(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 956 330 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
13.08.2008 Bulletin 2008/33

(51) Int Cl.:
F28D 9/00 *(2006.01)* ***F28F 3/02*** *(2006.01)*

(21) Application number: **08151109.9**

(22) Date of filing: **06.02.2008**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(30) Priority: **07.02.2007 IT UD20070025**

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(54) **Heat exchanger**

(57) A heat exchanger (10) having at least a heat exchange unit (20, 22) comprises a first circuit having a plurality of first passage ways in which a first fluid is able to flow, along a predetermined direction (S), and a second circuit (26, 44) in which a second fluid is able to flow. The second circuit (26, 44) is provided with a plurality of second passage ways (29, 46) in which the second fluid is able to flow. Each first passage way and/or each second passage way (29, 46) defines a substantially obligatory path for the first and/or second fluid from a relative entrance (29a, 46a) to a relative exit (29b, 46b). The combination of the obligatory paths substantially covers the whole heat exchange surface of the first circuit and/or the second circuit (26, 44).

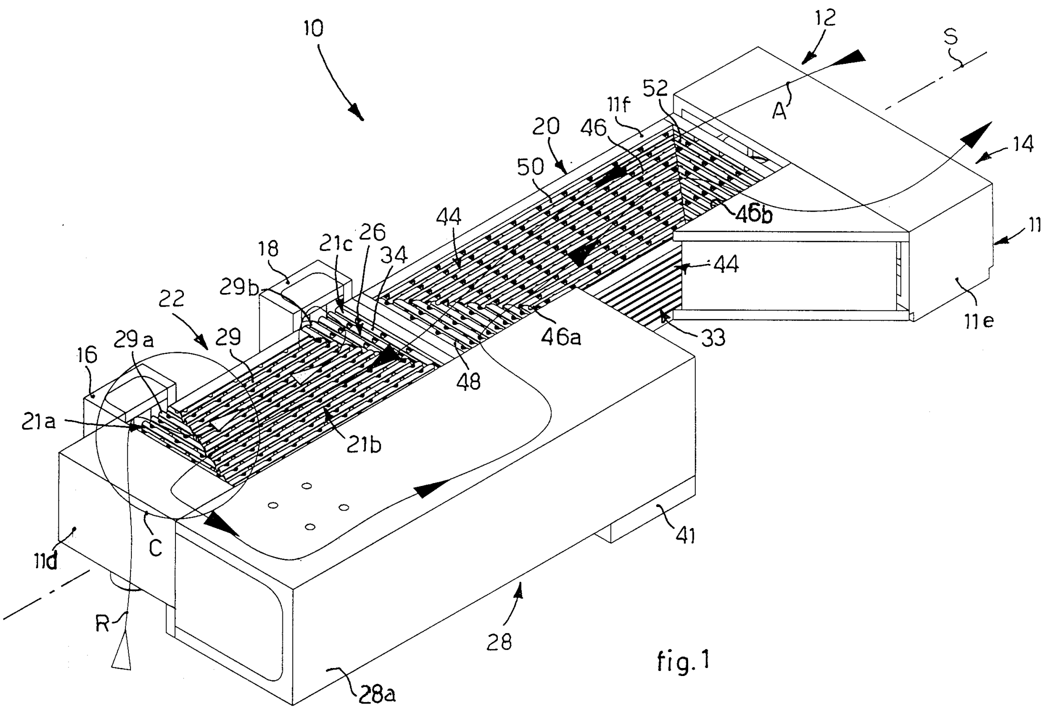

fig.1

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Printed by Jouve, 75001 PARIS (FR)

Description

FIELD OF THE INVENTION

[0001] The present invention concerns a heat exchanger usable in cooling machines and/or plants for refrigeration or drying, such as for example drying plants for compressed air, able to be used in those applications where it is necessary to have available de-humidified and almost totally dry air.

[0002] The invention is advantageously applicable not only in dryers for compressed air, but also for industrial, commercial and residential cooling plants, or any other similar or comparable application.

BACKGROUND OF THE INVENTION

[0003] It is known to make heat exchangers formed by a pre-cooling unit, or air-to-air pre-exchanger, a cooling unit, or cooling-air exchanger, consisting of a plurality of circuits disposed in layers, consisting of fins, plates and horizontal walls, made of heat-conducting metal material, packed and alternating with each other, in which a fluid to be cooled and a cooling fluid respectively flow, and of a separation unit to separate the condensation which has accumulated due to the cooling, from the cooled fluid. At head and tail of these circuits there are collectors, in turn connected to the entrance and exit of the respective fluids.

[0004] Known heat exchangers have the disadvantage that, as the flow rate of the cooling fluid and/or the fluid to be cooled varies, the distribution of the stream of fluids by the entrance collectors inside the circuits is not homogeneous and uniform. In fact, with low flow rates, the two fluids prefer the shortest path to reach the exit, that is to say, they prefer to occupy a partial surface of the whole heat exchange surface nearest the collector. Therefore, in a plurality of operating conditions the whole heat exchange surface of the exchanger is not exploited, but only a limited part, sometimes only half, and therefore the exploitation of the whole cooling capacity of the plant is limited. This entails considerable difficulty in obtaining a highly efficient heat exchange, due to the formation of the preferential paths of the two fluids and the consequent formation of dead zones, where no heat exchange occurs.

