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(54) **EVAPORATOR CONSISTING OF STACKED FLAT TUBES HAVING TWO OPPOSITE FLUID BOXES**

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(57) **ABSTRACT**

The invention concerns an evaporation unit for a heat exchanger between an air flow and a refrigerating fluid, comprising an array consisting of a single row of flat tubes (1) alternately stacked with corrugated spacers (2) retaining the tubes mutually spaced apart by a distance d and whereof the undulations define passages for the air flow in the direction of the tube width, the two ends of each tube respectively communicating with the two fluid boxes located opposite each other relative to the array, so as to define for the refrigerating fluid, in the evaporator, a path for at least two passages. The invention is characterized in that the dimension 1 of the evaporator in said direction ranges between 20 and 55 mm and the distance d ranges between 4.0 and 7.6 mm.
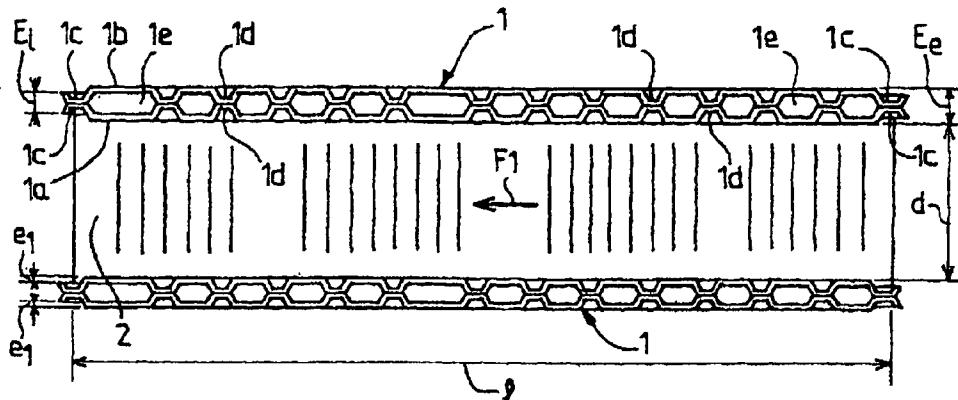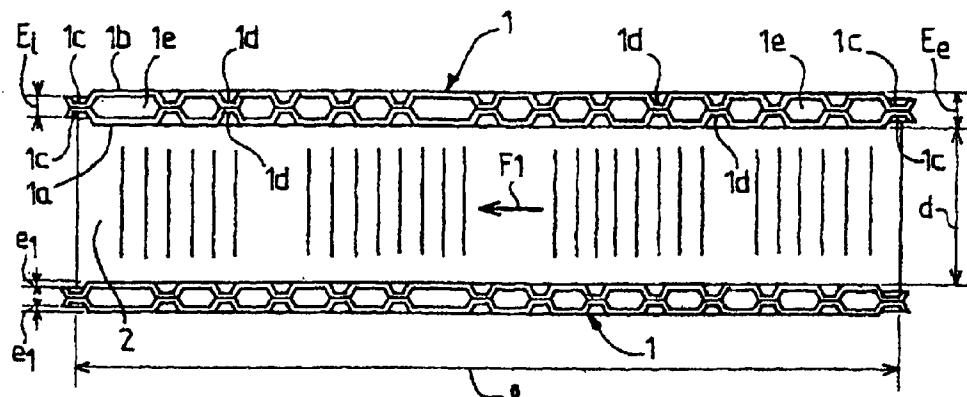
FIG.1
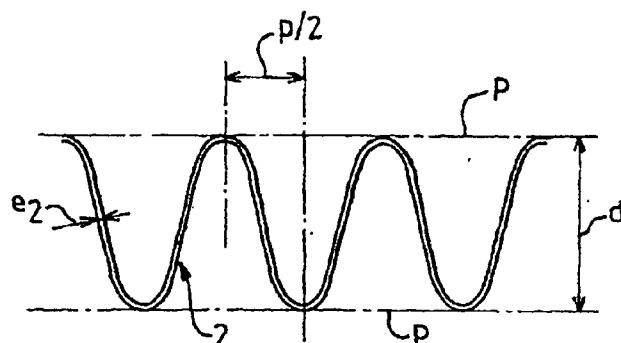
FIG. 2
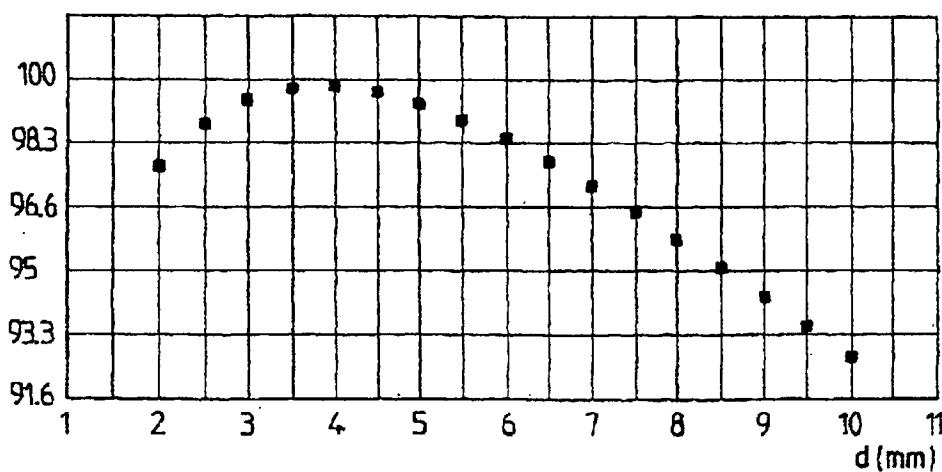
FIG. 3
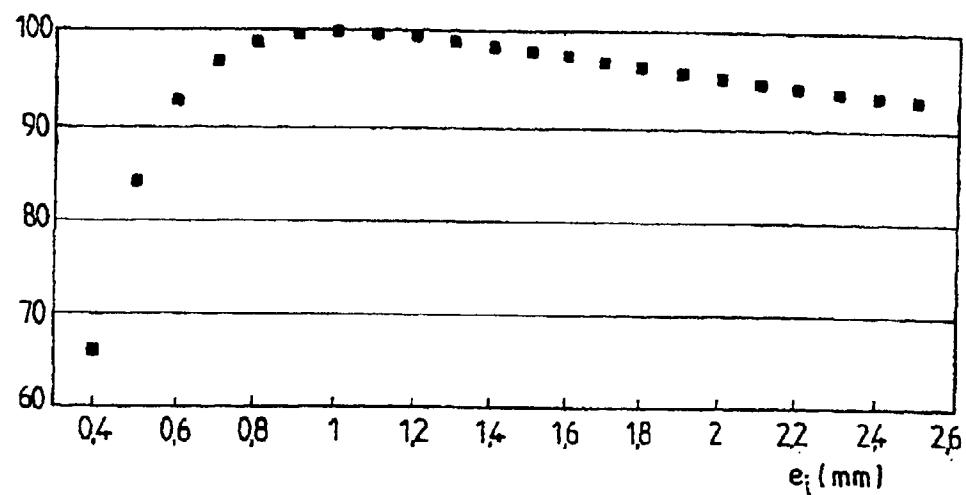
FIG.4

