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(54) Title: EVAPORATOR OF AN AIR CONDITIONING CIRCUIT, ESPECIALLY FOR A MOTOR VEHICLE

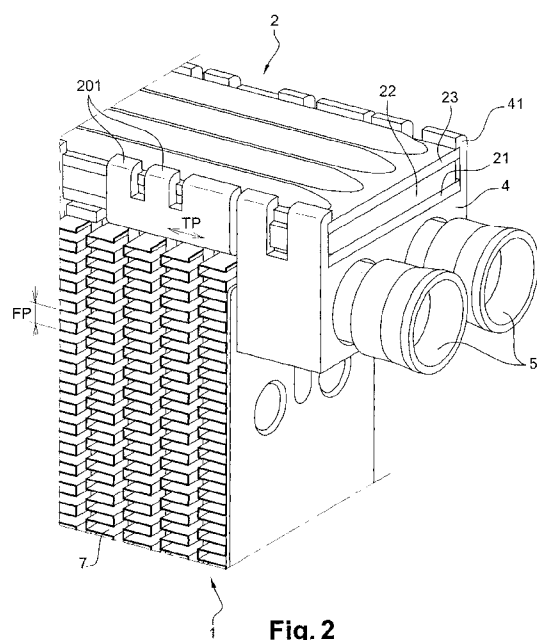


Fig. 2

(57) Abstract: An evaporator (1) of an air conditioning circuit contains an exchanger body, an upper head (2) with an inlet for liquid phase and an outlet for gaseous phase, and a lower head (3), wherein the exchanger body is created by a bundle of two rows of flat heat exchange tubes (6), arranged in parallel and at mutual spacings, wherein between said flat tubes (6) there are arranged heat exchange elements (7) with a plurality of ribs (11). The thickness (T) of the exchanger body is less than 38 mm and the mutual spacing (TP) of the heat exchange tubes is always 5.5 to 9 mm. The mutual spacing (FP) of the ribs of the heat exchange elements is 1.3 to 1.5 mm and the heat exchange elements (7) in the direction of the thickness (T) of the evaporator (1) extend somewhat on both sides of the exchanger body beyond the ends of the heat exchange tubes (6).

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Evaporator of an air conditioning circuit, especially for a motor vehicleField of technology

5 This invention relates to an evaporator of an air conditioning circuit, especially for motor vehicles, for exchanging heat between a coolant circulating in a circuit with the evaporator, and a cooled medium, most often air, moving from the outside through an exchanger body. More particularly, the invention relates to an
10 evaporator of an air conditioning circuit which contains an exchanger body, an upper head with an inlet for liquid phase and an outlet for gaseous phase, and a lower head, wherein the exchanger body is formed by a bundle of two rows of flat heat exchange tubes arranged in parallel and at mutual spacings, with heat exchange elements arranged between these flat tubes.

15 Prior art

Evaporators of an air conditioning circuit for motor vehicles according to the prior art generally utilize as their working medium the coolants R134a or R1234yf, whose working pressures vary from around 3 bar to a maximum of 30 bar (in
20 extreme situations).

EU directive 2006/40/EC of 2017 orders the use in new air conditioning units of motor vehicle of coolants with a global warming potential (GWP) > 150 (the reference value is GWP = 1, which is that of CO₂). Coolant R134a with a value of
25 GWP = 1430 is thus prohibited for use in new air conditioning units of motor vehicles by this directive. Coolant R1234yf with a value of GWP = 4 meets the legislation.

The existing head designs are thus constructed for low-pressure media with
30 maximum pressure strength up to 30 bar(g) and are not suitable for use in high-pressure exchangers.

The use of CO₂ as a coolant is not in itself new, having commenced already in the mid-1800s and having reached its peak in the 1920s, from which time onward it
35 was gradually replaced in most applications by synthetic coolants (CFC, HFC, HFO, etc.) and by ammonia (R717), which work at much lower pressures.

Especially in view of contemporary ecological and safety requirements, efforts have been made to once again use the coolant R744 (CO₂) for the evaporators of an
40 air conditioning circuit, especially for motor vehicles. Unlike the synthetic coolants used recently, this is a natural substance, which moreover does not contribute to the formation of a hole in the ozone layer, has little influence on global warming, and what is more it is cheap, easily available, noncorrosive, nontoxic and nonflammable in usual concentrations. With a value of GWP = 1, it is most
45 suitable from the standpoint of legislation. However, the pressure in the evaporator in the case of CO₂ is significantly higher than in the case of the previous coolants.

Designs are known for heat exchangers working with the coolant R744, being formed by a bundle of heat exchange tubes between which are arranged heat

exchange elements, these heat exchange tubes carrying a coolant between an upper head and a lower head, often called the upper and lower tank in this industry.