[0005] The machines with which the heat exchangers have to be associated normally have a pre-determined and particularly compact bulk. In view of this application, said known heat exchangers have the advantage that they can also be applied in plants with particular geometric constraints, but have the disadvantage that they cannot exploit the natural circulation of the fluids due to the force of gravity.

[0006] Purpose of the present invention is to make a heat exchanger which has an optimum and uniform distribution of the streams of the heat exchange fluid over the whole heat exchange surface of the exchanger, to enable a high and homogeneous heat exchange efficiency.

[0007] The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other purposes and advantages.

SUMMARY OF THE INVENTION

[0008] The present invention is set forth and characterized in the independent claim, while the dependent claims describe other characteristics of the invention or variants to the main inventive idea.

[0009] In accordance with the above purpose, a heat exchanger has at least a heat exchange unit comprising at least a first circuit having a plurality of first passage ways in which a first fluid is able to flow in a pre-determined direction, at least a second circuit in which a second fluid is able to flow, which is disposed in contact with and separate from the first circuit so as to effect a heat exchange between the two fluids, and which is provided with a plurality of second passage ways in which the second fluid is able to flow.

[0010] The heat exchanger has at least a delivery and a discharge for the first and second fluid, connected to the first circuit and the second circuit.

[0011] According to a characteristic feature of the present invention, each first passage way and/or each second passage way defines a substantially obligatory path for the first and/or second fluid from a relative entrance to a relative exit, in which the combination of the obligatory paths substantially covers the whole heat exchange surface of the first circuit and/or the second circuit.

[0012] The present invention allows to embody a heat exchanger with an optimum and uniform distribution of the streams of heat exchange fluids, over the whole heat exchange surface of the exchanger, even at low flow rates of the fluids, which allows a high and homogeneous efficiency of heat exchange. In fact, the particular geometry defined for the pipes in which the fluids pass prevents the formation of preferential paths of the fluids through the heat exchanger, both on the air side and also on the cooling side, thus reducing or eliminating the dead zones where no heat exchange is performed.

[0013] Advantageously, the heat exchanger has two heat exchange units, in particular a pre-cooling unit and, in series, a cooling unit, which advantageously have a substantially identical structure.

[0014] Another advantageous form of embodiment provides that the feed pipe of the second, cooling fluid is disposed in an elevated position with respect to the discharge pipe of the same second fluid. In this way we obtain an optimum, rapid and uniform filling or flooding of all the pipes where the cooling fluid passes.

[0015] The heat exchanger is also provided with a unit to separate the condensation, downstream of the cooling unit; this advantageously comprises an anti-drawing grid means, which retains the possible humidity present in the cooled air and allows it to be discharged as condensation.

[0016] In particular, the present invention is advantageously applied to horizontal heat exchangers, in which it allows the optimum filling of the circuits but in any case the inventive concept on which the present invention is based can also be applied to vertical heat exchangers or heat exchangers of any other type.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other characteristics of the present invention will become apparent from the following description of a preferential form of embodiment, given as a non-restrictive example with reference to the attached drawings wherein:

- fig. 1 is a partly sectioned perspective view of a heat exchanger according to the present invention;
- fig. 2 is an enlarged detail of fig. 1;
- fig. 3 is another partly sectioned perspective view of a heat exchanger according to the present invention;
- fig. 4 is a lateral section of a heat exchanger according to the present invention;
- fig. 5 is another partly sectioned perspective view of a heat exchanger according to the present invention.

DETAILED DESCRIPTION OF A PREFERENTIAL FORM OF EMBODIMENT

[0018] With reference to fig. 1, a heat exchanger 10 according to the present invention, in this case of the horizontal type, can be used to perform heat exchange between a stream of air to be cooled and a stream of cooling fluid, able to evaporate after the heat exchange, for example Freon.

[0019] The exchanger 10 comprises a frame 11 having an upper wall 11a, disposed at a level conventionally equal to H_1, and a lower wall 11b, disposed at a lower level conventionally equal to H_0 (fig. 4), two lateral collectors, a distribution collector 11c and an exit collector 11d, a collector 11e, connected to the exit collector 11d, and a substantially rectilinear long lateral wall 11f (figs. 1 and 3). On the lateral collector 11c there is the entrance 12 and the exit 14 for the air (figs. 1 and 3), whereas along the wall 11f there is the entrance 16 and exit 18 for the cooling fluid (fig. 4), provided with a respective feed pipe 40 and discharge pipe 42.

[0020] The path of the stream of air to be cooled, indicated by the arrow A in figs. 1 and 3, substantially develops along a pre-determined and obligatory direction S, from the entrance 12 at the distribution collector 11c to the exit collector 11d. The stream of air passes in succession through a pre-cooling unit, or pre-exchanger 20, in which it exchanges heat with the cooled stream of air exiting, and through a subsequent cooling unit, or evaporator, 22, in which the heat exchange with the cooling fluid occurs.

[0021] Furthermore, the exit collector 11d functions as a lateral delimitation of the exchanger 10, so as to define a compartment 17 (fig. 5) in which the direction of the stream of air makes a diversion and is re-directed towards a unit to separate condensation 28, from which it then passes to the pre-cooling unit 20 and from here it is directed towards the exit 14.

