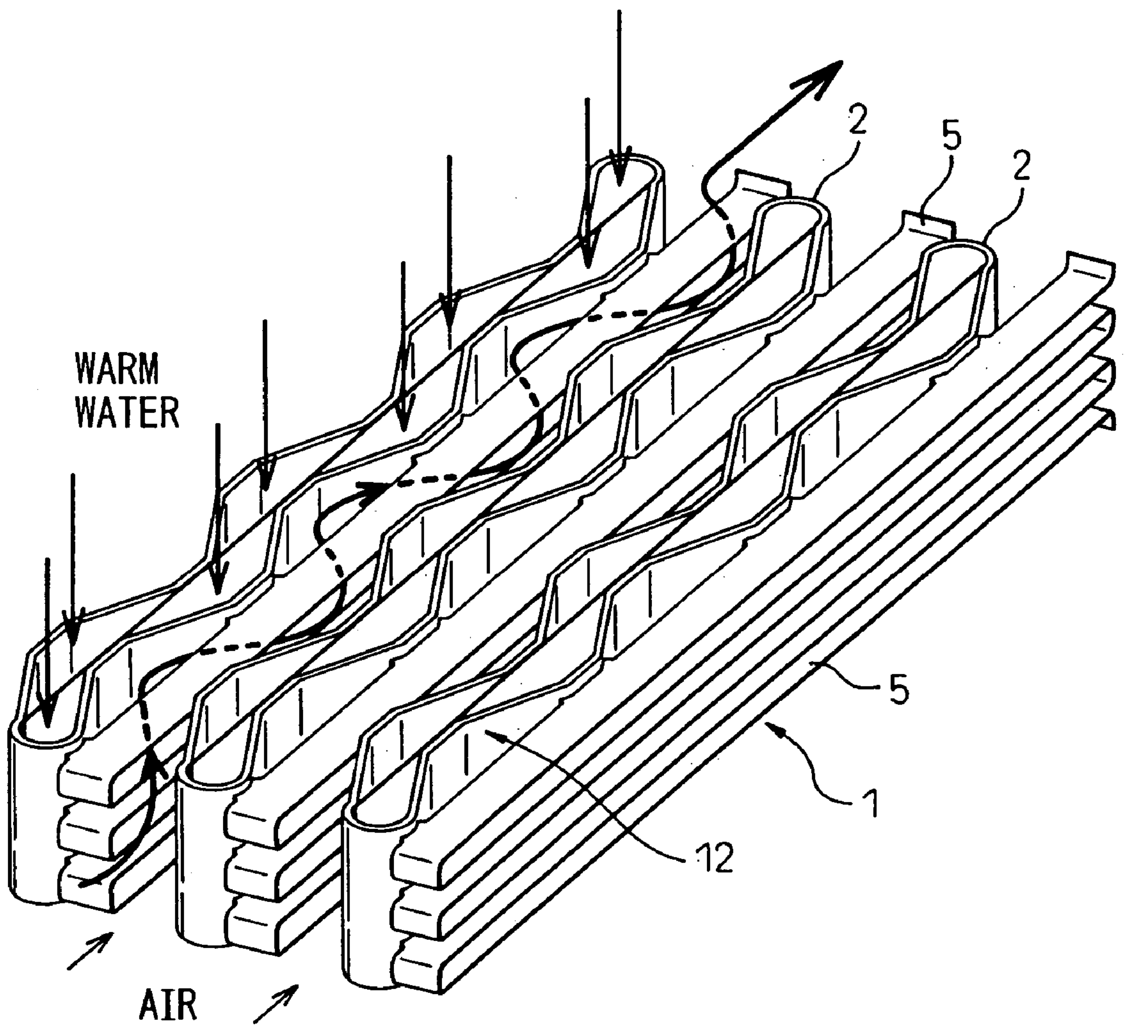

Fig.4

PRIOR ART

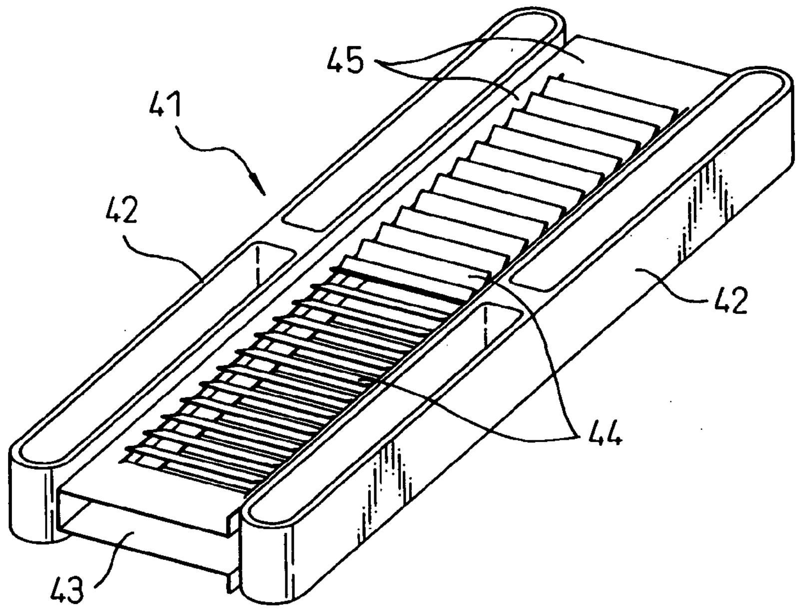

Fig.5

PRIOR ART