5 The dimensions of the evaporator are governed by the space which is used to heat or cool and also by the available space laid out in the ventilation unit of the automobile. The height dimension of the evaporator is dictated again by the space dimension in the ventilation unit and this dimension is directly dictated by the manufacturer of the unit. This dimension differs in regard to the size of the unit as
10 a function of the size of the motor vehicle and the required thermal efficiency. The length dimension of the evaporator, like its height, is dictated by the space in the ventilation unit, this dimension being dictated by the manufacturer or that unit.

For example, from document US2006185386 there is known an evaporator of an air conditioning circuit working in this way with carbon dioxide coolant, which
15 contains a bundle of two rows of flat heat exchange tubes, which are connected at their upper and lower ends to an upper and lower head of the evaporator, respectively. This document indicates as the advantageous length 200 to 350 mm and height 100 to 235 mm. Specifically, it describes an evaporator with length of 307 mm, height of 235 mm and thickness of 38 mm.

20 The known solutions are unsatisfactory in terms of withstanding the required high pressures and also in terms of dimensions. The excessive thickness of the evaporator on the one hand increases the requirements for the installation space and thus the manufacturing expense, and on the other hand makes the assembly of
25 the evaporator more demanding and increases the unwanted uptake of water.

The aim of this invention is to design an evaporator of an air conditioning circuit, especially for motor vehicles, which provides the required thermal efficiency with
30 the smallest possible thickness of the exchanger body.

30 Essence of the invention

The evaporator of an air conditioning circuit of the invention has an exchanger body, created by a bundle of two rows of flat heat exchange tubes, arranged in
35 parallel and at mutual spacings, the upper and lower ends of the heat exchange tubes being connected to upper and lower heads, respectively, while between said flat tubes there are arranged, over the entire thickness of the exchanger body, heat exchange elements with a plurality of ribs. The essence of the invention is that the thickness of the exchanger body, the mutual spacings of the flat heat exchange
40 tubes, and the geometries of the heat exchange elements are mutually optimized to achieve a cooling performance when using CO₂ as the coolant of at least 15 W per cm² of gross area of the exchanger body for an air flow rate of 600 kg per hour, relative humidity of 40%, and air temperature of 40° C.

45 The exchanger body refers to the core of the evaporator, which is active in terms of heat transfer, and comprises two rows of flat heat exchange tubes and wave-shaped heat exchange elements located in the spaces between the heat exchange tubes. The heat exchange elements may but need not stand out somewhat beyond the heat exchange tubes at both sides of the exchanger body in the direction of the thickness
50 of the evaporator. The heat exchange elements create a plurality of ribs, which are

- always formed between the waves of the wave-shaped heat exchange element, the mutual spacing of the ribs of the heat exchange elements being advantageously 1.3 to 1.5 mm. The gross area of the exchanger body refers here to the product of the length and height of the evaporator core in the imaginary envelope plane
- 5 surrounding the outer ends, accessible from the front side, of the heat exchange surfaces. Thus, the gross area of the exchanger body is the plane in which lie the ends of the flat heat exchange tubes or the ends of the wave-shaped heat exchange elements, if they extend beyond the heat exchange tubes.
- 10 The thickness of the exchanger body is advantageously less than 38 mm and the mutual spacing of the heat exchange tubes is advantageously 5.5 to 9 mm. The thickness of the exchanger body is especially advantageously 26 to 34 mm, for example 26 mm or 32 mm.
- 15 The thickness of the exchanger body may equal the distance from the outer end of the flat heat exchange tube of one row to the outer end of the flat heat exchange tube of the other row. But in an advantageous embodiment, the heat exchange elements in the direction of the thickness of the evaporator extend somewhat on both sides of the exchanger body beyond the heat exchange tubes, that is, by 1 to
- 20 15% of the thickness of the exchanger body, advantageously by 1 to 4 mm. In this advantageous embodiment, the thickness of the exchanger body is greater by the amount of both these projections than the distance from the outer end of the flat heat exchange tube of one row to the outer end of the flat heat exchange tube of the other row. The thickness of the exchanger body in this case is advantageously 28 to
- 25 34 mm.
- The ribs of the heat exchange elements are advantageously provided with louvers for tilting the air flow, arranged in parallel in the direction of the length of the exchanger body, which are oriented, in the half of the heat exchange element
- 30 situated between the flat heat exchange tubes in the portion of the thickness of the exchanger body belonging to the first row of flat heat exchange tubes, opposite those in the half of the heat exchange element situated between the flat heat exchange tubes in the portion of the thickness of the exchanger body belonging to the second row of flat heat exchange tubes, so that the apertures bounded by the
- 35 louvers in one row of tubes open in the opposite direction to that in the other row of tubes.