[0022] The cooling unit 22 consists, on the air side, of circuits 23, in this case five, for the passage of the air, disposed vertically one on the other, an upper circuit 23a in contact with the upper wall 11a, three intermediate circuits 23c and a lower circuit 23b in contact with the lower wall 11b and fluidly communicating with each other (fig. 3). Each circuit 23 includes fins 25 which, overall, extend substantially in the direction S, with a broken line plane profile, in this case a fretted profile, to promote turbulence and heat exchange. The fins 25 are suitably distanced from each other, to define respective channels 24 in which the air is able to flow (figs. 3 and 4). Therefore, each circuit 23 has a plurality of channels 24, substantially aligned with the direction S and parallel to each other, in which the air to be cooled passes.

[0023] The channels 24 are disposed in the circuit 23 in such a manner that the air follows an obligatory path through each of them, and that the relative entrance 24a and exit 24b of each of the channels 24 is adjacent and in close proximity to the relative entry 12 of the air to be cooled and the relative exit 39 of the air which has been cooled but which still has to be de-humidified. In this way, the air is distributed uniformly over the whole heat exchange surface of the circuit 23.

[0024] Furthermore, in the cooling unit 22, on the cooling fluid side, four circuits 26 are also provided, for the passage of the cooling fluid, communicating fluidly with each other, disposed vertically and alternated with respect to the five circuits 23 and separated from said circuits 23, so that there is no direct contact between the air and the cooling fluid. Therefore, the circuits 23 and 26 are disposed in layers and define a packing or wafer (figs. 1, 3, 4 and 5).

[0025] Each circuit 26 is formed by two horizontal walls 15, upper and lower (fig. 4), between which there are three fret-shaped sheets 21a, 21b, 21c, disposed on the same level and adjacent to each other (figs. 1 and 2). Said fins 25 of the circuits 23 of the air side are disposed above the upper wall 15.

[0026] Due to the way it is shaped, each sheet 21a, 21 b, 21 c defines beveled fins 27a and respective rounded throats 27b. In this way, for each circuit 26, a plurality of pipes 29 are defined, in which the cooling fluid is able to flow. The beveled fins 27a are provided with eyelets 27c which allow the cooling fluid to pass between the various pipes 29 and promote turbulence, as can also be seen in the detail C in fig. 1, enlarged in fig. 2.

[0027] The pipes 29 of each circuit 26 are disposed adjacent to each other and lie on a common plane. The entrance 29a and exit 29b of each pipe 29 is disposed adjacent and in close proximity, respectively, to the entrance 40a of the feed pipe 40 and the exit 42a of the discharge pipe 42, so that the cooling fluid entering from the feed pipe 40 is distributed uniformly in all the pipes 29, just as the exit from the pipes 29 occurs uniformly over the whole discharge pipe 42.

[0028] The pipes 29 have a particular geometry that obliges the stream of cooling fluid to follow a pre-determined path, so that the fluid is distributed over the whole heat exchange surface.

[0029] In particular, two sheets 21a, 21c are provided, respectively disposed in correspondence with the pipe 40 and the pipe 42, shaped as a rectangular trapezium, and a sheet 21b, disposed central to the previous two, shaped as an isosceles trapezium and having its oblique sides coinciding with the oblique sides of the sheets 21 a and 21 c. According to the requirements of feed and discharge, the inclination of the oblique sides can be varied, for example they can have an inclination of 30°, 45°, 60° or other.

[0030] Therefore, as can also be seen in the detail in fig. 2, the pipes 29 are formed by a first portion 30, relating to the sheet 21a, disposed perpendicular to the direction S and directly connected to the feed pipe 40, a second portion 32, relating to the sheet 21b, disposed parallel to the direction S, and a third portion 34, relating to the sheet 21c, disposed perpendicular to the direction S and directly connected to the discharge pipe 42. It is clear that the sense of the stream of cooling fluid in the portion 34 is the same direction and opposite sense with respect to the stream of cooling fluid in the portion 30, in the first case towards the wall 11f and in the second case in the opposite sense. The path of the cooling fluid is in this case indicated by the arrow R in figs. 1 and 2. This type of disposition is called, here and hereafter, "double right angle geometry". By means of this "double right angle geometry" the cooling fluid that is fed by the pipe 40 immediately meets a plurality of pipes 29, and therefore is distributed uniformly through them, even at low flow rates. Afterwards, the cooling fluid is obliged to flow in each of the obligatory paths defined by the individual pipes 29, as far as the exit into the discharge pipe 42.

[0031] There is also a uniform distribution of the fluid towards the exit at the discharge pipe 42, determined by the obligatory paths of each pipe 29.

[0032] In this way we have a uniform distribution of the cooling fluid over the whole heat exchange surface of the circuit 26.

[0033] In exactly the same way as the cooling unit 22 is formed, the pre-cooling unit 20 is formed, on the air side, by five circuits 33, disposed between the walls 11a and 11b, structurally identical to the previous circuits 23. Each circuit 33 has respective channels 35 identical to the channels 24 and directly connected to them, which define, from the relative entrance 35a to the exit 35b, respective obligatory paths, so as to determine a continuous stream of air, in the direction S, from the entrance 12 to the exit 39 at the compartment 17. From a functional point of view, the circuits 33 allow the air to be cooled to pass from the entrance 12 into the pre-cooling unit 20 and in said direction S, to the subsequent cooling unit 22.

[0034] Each circuit 33 and the respective channels 35 are connected without a break in continuity to the adjacent circuit 23 and the respective channels 24, in correspondence with the connection zone indicated by the reference number 37 in fig. 3, so that the air flows, uniformly and along the same obligatory paths, from the entrance 12 to the exit 39.