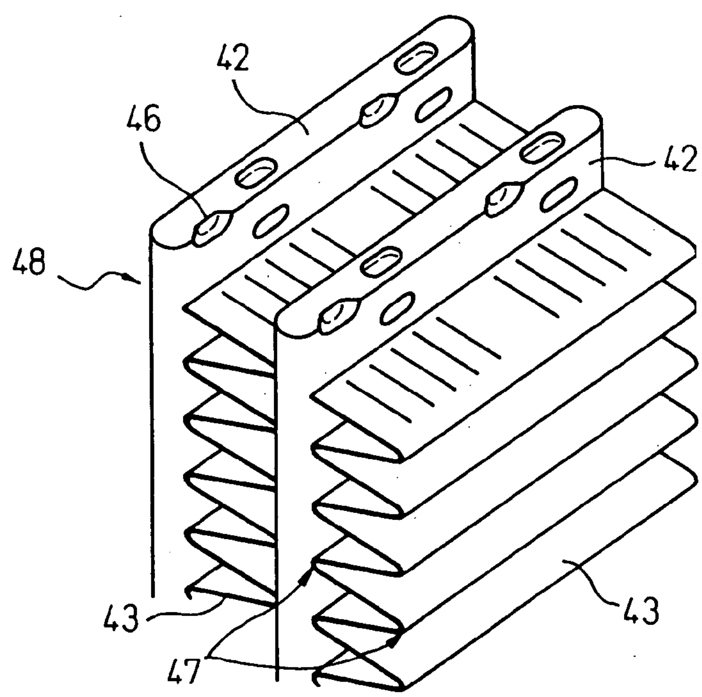

Fig. 6

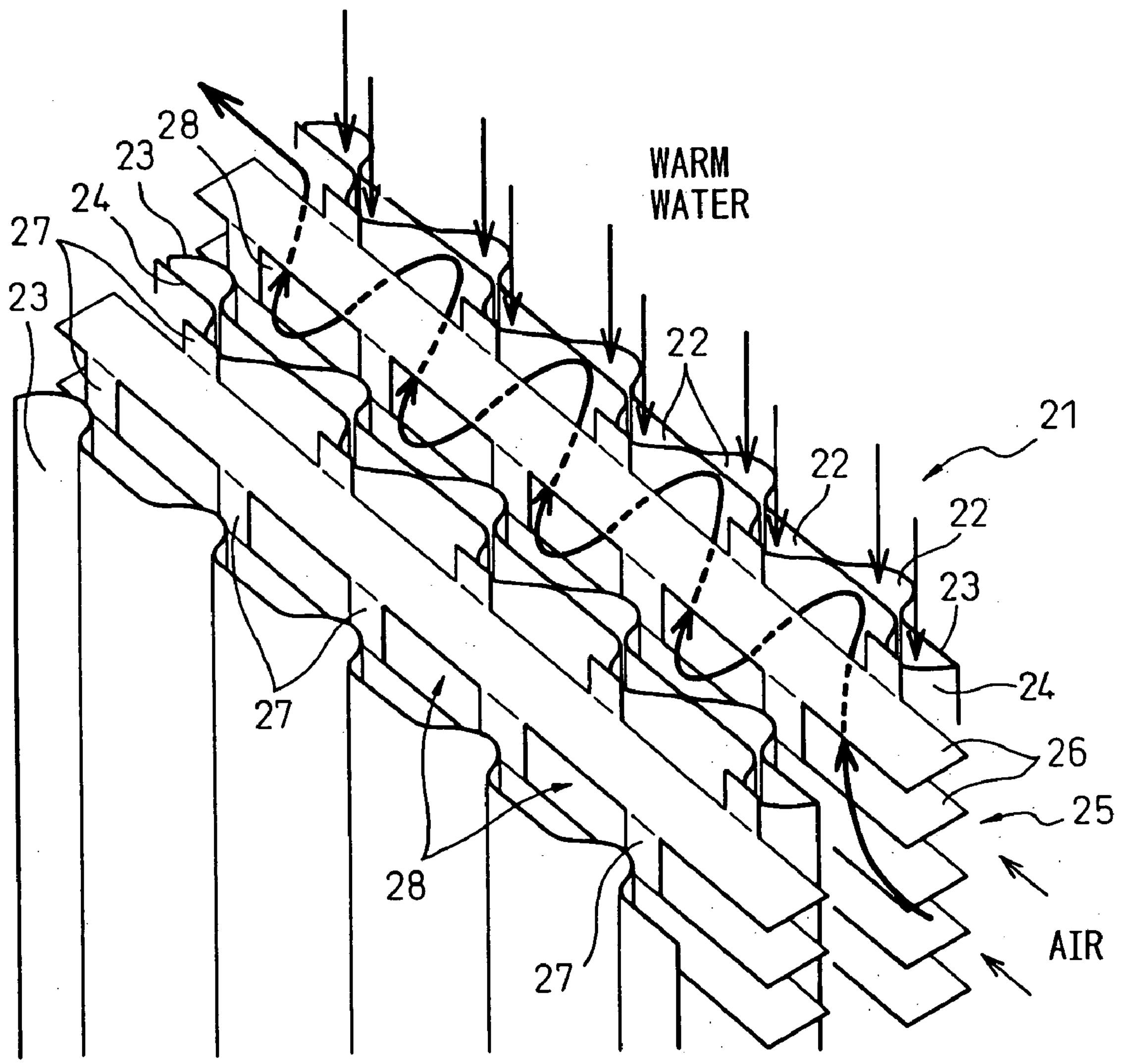
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Fig. 7