FIG.5

FIG.6



FIG.7

FIG.8

FIG.11
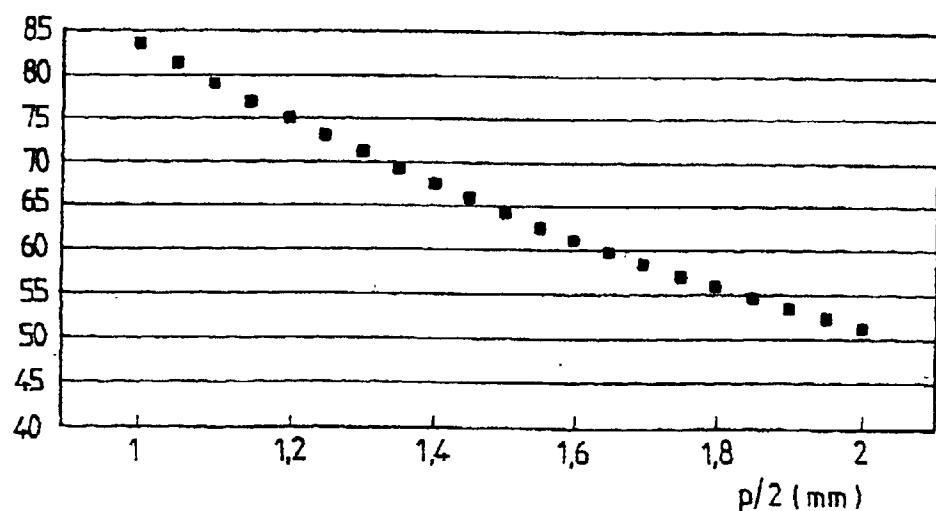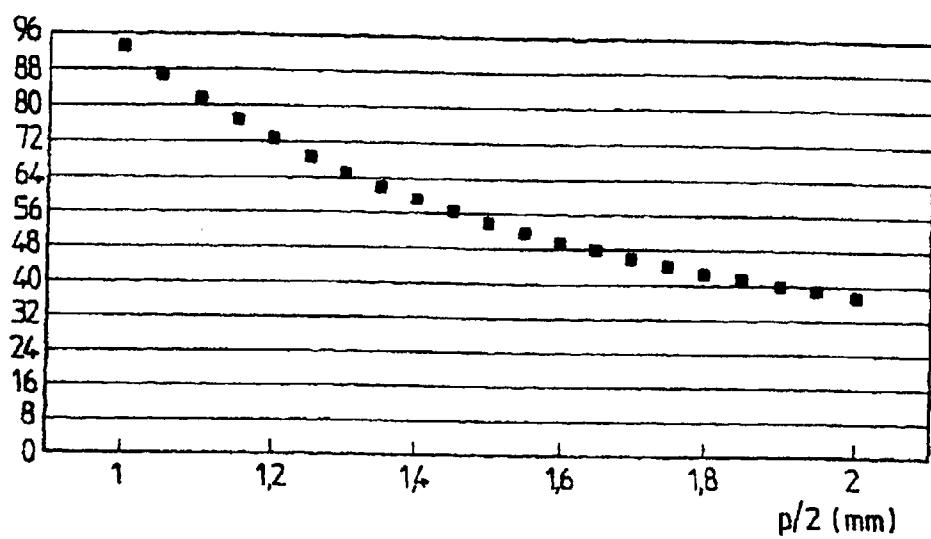