[0035] The circuit 33 therefore also distributes uniformly the stream of air from the entrance 14 through the channels 35, exploiting the whole heat exchange surface available.

[0036] Again in the pre-cooling unit 20, on the cold air side, between the circuits 33, four circuits 44 are disposed, vertically alternating, separated from the circuits 33 and fluidly communicating with each other. In this way, the circuits 33 and 44 are disposed in layers and define a packing or wafer.

[0037] The circuits 44 are structurally identical to the circuits 26, that is, they are formed by fret-shaped sheets as described above which define pipes 46 (figs. 1 and 5), identical to said pipes 29.

[0038] The fins and horizontal walls which define the circuits 33 and the circuits 44 are visible in the drawings but, for convenience, they are not indicated with a reference number, since they are structurally identical to the fins 25 and 27a and the walls 15.

[0039] The circuits 44, from the functional point of view, are able to allow the passage of the cooled air from the condensation separation unit 28 to the exit 14, passing through the pre-cooling unit 20. In this case, the pipes 46 of each circuit 44 determine obligatory paths for the cooled and de-humidified air, so as to receive, by means of their entrance 46a, the stream of cooled air directly that arrives through the aperture 31 from the condensation separation unit 28, allowing the uniform distribution thereof along obligatory paths, over the whole heat exchange surface, as far as the exit 46b, directly in proximity with the exit 14 of the cooled and de-humidified air. In this case too, by doing this, the whole heat exchange surface of the circuit 44 available is exploited, without determining preferential paths and dead zones.

[0040] Compared with the disposition of the circuits 26, the disposition of the circuits 44 is inverted by 180°, with respect to an ideal median axis parallel to the direction S, to determine the correct path of the cooled and de-humidified air from the condensation separation unit 28 through the pre-cooling unit 20 to the exit 14.

[0041] Therefore, each pipe 46 comprises a first portion 48, directly connected to the aperture 31 of the condensation separation unit 28 and disposed perpendicular to the direction S, a second portion 50 disposed parallel to the direction S and a third portion 52, directly connected to the exit 14 and disposed perpendicular to the direction S. It is clear that the sense of the stream of cooled air in the portion 48 is the same direction and opposite sense with respect to the stream of cooled air in the portion 52, in the first case towards the wall 11f and in the second case in the opposite sense. This type of disposition is also called, here and hereafter, "double right angle geometry".

[0042] By means of this "double right angle geometry", the cooled air arriving directly from the condensation separation unit 28 immediately meets a plurality of pipes 46 and hence is distributed uniformly through them, even at low flow rates. Afterwards, the cooled air is obliged to flow in each of the obligatory paths defined by the individual pipes 46, to the exit 14.

[0043] There is also a uniform distribution of the fluid at the exit 14, determined by the obligatory paths of each pipe 46.

[0044] Another characteristic of the present invention is that the feed pipe 40 is disposed at a different height with respect to the discharge pipe 42, that is, with its exit 40a at a height greater than the respective entrance 42a of the discharge pipe 42. This is obtained by extending the discharge pipe 42 by a determinate length inside the heat exchange unit 22; in this way, it functions as a stopper, substantially preventing the discharge of the cooling fluid until the latter has reached a pre-determined height which corresponds to an optimum filling of all the circuits 26.

[0045] In this case, the exit 40a of the feed pipe 40 is made in correspondence with a lower circuit 26b, disposed immediately above the lower circuit 23b, that is, about level H_0 (fig. 4).

[0046] The entrance 42a of the discharge pipe 42 on the contrary is disposed in correspondence with an upper circuit 26a, disposed immediately above the third intermediate circuit 23c from below, at a height L, generally higher than H_0 and lower than level H_1, in this case a little more than half the distance between H_0 and H_1 (fig. 4). In this way, the pipes 29 are filled with the cooling fluid in an optimum manner, since the cooling fluid reaches the discharge pipe 42 only after the whole volume corresponding to the height L has been flooded.

[0047] Another characteristic of the present invention is that the condensation separation unit 28, downstream of a demister 36 conventionally disposed adjacent to the compartment 17, immediately after the stream of cooled air has been inverted, also comprises an anti-drawing grid 38 to retain the humidity or condensation present in the cooled air. In this case, the grid 38 is formed by a holed plane, with an S-shaped section, that is, it comprises two plane portions disposed at heights staggered and connected to each other by an inclined step. The condensation falls due to gravity into a suitable condensation discharge 41. Advantageously, therefore, apart from a vertical separation surface represented by the demister 35, a horizontal separation surface for the condensation is also defined, represented by the grid 38.

[0048] The condensation separation unit 28 is enclosed in a suitable box-shaped portion 28a of the frame of the exchanger 10.

[0049] Immediately after the grid 38, the stream of air, at this point cooled and de-humidified, performs a right-angled diversion and continues into the pre-cooling unit 20, distributing itself uniformly along all the pipes 46 described above, and following the relative obligatory path. From here, through an elbow-shaped compartment 19, defined by the collector 11e, the air exits from the exchanger 10 through the exit 14.

[0050] It is clear that modifications and/or additions of parts may be made to the heat exchanger as described heretofore, without departing from the field and scope of the present invention.

[0051] It is also clear that, although the present invention has been described with reference to some specific examples, a person of skill in the art shall certainly be able to achieve many other equivalent forms of heat exchanger, having the characteristics as set forth in the claims and hence all coming within the field of protection defined thereby.