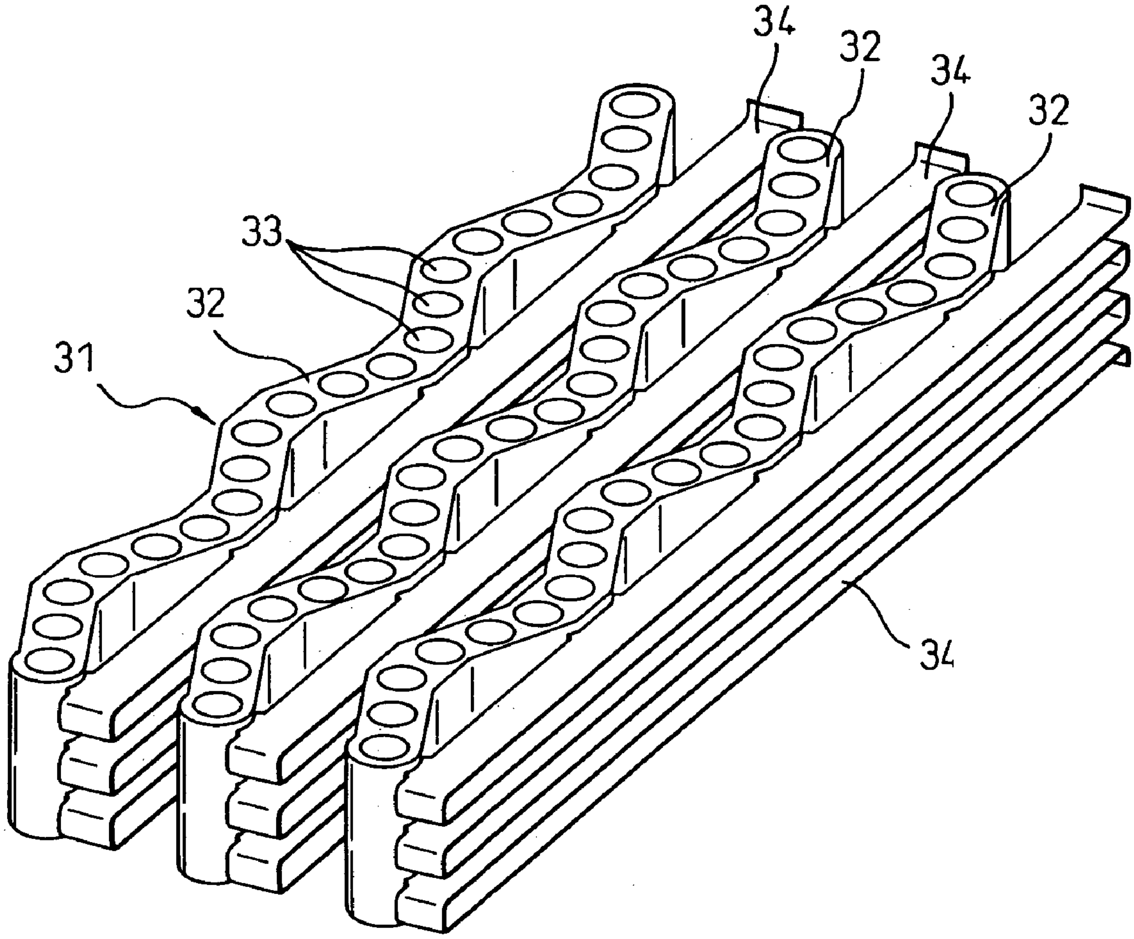