List of figures in the drawings

- 40 The invention will be explained more closely with the aid of specific sample embodiments illustrated in the drawings, which show:
- Fig. 1, an overall view of the evaporation according to the invention,
 Fig. 2, a detail view of part of the assembled evaporator according to the invention
- 45 at the site of connection of the inlet and outlet,
 Fig. 3a, a wavy heat exchange element in a front view of the evaporator,
 Fig. 3b, a detail of the configuration of the wavy heat exchange element along the thickness of the evaporator,
 Fig. 4, a flat heat exchange tube in cross section,
- 50 Fig. 5, a detail of the arrangement of the heat exchange tubes in the evaporator, and

Fig. 6, a graphic illustration of the optimization of the thickness of the exchanger body and the mutual spacings of the flat heat exchange tubes according to the invention.

5 **Sample embodiment of the invention**

In this entire document, terms relating to the orientation of the evaporator such as upper, lower, vertical, horizontal, etc., are related to its orientation as is depicted in the figures, see for example Fig. 1. The evaporator 1 of the air conditioning circuit, especially for a motor vehicle, is often installed in just such an orientation and the indicated directions thus correspond to the position of such an evaporator 1 during its use. The height H of the evaporator body is in the vertical direction, the length L of the evaporator body is in the left to right direction in Fig. 1, and the thickness T of the evaporator body is in the direction perpendicular to the vertical and the left-right direction.

A coolant moves through the evaporator 1, entering the evaporator 1 as liquid phase essentially in the liquid form (but it may contain some coolant already in the gas state) and exiting from it as gas phase (also known as the vapour phase).

The evaporator 1 is formed by two heads 2, 3, situated opposite each other and joined together by two rows of flat heat exchange tubes 6, between which are located heat exchange elements 7 serving for the exchanging of heat with another medium, air, which passes through the evaporator 1 transversely in the direction of its thickness T. In the sample embodiment shown, each heat exchange tube 6 has nine channels 14 which ensure the flow of coolant in the evaporator 1.

In Fig. 1, the heat exchange elements 7 are shown only at the left-hand side, in order to better see the heat exchange tubes 6 leading between the two heads 2, 3 of the evaporator.

Each head 2, 3 of the evaporator according to the invention comprises an assembly of distribution panels 21, 31, intermediate plates 22, 32, and cover panels 23, 33, set in a U-shaped profile 20 or an inverted U-shaped profile 30, mutually joined together with such an internal arrangement of the panels as determines the desired direction or directions of flow of medium through the head and distributing the medium to the active portion of the evaporator in the direction of the bundle of heat exchange tubes. In terms of the transfer of energy of the air, this distributing head is essentially an inactive part. The mentioned parts are mutually joined by brazing.

The head 2, 3 of the evaporator also serves to distribute coolant in the liquid state (and possibly already partly in the gas state), arriving by the inlet connected to one of the two heads 2 or 3 gradually to the individual heat exchange tubes 6 leading between the two heads 2, 3, and ultimately (now in the form of a gaseous vapour phase) to the outlet.

Figure 2 illustrates a detail of the evaporator 1 according to the invention with attached connector 4, which integrates the coolant inlet and outlet in itself. Mounted in the connector 4 are sockets 5 for connecting of piping for the arrival of

liquid phase and the removal of gas phase. The connector 4 has the basic shape of a block with at least two arms 41, 42 projecting upward in prolongation of its two opposite walls.

- 5 The evaporator 1 has an exchanger body, which forms the active part in terms of heat exchange, and two heads 2, 3. The active part is composed of heat exchange tubes 6 and wave-shaped heat exchange elements 7. The flat heat exchange tube 6 always has several channels 14 for the flow of coolant and is made by extrusion from aluminium alloy. On the wider surface of the flat heat exchange tube 6 is
10 attached the wave-shaped heat exchange element 7 by brazing. The current of air passing through the active part of the evaporator is cooled by the wave-shaped heat exchange element 7, which takes up the heat and passes it on to the heat exchange tube 6.
- 15 The overall form of the wave-shaped heat exchange element 7 can be seen in Fig. 2. A detail of the wavy heat exchange element 7 in a front view of the evaporator is shown in Fig. 3a. The ribs 11 of the wavy heat exchange element 7 are provided with louvers 12 for tilting the flow of air, arranged in parallel in the direction of the length L of the exchanger body. The components illustrated in Fig. 3a are not
20 shown to scale, for clarity. The louvers 12 are best seen in Fig. 3b, which illustrates the portion of the heat exchange element 7 corresponding to Fig. 3a in a top view. This shape influences the performance parameters of the exchanger body. The output depends on the size and aperture of the louvers 12, and the number of waves 13 forming the ribs. This shape also provides for the removal of
25 moisture condensed in portions of the wave-shaped heat exchange element 7. The quality of the brazed connection between the wave-shaped heat exchange element 7 and the heat exchange tube 6 is influenced by the shape of the waves 13 of the wave-shaped heat exchange element 7. The design of the heat exchange tube 6 is illustrated in Fig. 4 and the arrangement of the heat exchange element 7 in the
30 spaces between the tubes 6 is indicated in Fig. 5.