Claims

1. Heat exchanger having at least a heat exchange unit (20, 22) comprising:

- at least a first circuit (23, 33) having a plurality of first passage ways (24, 35) in which a first fluid is able to flow, along a predetermined direction (S);
- at least a second circuit (26, 44) in which a second fluid is able to flow, said second circuit (26, 44) being disposed in contact with and separated from said first circuit (23, 33) so as to effect a heat exchange between said first and said second fluid, and being provided with a plurality of second passage ways (29, 46) in which said second fluid is able to flow; and
- at least a delivery (12, 31, 40a) and a discharge (14, 39, 42a) for said first and said second fluid, connected to said first circuit (23, 33) and said second circuit (26, 44);

characterized in that each first passage way (24, 35) and/or each second passage way (29, 46) defines a substantially obligatory path for said first and/or second fluid from a relative entrance (24a, 29a, 35a, 46a) to a relative exit (24b, 29b, 35b, 46b), wherein the combination of said obligatory paths substantially covers the whole heat exchange surface of said first circuit (23, 33) and/or said second circuit (26, 44).

2. Heat exchanger as in claim 1, **characterized in that** said first passage ways (24, 35) and/or said second passage ways (29, 46) are disposed adjacent and in close proximity respectively to said delivery (12, 31, 40a) and of said discharge (14, 39, 42a), so that each first (24, 35) and/or second passage way (29, 46) is able in sequence to receive directly, by means of the entrance (29a, 35a, 46a) said second fluid from said delivery (12, 31, 40a), to direct it along said substantially obligatory path and to discharge it, by means of said exit (29b, 35b, 46b) directly into said discharge (14, 39, 42a).

3. Heat exchanger as in claim 1 or 2, **characterized in that** said first passage ways (24, 35) and/or said second passage ways (29, 46) are made as substantially closed pipes for most of their surface, so that the first and the second fluid flow in them following the relative obligatory path.

4. Heat exchanger as in claim 1, **characterized in that** it comprises a cooling unit (22) which comprises a plurality of fins (25, 27a) and walls (15) reciprocally disposed so as to define said first and second circuits (23, 26) vertically superimposed and so as to delimit said first (24) and said second passage ways (29), the second fluid consisting of cooling fluid being able to flow in said second passage ways (29), wherein said first passage ways (24) are vertically alternated and separated from said second passage ways (29), wherein each of said second passage ways is made as a pipe (29) which comprises a first portion (30) able to be connected to said delivery (40a) of said second fluid and disposed transverse to said direction (S), a second portion (32) disposed parallel to said direction (S) and a third portion (34) able to be connected to said discharge (42a) of said second fluid and disposed transverse to said direction (S).

5. Heat exchanger as in claim 4, **characterized in that** said first portion (30) and said third portion (34) are perpendicular to said direction (S).

6. Heat exchanger as in claim 1, having a pre-cooling unit (20) between the first fluid at entry and the second fluid, consisting of the first fluid at exit, cooled, **characterized in that** said pre-cooling unit (20) comprises:

    - a plurality of fins defining third circuits (33), identical to said first circuits (23) and in direct communication with said first circuits (23), in which said first fluid is able to pass;
    - a plurality of fins defining fourth circuits (44) disposed vertically alternated and separated from said third circuits (33), each of which is provided with said second passage ways (46) in which the second fluid consisting of the first cooled fluid is able to flow;

    wherein each of said second passage ways is made as a pipe (46) which comprises a first portion (48) able to be connected to a condensation separation unit (28) and disposed transverse to said direction (S), a second portion (50) disposed parallel to said direction (S) and a third portion (52) able to be connected to the exit (14) and disposed transverse to said direction (S).

7. Heat exchanger as in claim 6, **characterized in that** said first portion (48) and said third portion (52) of said pipes (46) are perpendicular to said direction (S).

8. Heat exchanger as in any claim hereinbefore, **characterized in that** it comprises a frame (11) having an upper wall (11a) and a lower wall (11b) between which at least said first circuits (23) and said second circuits (26) are disposed, **in that** said feed pipe (40) of said second fluid extends vertically as far as a lower circuit (26b) of said second circuits (26) to a level (H_0) and disposed in correspondence with said lower wall (11b) and **in that** said discharge pipe (42) of said second fluid extends vertically as far as an upper circuit (26a) of said second circuits (26), disposed at a height (L), higher than said level (H_0) of said lower circuit (26b).

9. Heat exchanger as in any claim hereinbefore, **characterized in that** it also comprises a condensation separation unit (28), disposed downstream of said cooling unit (22), provided with grid means (38) able to retain the humidity present in the stream of said first fluid.