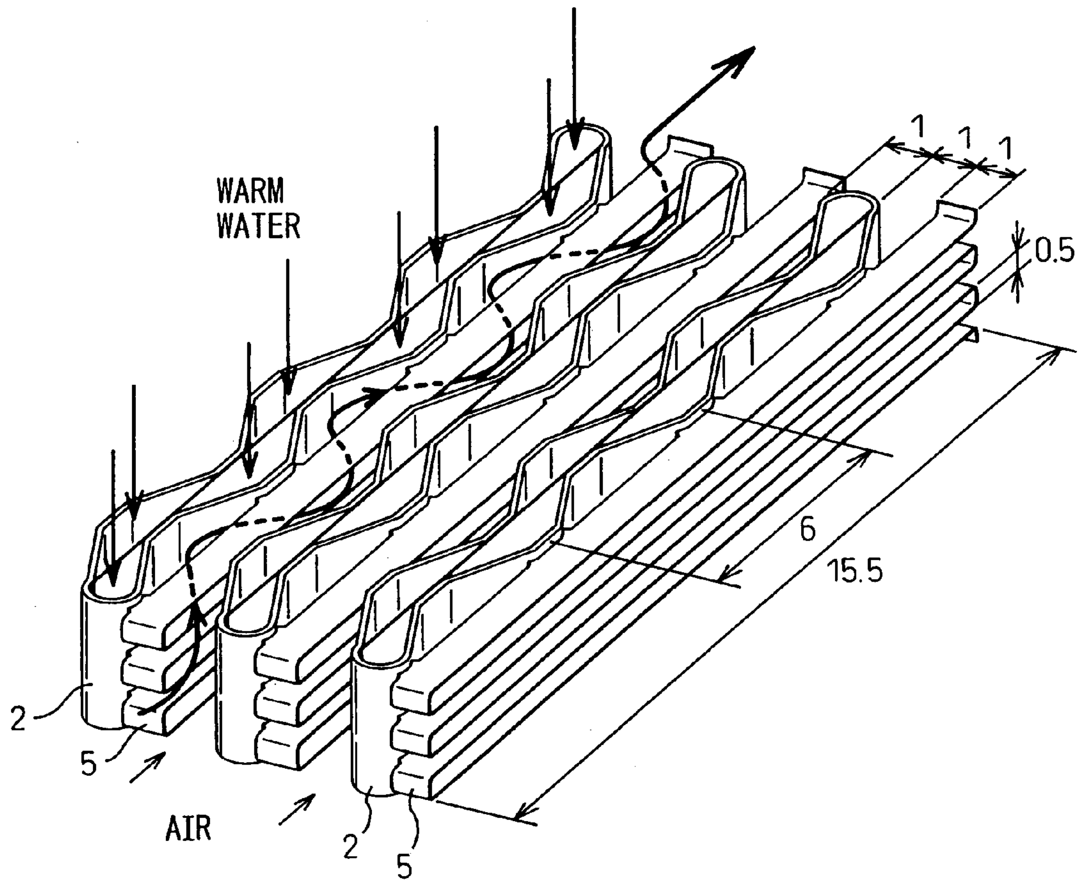