The inventors upon conducting an optimization of the geometry of the exchanger body were surprised to find that a small thickness T of the exchanger body can be used to achieve the required cooling performance, being less than 38 mm, most
35 suitably 26 to 32 mm. The fundamental parameters for effective cooling of the other medium by the exchanger body are fulfilled for all these thicknesses.

The mutual spacing between two adjacent heat exchange tubes also has influence on the pressure loss, similar to the thickness T of the evaporator body. The optimal
40 mutual spacing between two adjacent tubes is 5.59 to 8.94 mm. The relation between the thickness T of the evaporator body and the mutual spacing between two adjacent tubes 6 is illustrated in Fig. 6. The mutual spacing between two adjacent heat exchange tubes 6 is one of the principal factors determining the pressure loss during a flow of air through the active part of the evaporator 1.

45 The region A in Fig. 6 represents the region where the mutual spacing between two adjacent tubes is 5.59 to 8.94 mm and likewise the thickness T of the evaporator body is between 26 and 38 mm. This region represents the region of optimal efficiency, expressed by a cooling performance of at least 15 W per cm² of gross
50 surface of the exchanger body, given the use of CO₂ as coolant and an air flow of

600 kg per hour, relative humidity of 40%, and air temperature of 40° C. The trapping of water between the heat exchange surfaces 9, 7, 11, 12, 13 is satisfactorily low in region A.

- 5 Region B in Fig. 6 represents the region of an over-dimensioned exchanger body. The thickness greater than 38 mm already produces no increase in efficiency. The trapping of water between the heat exchange surfaces 9, 7, 11, 12, 13 is on the borderline of unsatisfactory.
- 10 Region C in Fig. 6 represents the region of inadequate efficiency, that is, a cooling performance less than 15 W per cm² of gross area. The trapping of water would be satisfactorily low.

- 15 Region D in Fig. 6 represents a region of adequate efficiency, but large amounts of water are trapped between the ribs of the evaporator, which may be manifested by a spraying of water from the air conditioner.

- 20 Region E in Fig. 6 represents a region in which, because of the influence of the pressure loss of the air, the evaporator can have the required performance only at the cost of high performance of the fan. A high pressure loss generally increases the output of the cooling device, and at the same time increases the build-up of water in the wave-shaped heat exchange element 7 and the possible freezing of this water when the unit is at rest, and the surrounding temperature drops to below 0° C. A high pressure loss also increases the electricity consumption of the fan which
- 25 forces air through the evaporator 1.

- 30 Another important parameter of the evaporator 1 is the mutual spacing between the ribs 11 of the wave-shaped heat exchange element. This corresponds to the spacing of two adjacent waves 13 of the wave-shaped heat exchange element and in the sample embodiments described it is in the range of 1.3 to 1.5 mm.

- 35 According to one sample embodiment, the thickness of the exchanger body T is 26 mm and the wave-shaped heat exchange elements 7, which in this case have a width also equal to 26 mm, do not extend beyond the ends of the heat exchange tubes 6 in the thickness direction of the exchanger body. The thickness T of the exchanger body in this case is equal to the distance from the outer end of the surface of the heat exchange tube 6 of one row of tubes to the outer end of the surface of the heat exchange tube 6 of the other row of tubes.

- 40 If one were to use, in an otherwise identical evaporator, heat exchange elements 7 with a width equalling 32 mm, they would extend at both sides beyond the ends of the heat exchange tubes 6 by 3 mm and the overall thickness of the exchanger body would also be T = 32 mm. The heat exchange in the evaporator is increased from 74% to 82% as compared to the embodiment without an extension. This extension
- 45 improves the air cooling and limits the freezing of moisture condensed in parts of the wave-shaped heat exchange elements 7 during the operation of the exchanger body.