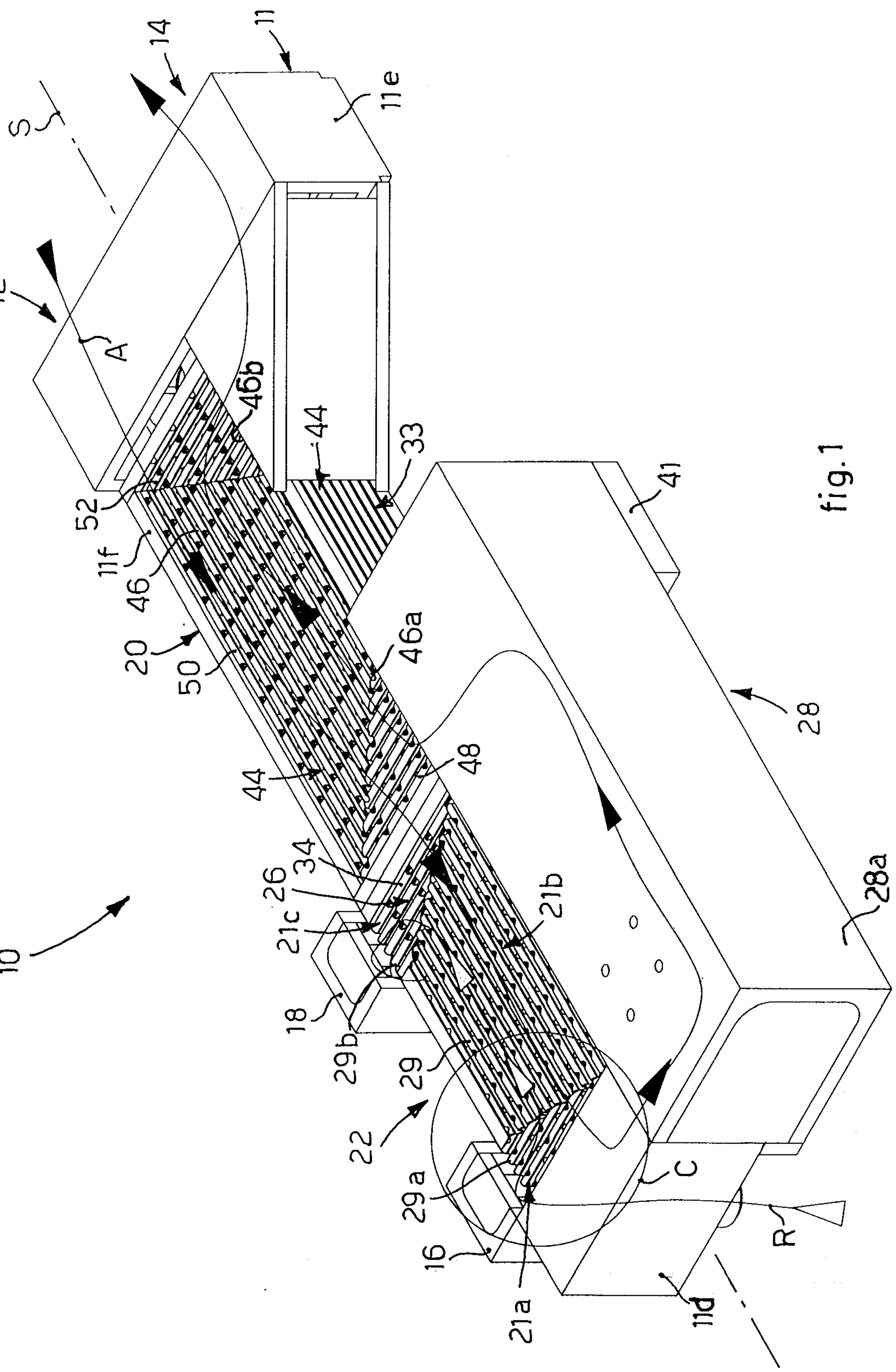
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fig.1