Fig.8



HEAT EXCHANGER

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a heat exchanger such as a radiator for radiating heat of cooling water of an internal combustion engine used for an automobile and a heater core for heating and a condenser or evaporator for cooling in an air-conditioning system.

[0003] 2. Description of the Related Art

[0004] The principal structure of an example of a heater core **41** serving as a heat exchanger for heating the air in a passenger compartment using the high temperature cooling water of an internal combustion engine in a conventional air-conditioning system is shown in **FIG. 4**. The overall configuration of the heater core **41** is substantially the same in appearance in **FIG. 2** explained in detail later with reference to an embodiment of the present invention. In a conventional heater core **41**, a plurality of flat tubes **42** formed into flat tubular shapes by extrusion of an aluminum material are arranged vertically in parallel at predetermined intervals. A common top tank is bonded to the top ends of these tubes **42** and a common bottom tank is bonded to the bottom ends to form a coolant water passage. Corrugated fins **43** formed by bending thin sheets of aluminum back and forth into wave shapes are attached and bonded by soldering so as to be sandwiched between the adjoining flat tubes **42** and thereby form air passages.

[0005] In the conventional heater core **41** of this configuration as well, to promote heat exchange between the corrugated fins **43** and the flow of air, sometimes pieces of the corrugated fins **43** are cut and raised to form a large number of for example rectangular or other shaped louvers **44**, but the surfaces of the flat tubes **42** are smooth. Further, even at the corrugated fins **43**, the parts **45** where the louvers **44** cannot be formed are smooth. Therefore, there is the problem that by just forming louvers **44** at parts of the corrugated fins **43**, the heat exchange efficiency between the outer surfaces of the flat tubes **42** and the flow of air at the outsides of the tubes **42** is not improved much at all.

[0006] Further, in a separate conventional type heater core **48** shown in **FIG. 5**, the smooth surfaces of the flat tubes **42** are sometimes formed with a large number of dimples **46** or formed with a plurality of ribs, but the insides of the dimples **46** or ribs become areas where no air flows, so this is not necessarily effective. Even at the surfaces of the flat tubes **42**, at parts bonded with the bent parts **47** of the corrugated fins **43**, the solder used for the bonding buries the dimples **46** etc., so at such parts, the dimples **46** etc. do not improve the heat conduction performance between the air and flat tubes **42**. They are only useful for improving the heat conductance performance between the wall surfaces of the flat tubes **42** and the cooling water (warm water) flowing through the insides.

SUMMARY OF THE INVENTION

[0007] An object of the present invention is to provide a heat exchanger such as a radiator, heater core, condenser, or evaporator wherein not only is the heat exchange efficiency improved between fins attached to flat tubes in which a first fluid such as cooling water (warm water) flows and a second fluid such as air flowing in contact with the same, but also novel means are devised so as to improve the heat exchange efficiency between the outer surfaces of the flat tubes themselves through which the first fluid flows and the second fluid flowing at the outside so as to greatly improve the heat exchange efficiency between the first fluid and the second fluid compared with the past.

[0008] According to the present invention, there is provided a heat exchanger provided with a plurality of flat tubes forming passages for a first fluid inside them and having outside surfaces formed to a wave shape so that passages for a second fluid flowing at the outside of the flat tubes meander in a wave shape and plate-shaped fins in the meandering passages, so when a second fluid such as air flows at the outsides of the flat tubes, it vigorously strikes the outside surfaces of the wave shapes of the flat tubes and is agitated to become turbulent and flows through the meandering passages along the plate-shaped fins. Therefore, the surfaces of the flat tubes are not formed with thick boundary layers such as when a laminar flow of the second fluid flows, so the efficiency of direct heat exchange between the flat tubes and the second fluid is remarkably improved. Needless to say, the heat exchange efficiency between the plate-shaped fins and second fluid also becomes higher since the second fluid becomes turbulent, so as a result the heat exchange efficiency between the first fluid and the second fluid is improved.

[0009] The flat tubes may be formed by bending corrugated sheets to tubular shapes or may be formed by assembling pairs of corrugated sheets. In these cases, it is possible to attach reinforcing plates at their insides. Further, the flat tubes may be fabricated by extrusion so that passages for a first fluid are formed inside.

[0010] If the plate-shaped fins are arranged so that their longitudinal directions become substantially vertical to longitudinal directions of the flat tubes, the directions of the first fluid flowing through the insides of the flat tubes and the second fluid flowing at the outsides of the flat tubes along the fins become perpendicular and the agitating action of the meandering passages for the second fluid formed by the wave-shaped surfaces of the flat tubes is strengthened the most, so the efficiency of the heat exchanger can be raised the most.

[0011] The plate-shaped fins can be formed by bending narrow ribbon-shaped sheets so as to be folded back at the ends in their longitudinal directions. Due to this, it is possible to fabricate multistage fins as single pieces and support them integrally.

[0012] Further, a plurality of the plate-shaped fins may form a fin assembly by being connected through leg parts like a multilevel shelf. In this case, it is also possible to form windows through which the second fluid may pass between adjoining leg parts. The fin assembly may be formed integrally by punching out windows for the second fluid from a single sheet and bending between the leg parts thereby formed and the fins.