- 50 Although the above-described embodiment of the invention has been described only in connection with the evaporator of a cooling device, it will be obvious to the

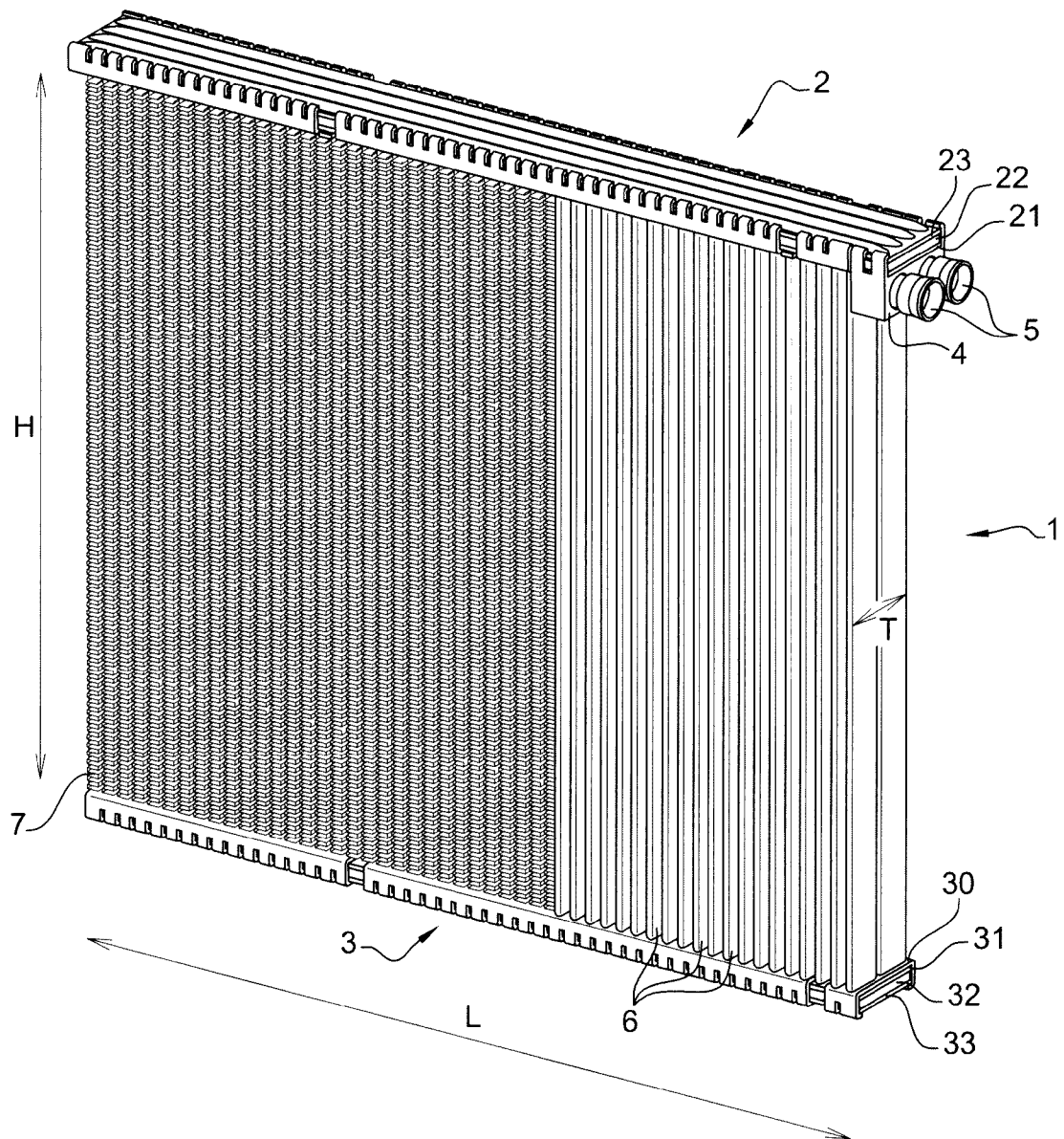
skilled person that an exchanger having the features indicated in the patent claims can also be used for other heat exchange applications.