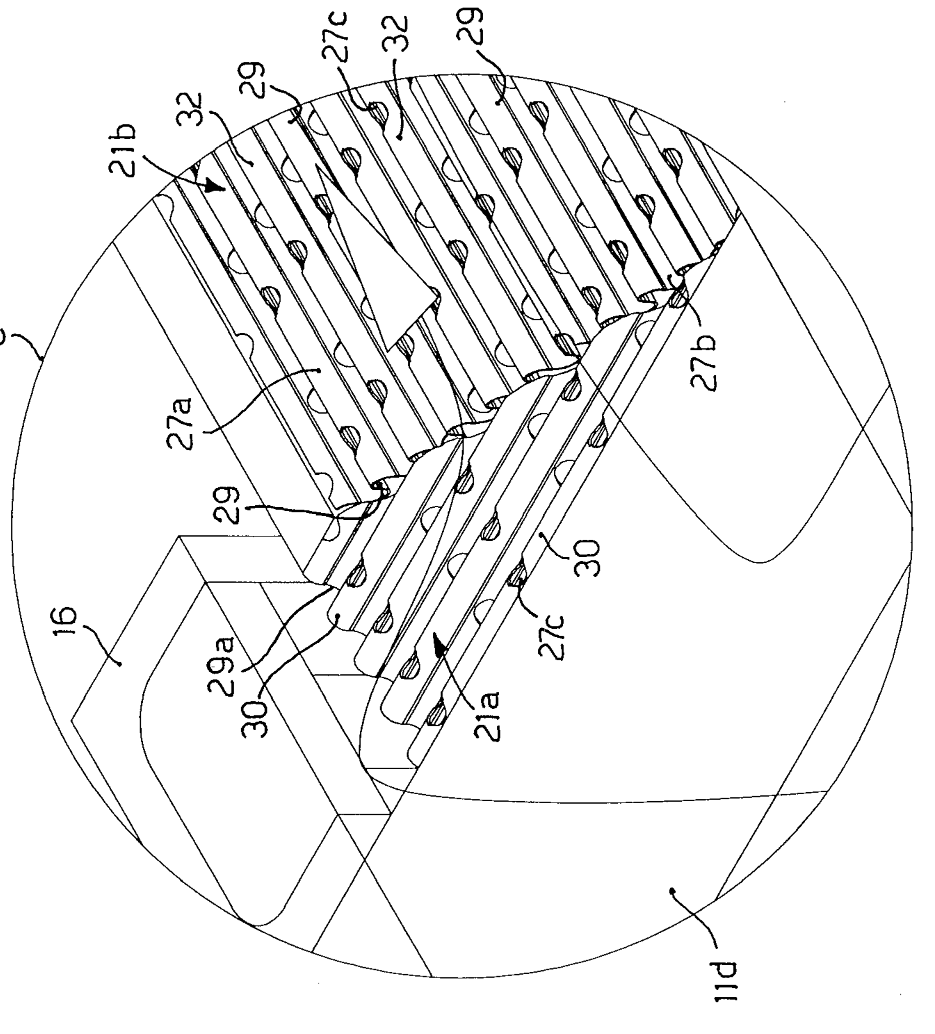

fig. 2

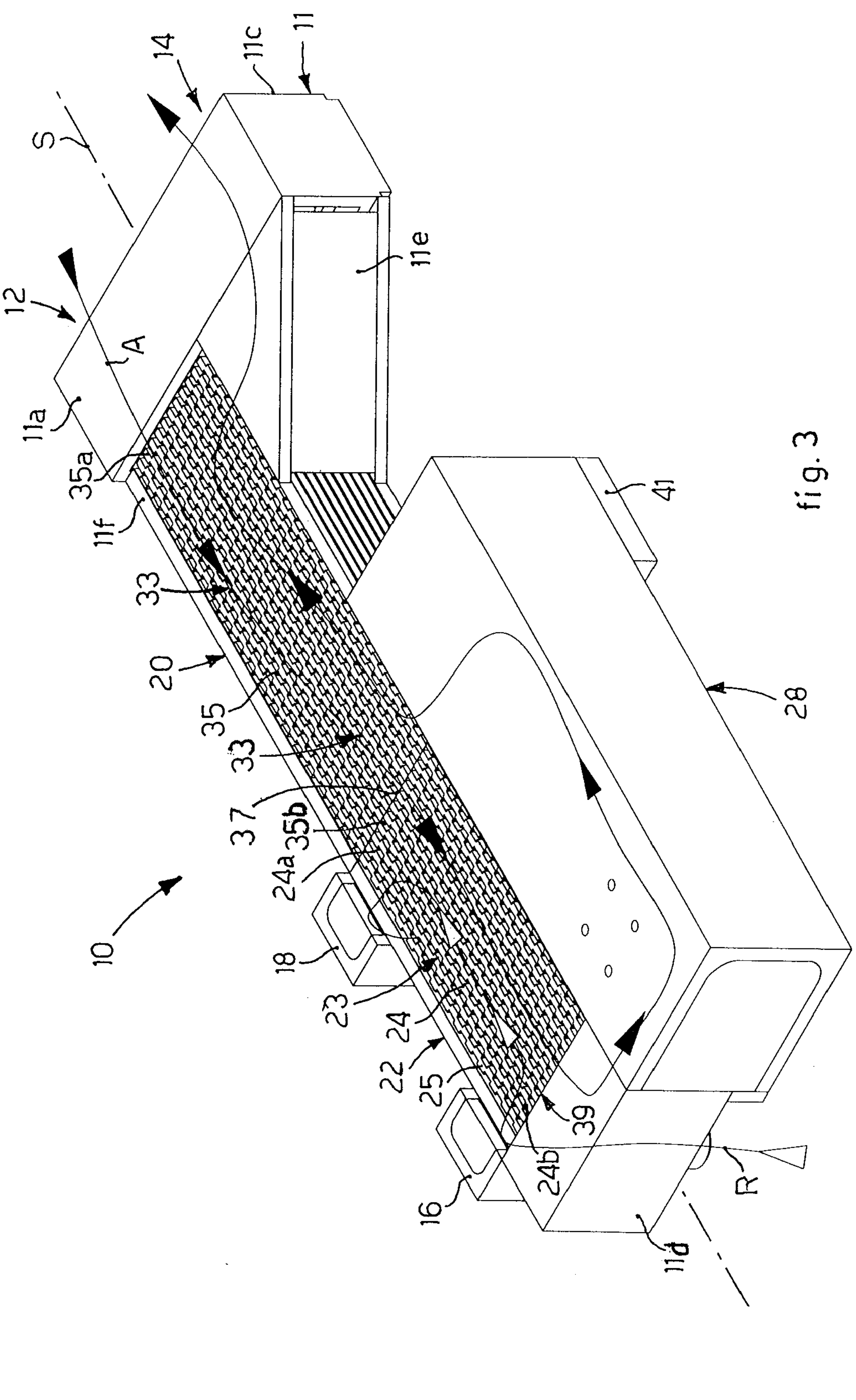
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fig. 3