[0013] The plate-shaped fins may be bonded to the tops or bottoms of wave-shaped surfaces at the outside surfaces of the flat tubes. If forming the above fin assembly, if the leg parts are bonded to the tops or bottoms of the wave-shaped surfaces formed at the outside surfaces of the flat tubes, not only does bonding become easier, but also the windows for passing the second fluid will not be blocked and the mechanical strength of the heat exchanger as a whole will become higher.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] These and other objects and features of the present invention will become clearer from the following description of the preferred embodiments given with reference to the attached drawings, wherein:

[0015] **FIG. 1** is a cutaway, enlarged perspective view of principal parts of a heater core of a first embodiment of the present invention;

[0016] **FIG. 2** is a perspective view illustrating the overall configuration of a heater core of an embodiment of a heat exchanger of the present invention as represented by the first embodiment;

[0017] **FIG. 3** is a perspective view of the state of operation at principal parts of the heater core of the first embodiment;

[0018] **FIG. 4** is a cutaway, enlarged perspective view of principal parts of a heater core of the related art;

[0019] **FIG. 5** is a cutaway, enlarged perspective view of principal parts of another heater core of the related art;

[0020] **FIG. 6** is a cutaway, enlarged perspective view of principal parts of a heater core of a second embodiment;

[0021] **FIG. 7** is a cutaway, enlarged perspective view of principal parts of a heater core of a third embodiment; and

[0022] **FIG. 8** is a perspective view illustrating specific dimensions of principal parts of a heater core of the first embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] Preferred embodiments of the present invention will be described in detail below while referring to the attached figures.

[0024] The configuration and operation of a heater core **1** for an air-conditioning system to be mounted in an automobile are illustrated in **FIG. 1** to **FIG. 3** as a first embodiment of a heat exchanger of the present invention. The heater core **1** is used for heating the air in a passenger compartment by the cooling water (warm water) in the internal combustion engine in a not shown air-conditioning system for an automobile. **FIG. 1** shows enlarged the characterizing parts (principal parts) of the heater core **1** of the first embodiment, the overall configuration including these parts is illustrated in **FIG. 2**, and the state of operation of the principal parts is shown in **FIG. 3**.

[0025] As shown in **FIG. 1**, in the heater core **1** of the first embodiment, the flat tubes **2** are fabricated by press forming thin sheets of aluminum to tubular shapes having predetermined surface shapes and joining longitudinal direction seams **2*a*** by soldering. A plurality of flat tubes **2** fabricated in this way are arranged vertically in predetermined intervals, a common inlet tank **3** is joined to the top ends of these tubes **2**, and a common outlet tank **4** is joined to the bottom ends of the tubes **2**.

[0026] Further, in the illustrated embodiment, an inlet pipe **6** is attached to an inlet of warm water provided at the inlet tank (top tank) **3** and an outlet pipe **7** is attached to an outlet of warm water attached to the outlet tank (bottom tank) **4**.

[0027] As clear from **FIG. 1** showing the flat tubes **2** cut away at a certain height, the sectional shapes of the flat tubes **2** are not shapes where the arcs **9** of the two ends may be connected by two parallel straight lines, but are shapes where the arcs **9** of the two ends may be connected by two parallel wavy lines of substantially the same shape. Therefore, these flat tubes **2** have surfaces formed in wave shapes in a direction perpendicular to the longitudinal direction (called "wave-shaped surfaces **12**"). The wave-shaped surfaces **12** form tops **10** and bottoms **11** of wave shapes extending along the longitudinal direction of the flat tubes **2**.

[0028] Further, fins **5** obtained by cutting thin sheets of aluminum into narrow ribbon shapes and bending them into wave shapes with larger amplitudes than the widths are attached so as to fit between adjoining flat tubes **2**, then the contact parts of the fins **5** and flat tubes **2** are joined by soldering. Since the surfaces **12** of the flat tubes **2** are wave shaped, when the fins are shaped as ribbons having predetermined widths as in the illustrated embodiment, the contact parts of the flat tubes **2** and fins **5** do not become long linear shapes, but become points or short lines at the tops **10** or bottoms **11** of the wave-shaped surfaces **12** of the flat tubes **2**.

[0029] Further, while not essential, in the heater core **1** of the first embodiment, plates **8** for reinforcement are inserted and secured inside the flat tubes **2** with the wave-shaped surfaces **12**. As the plates **8**, it is possible to use aluminum plates etc. If making the plates contact parts of the arc surfaces **9** of the ends of the flat tubes **2** at their two edges and making them contact the tops **10** and bottoms **11** of the wave-shaped surfaces of the flat tubes **2** at their front surfaces and rear surfaces, it is possible to prevent deformation of the flat tubes **2** most effectively when the pressure of the warm water etc. acts inside the flat tubes.

[0030] Note that in the heater core **1** of the first embodiment, the flat tubes **2**, inlet tank **3**, outlet tank **4**, fins **5**, reinforcing plates **8**, etc. are all soldered together. For this, the materials of these parts are covered in advance with solder, the parts assembled, then the assembly is heated in a furnace, whereby the solder melts and solidifies to join the parts.