Patent claims

1. Evaporator (1) of an air conditioning circuit, especially for motor vehicles,
5 containing
- an exchanger body having a thickness (T) and a gross area dictated by its length (L) and height (H),
- an upper head (2) with an inlet for liquid phase and an outlet for gaseous phase, and
10 - a lower head (3),
wherein the exchanger body is created by a bundle of two rows of flat heat exchange tubes (6), arranged in parallel and at mutual spacings,
wherein the upper and lower ends of the heat exchange tubes (6) are connected to upper and lower heads (2, 3), respectively,
15 while between said flat tubes (6) there are arranged, over the entire thickness of the exchanger body, heat exchange elements (7) with a plurality of ribs,
characterized in that
the thickness (T) of the exchanger body, the mutual spacings (TP) of the flat heat exchange tubes (6), and the geometries of the heat exchange elements (7) are
20 mutually optimized to achieve a cooling performance when using CO₂ as the coolant of at least 15 W per cm² of gross area of the exchanger body for an air mass flow rate of 600 kg per hour, relative humidity of 40%, and air temperature of 40° C.
- 25 2. Evaporator according to Claim 1, wherein the thickness (T) of the exchanger body is less than 38 mm and the mutual spacing (TP) of the heat exchange tubes (6) is always 5.5 to 9 mm.
- 30 3. Evaporator according to Claim 2, wherein the mutual spacing (FP) of the ribs of the heat exchange elements (7) is 1.3 to 1.5 mm.
4. Evaporator according to Claim 1, 2 or 3, wherein the heat exchange elements (7) in the direction of the thickness of the evaporator (1) extend somewhat on both sides of the exchanger body beyond the ends of the heat exchange tubes (6), that is,
35 advantageously by 1 to 4 mm.
5. Evaporator according to any one of Claims 1 to 4, wherein the thickness (T) of the exchanger body is 26 to 34 mm, for example 26 mm or 32 mm.
- 40 6. Evaporator according to Claim 4, wherein the thickness (T) of the exchanger body is 28 to 34 mm.
7. Evaporator according to any one of the preceding claims, wherein the ribs (11) of the heat exchange elements (7) are provided with louvers (12) for tilting the air
45 flow, arranged in parallel in the direction of the length (L) of the exchanger body, which are oriented, in the half of the heat exchange element (7) situated between the flat heat exchange tubes (6) in the portion of the thickness of the exchanger body belonging to the first row of flat heat exchange tubes (6), opposite those in the half of the heat exchange element (7) situated between the flat tubes (6) in the
50 portion of the thickness of the exchanger body belonging to the second row of flat

heat exchange tubes (6), so that the apertures bounded by the louvers (12) in one row of tubes (6) open in the opposite direction to that in the other row of tubes (6).