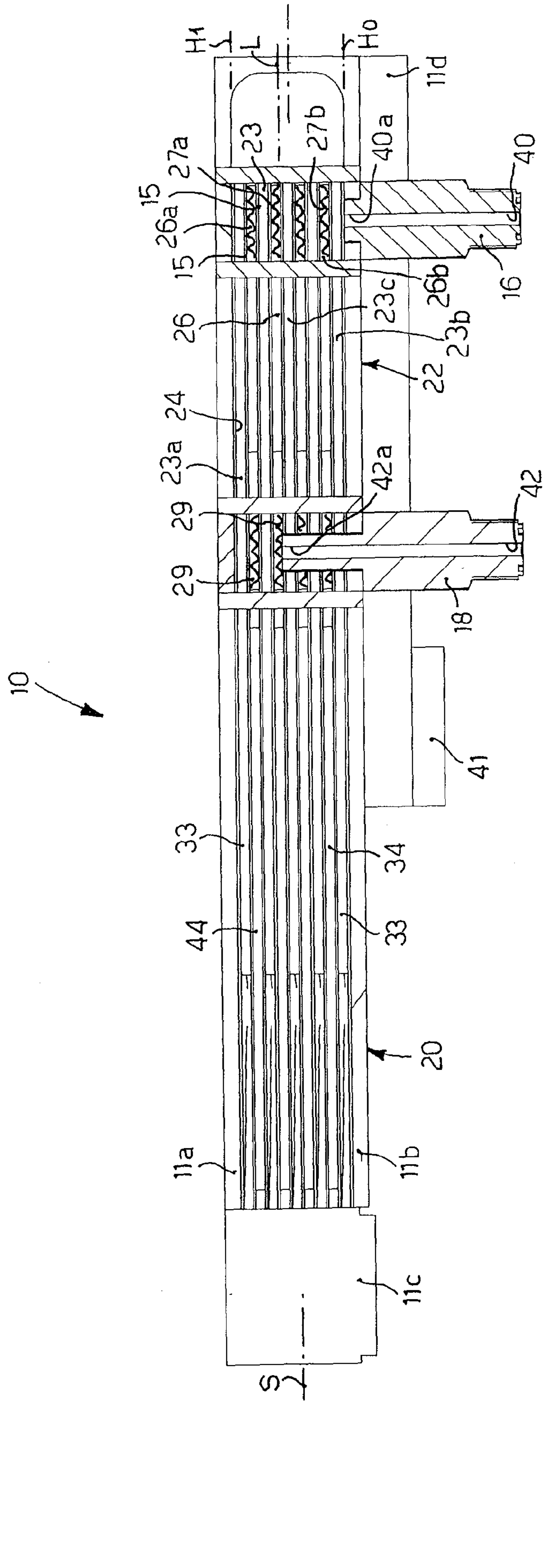
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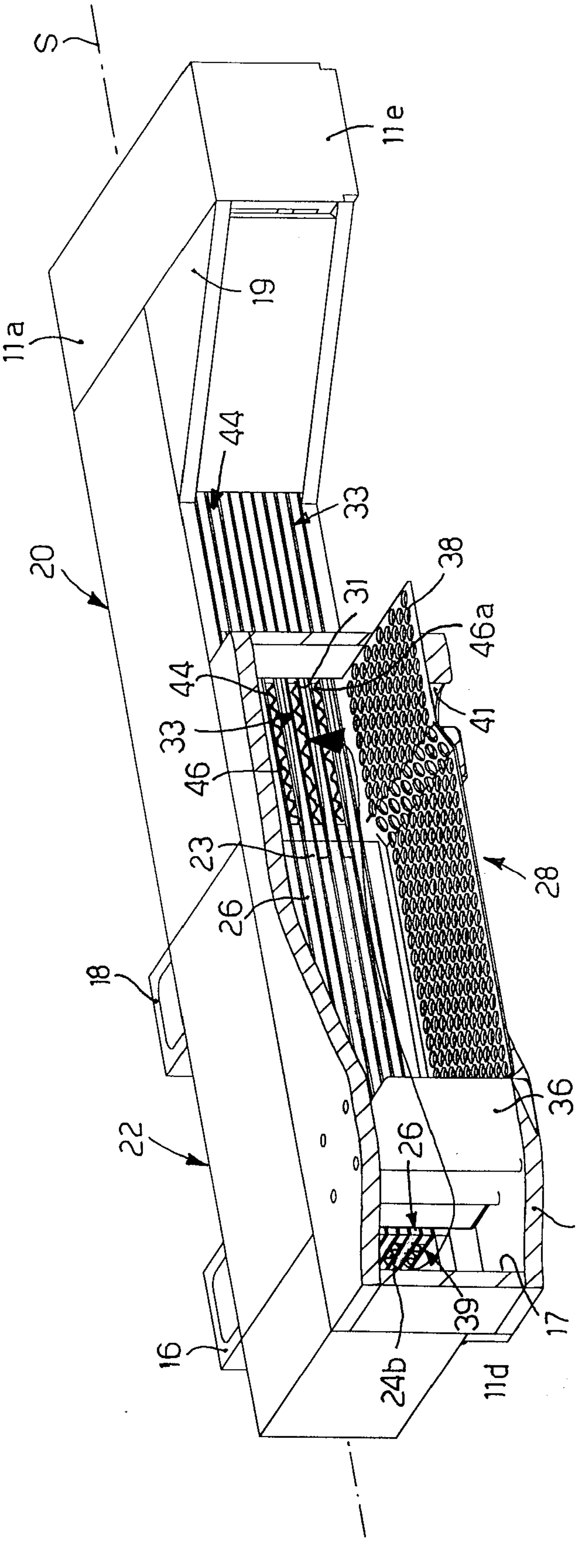
fig. 4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11d

fig. 5