[0031] While not shown, it is also possible to provide partitions in the longitudinal direction of one or both of the inlet tank **3** and outlet tank **4** to divide the insides to a plurality of sections. Due to this, the warm water flows back and forth between the inlet tank (top tank) **3** and outlet tank (bottom tank) **4**. The, method of flow of the warm water changes depending on the number of partitions and the positions where they are provided, so which of the top tank **3** and bottom tank **4** the inlet pipe **6** and outlet pipe **7** are provided is determined accordingly. Therefore, in the present invention, it is also possible to provide both of the inlet pipe **6** and the outlet pipe **7** at either of the top tank **3** or bottom tank **4**.

[0032] When the heater core **1** of the first embodiment is not provided with partitions in the inlet tanks **3** and **4**, the high temperature cooling water supplied from a not shown internal combustion engine flows from the inlet pipe **6** to the inside of the inlet tank **3**, is distributed to all of the flat tubes **2** in the entire region of the inlet tank **3**, and passes through the flat tubes **2** and flows down to the outlet tank **4**. The warm water from which heat has finished being radiated collected at the outlet tank **4** is returned from the outlet pipe **7** to a not shown cooling water sleeve of the internal combustion engine. The high temperature warm water supplied to the inlet tank **3** in this way gives heat to the flow of air flowing through the intervals of the flat tubes **2** or fins **5** while flowing through the flat tubes **2**. In the present invention, the fluid such as warm water flowing through the insides of the flat tubes **2** is called the "first fluid" and the fluid such as air flowing outside of the flat tubes **2** is called in general the "second fluid".

[**0033**] In this way, the heater core **1** of the first embodiment is characterized by the formation of wave shapes at the surfaces **12** of the outsides of the flat tubes **2** when producing the flat tubes **2** by press forming. Therefore, when the warm water (first fluid) flowing through the inlet pipe **6** shown in **FIG. 2** to the space in the inlet tank **3** is distributed to the plurality of flat tubes **2** and heat exchange is performed by the heat of the warm water being given to the air (second fluid) flowing in contact with their surfaces from the surfaces of the flat tubes **2** and the surfaces of the plate-shaped fins **5** attached to parts thereof, the air (second fluid) flowing between the flat tubes **2** along the plate-shaped fins **5** forms a meandering flow guided by the wave-shaped surfaces **12** of the flat tubes **2** and the flow is agitated.

[**0034**] By the air flowing meandering along the wave-shaped surfaces **12** of the flat tubes **2**, the air repeatedly strikes the surfaces of the flat tubes **2** and the flow of air is agitated by the wave-shaped surfaces **12** of the flat tubes **2** to form a fine whirlpool-like turbulence, so there is no longer the formation of a thick boundary layer of air which usually is formed on the surfaces of the tubes when the flow of air becomes laminar when the surfaces of the flat tubes **2** are smooth (the boundary layer becomes extremely thin), so the heat conduction action is promoted, and the heat exchange efficiency between the warm water and air is remarkably improved.

[**0035**] In this way, the second fluid, that is, air, flows meandering along the wave-shaped surfaces **12** of the flat tubes **2**, so to not obstruct the flow, it is preferable that the fins **5** be made elongated overall, there be no folded back parts at the middle, and the flow of air be guided in a direction perpendicular to the longitudinal direction of the flat tubes **2**. It is preferable to use even fins which are bent in a wave shape like the fins **5** of the first embodiment if of a shape bent back in the opposite directions at positions close to the side edges of the flat tubes **2**.

[**0036**] **FIG. 6** shows principal parts of a heater core **21** as a second embodiment of a heat exchanger of the present invention. The flat tubes **22** forming the passages for warm water in the second embodiment are formed by combining two corrugated sheets **23** and **24** comprised of aluminum etc. and joining them together, whereby pluralities of flat tubes **22** forming fluid passages of sectional shapes close to crescent shapes are formed between these corrugated sheets **23** and **24**. Exactly the required number of pairs of corrugated sheets **23** and **24** are stacked. A large number of shelves or a fin assembly **25** of a shape like a frame is arranged between the pairs of the corrugated sheets **23** and **24**. The contact parts of the adjoining corrugated sheets **23** and **24** are joined.

[**0037**] The fin assembly **25** of the second embodiment is comprised of shelf-like fins **26** comprised of a large number of narrow plates arranged in parallel at predetermined intervals in the vertical direction and a large number of leg parts **27** rising (or descending) vertically in the vertical direction from the front edge or rear edge in the width direction of the fins **26**. The fin assembly **25** comprised of the large number of shelf-like fins **26** and the large number of leg parts **27** connecting these can be fabricated by punching a large number of windows **28** from one aluminum sheet and bending the leg parts **27** at right angles to the fins **26** as if forming steps.