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**Fig. 1**

2 / 4

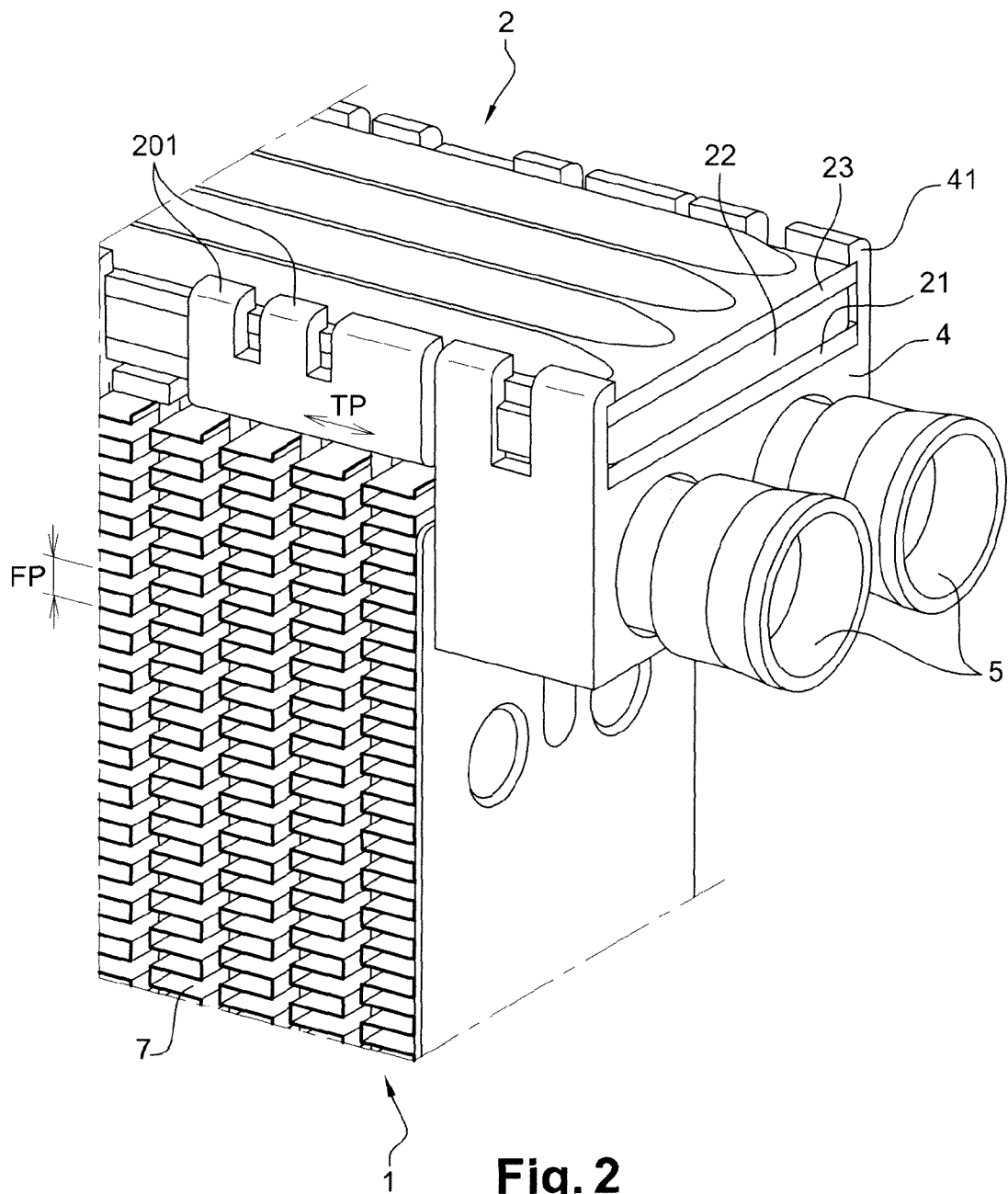
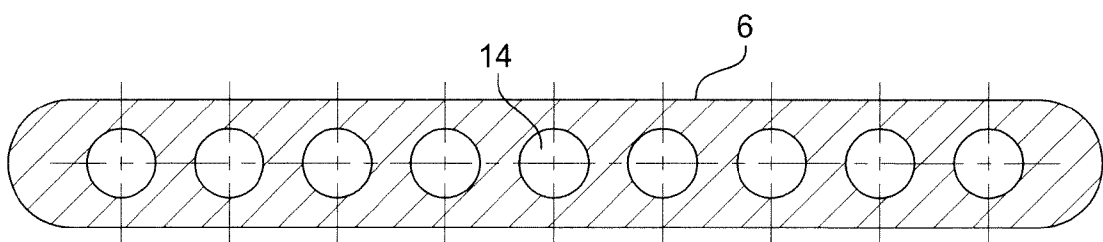
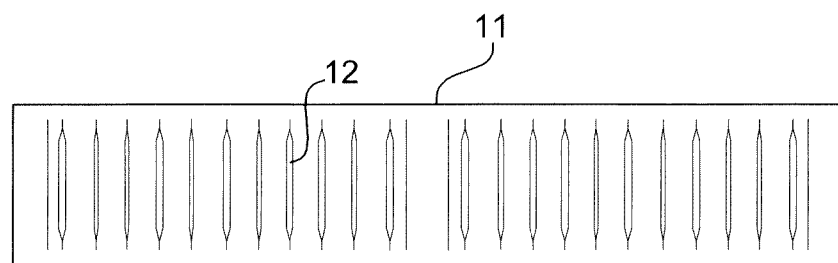
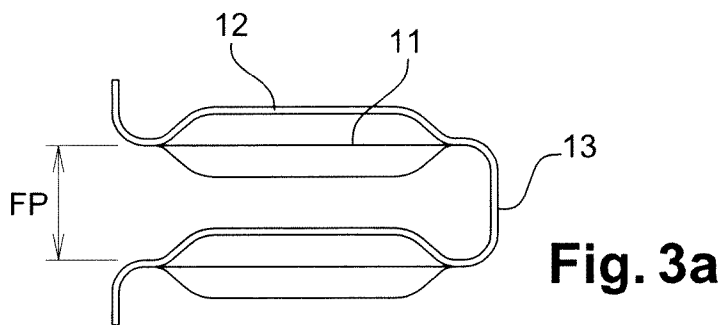
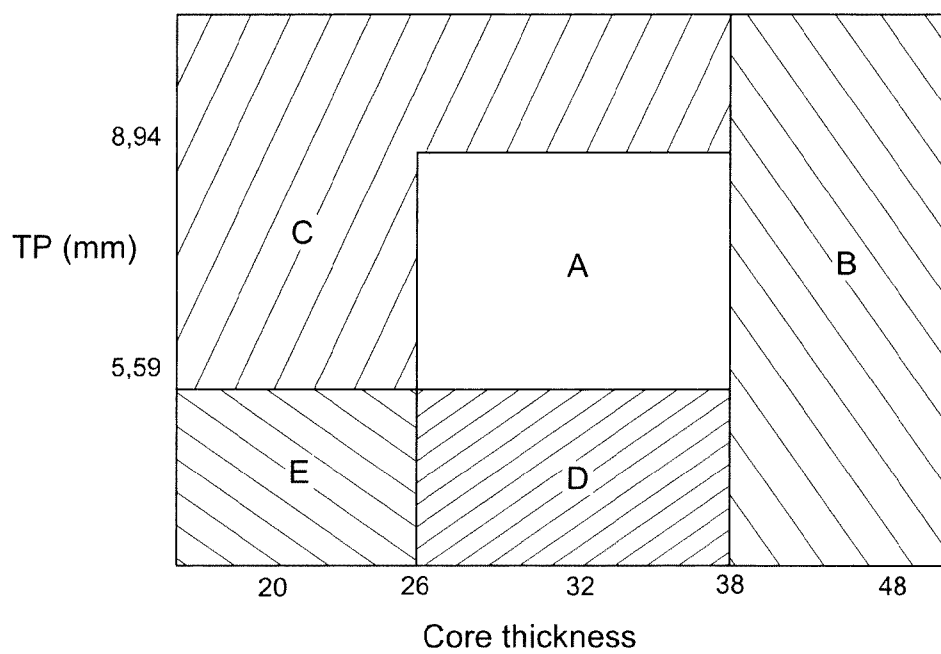
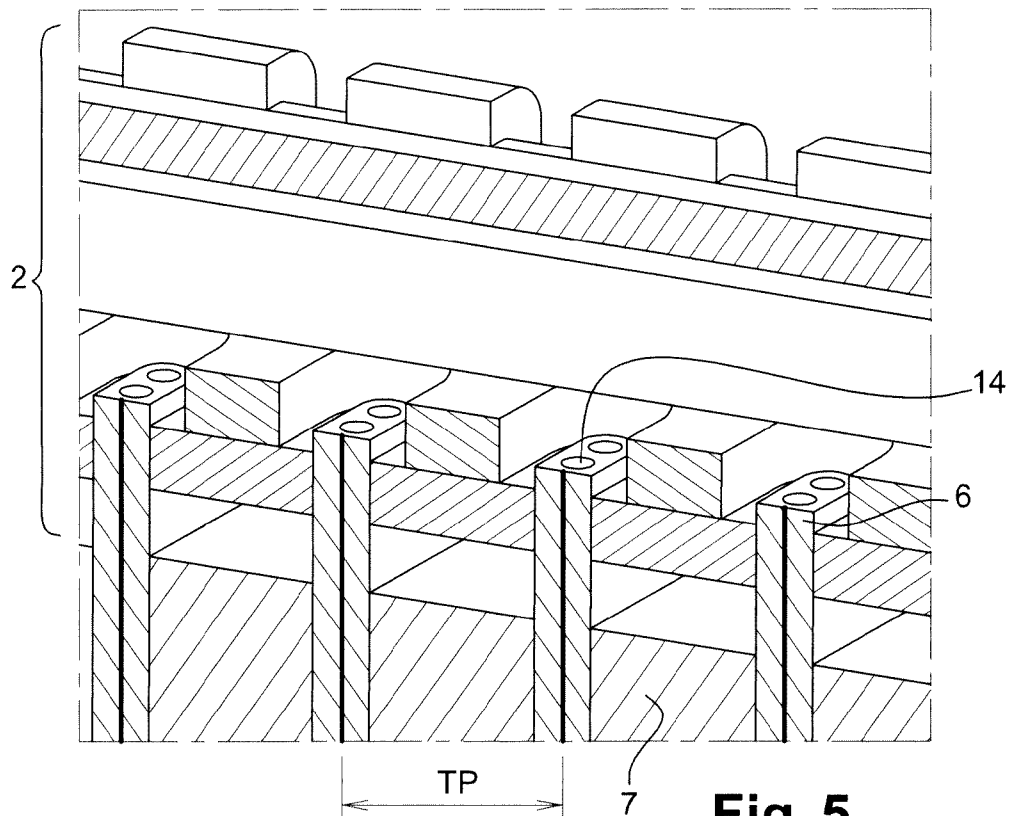


Fig. 2

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INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER

INV. F28F9/02 F28D1/053 F28F1/02 F28F1/12 B60H1/00
F25B39/02

ADD.

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)

F28F F28D B60H F25B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 311 935 A (YAMAMOTO MICHIIYASU [JP] ET AL) 17 May 1994 (1994-05-17) abstract; figures 1, 3, 4a, 4b, 8a, 8b column 3, lines 34-60	4,7
A	US 2006/185386 A1 (KATOH YOSHIKI [JP] ET AL) 24 August 2006 (2006-08-24) cited in the application paragraph [0136]; figures 1-4	1-7



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

5 June 2018

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Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

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