[**0038**] At this time, if the lengths of the waves of the corrugated sheet **24** and dimensions of the intervals of the adjoining leg parts **27** are made to match so that the tops or bottoms of the corrugated sheets **23** and **24** forming the flat tubes **22** contact the leg parts **27** and are soldered together at the time of soldering, the heater core **21** as a whole forms a strong frame structure. Note that while not shown, it is also possible to form the flat tubes **22** by sandwiching flat plates between the pairs of corrugated sheets **23** and **24** and soldering them together. The plates sandwiched between them act to increase the mechanical strength of the flat tubes **22**.

[**0039**] Since the heater core **21** of the second embodiment has this structure, if the first fluid, that is, the warm water, is made to flow from a not shown top tank through the plurality of flat tubes **22** down toward a bottom tank as shown by the vertical direction arrows, and the second fluid, that is, air, is made to flow along the fins **26** as shown by the horizontal direction arrows, the air is guided along the wave-shaped surfaces of the corrugated sheets **23** and **24** and flows in wave-shaped path so as to pass through the windows **28**. Due to this, in the same way as the first embodiment, the flow of air vigorously strikes the surfaces of the corrugated sheets **23** and **24** and becomes turbulent, so the thick boundary layer of air is ordinarily formed at the surfaces of the corrugated sheets **23** and **24** is peeled off and heat exchange is performed at a high efficiency between the warm water and air separated by the corrugated sheets **23** and **24**.

[**0040**] **FIG. 7** shows the principal parts of a heater core **3** of a third embodiment of a heat exchanger of the present invention. The heater core **31** of the third embodiment is similar to the heater core **1** of the first embodiment. The characterizing feature of the third embodiment over the first embodiment lies in the fabrication of the flat tubes **32** by extrusion of aluminum. However, the embodiment is the same in that the flat tubes **32** are wave-shaped as a whole, the warm water passages **33** are circular in sectional shape and formed in a plurality, and flat tubes **32** with adjoining fins **43** comprised of sheets bent in the same way as the fins **5** in the first embodiment are joined.

[**0041**] Since the flat tubes **32** of the third embodiment are fabricated by extrusion, instead of the mechanical strength becoming higher, the thickness seen from the passages **33** of the warm water becomes somewhat greater than the flat tubes **2** of the first embodiment. Due to this, the heat exchange efficiency becomes slightly lower, but the heater core **31** of the third embodiment exhibits substantially the same action and effects as the heater core **1** of the first embodiment.

[**0042**] Concrete dimensions of the principal parts of the heater core **1** of the first embodiment shown in **FIG. 1** will be illustrated in **FIG. 8** for reference. In the case of a heater core in an air-conditioning system of an automobile, the dimensions of the parts become small values such as illustrated.

[**0043**] Note that the heat exchangers of the illustrated embodiments all were heater cores, but the present invention is not limited to heater cores and clearly can also be worked as radiators for radiating heat of cooling water of an internal combustion engine, a condenser or evaporator for cooling in an air-conditioning system, or other heat exchanger.

[**0044**] While the invention has been described with reference to specific embodiments chosen for purpose of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.

What is claimed is:

1. A heat exchanger provided with a plurality of flat tubes forming passages for a first fluid inside them and having outside surfaces formed to a wave shape so that passages for a second fluid flowing at the outsides of said flat tubes meander in a wave shape and plate-shaped fins for guiding the second fluid at the outsides of said flat tubes forming the passages for the second fluid.

2. A heat exchanger as set forth in claim 1, wherein said flat tubes are fabricated by bending corrugated sheets to tubular shapes and joining their seams.

3. A heat exchanger as set forth in claim 1, wherein said flat tubes are formed by joining pairs of corrugated sheets.

4. A heat exchanger as set forth in claim 1, wherein said flat tubes are provided with reinforcing plates at their insides.

5. A heat exchanger as set forth in claim 1, wherein said flat tubes are fabricated by extrusion so that passages for a first fluid are formed inside.

6. A heat exchanger as set forth in claim 1, wherein a longitudinal direction of said plate-shaped fins is substantially vertical to a longitudinal direction of said flat tubes.

7. A heat exchanger as set forth in claim 6, wherein said plate-shaped fins are bent back at the ends in their longitudinal directions.

8. A heat exchanger as set forth in claim 6, wherein a plurality of said plate-shaped fins form a fin assembly by being connected through leg parts like a multilevel shelf.

9. A heat exchanger as set forth in claim 1, wherein said fins are bonded to the tops or bottoms of wave-shaped surfaces formed at the outside surfaces of said flat tubes.

10. A heat exchanger as set forth in claim 8, wherein said leg parts of said fin assembly are bonded to the tops or bottoms of wave-shaped surfaces formed at the outside surfaces of said flat tubes and windows for passing the second fluid are formed by said leg parts.

* * * * *