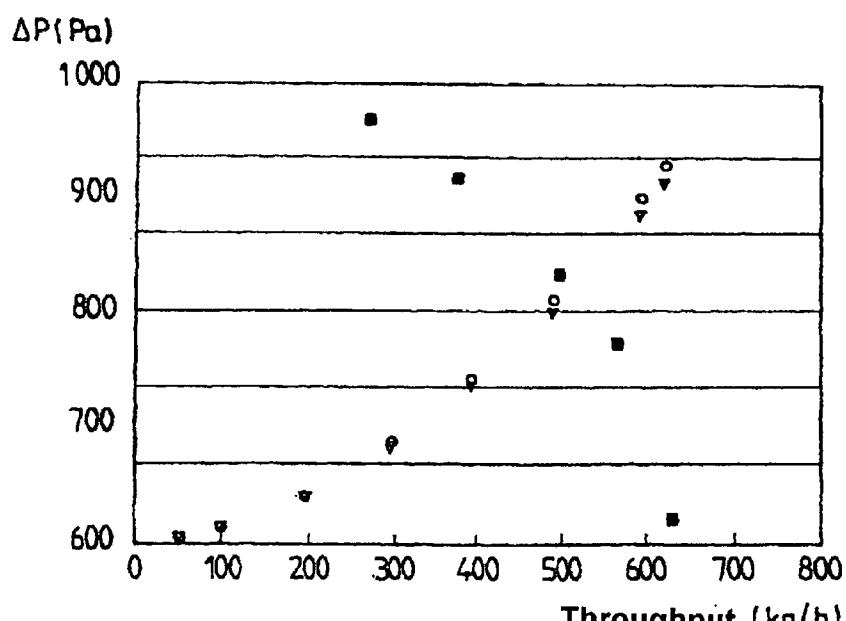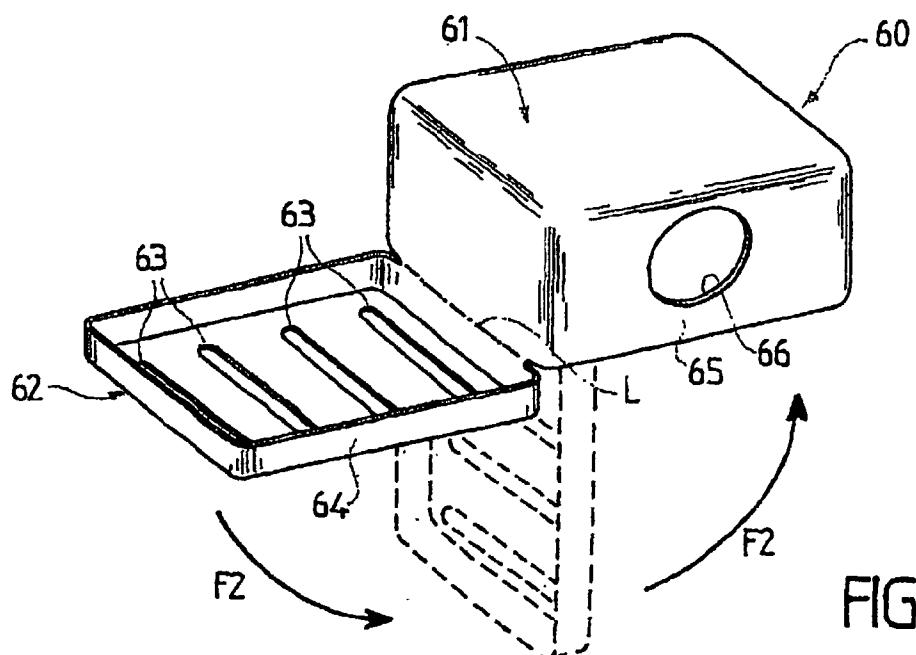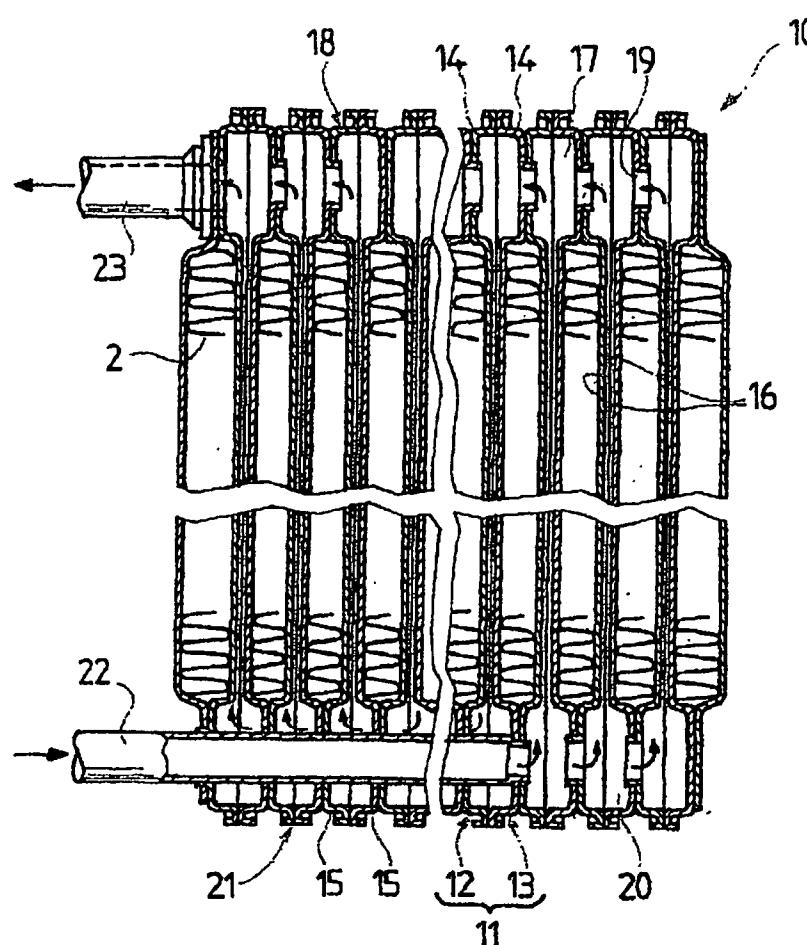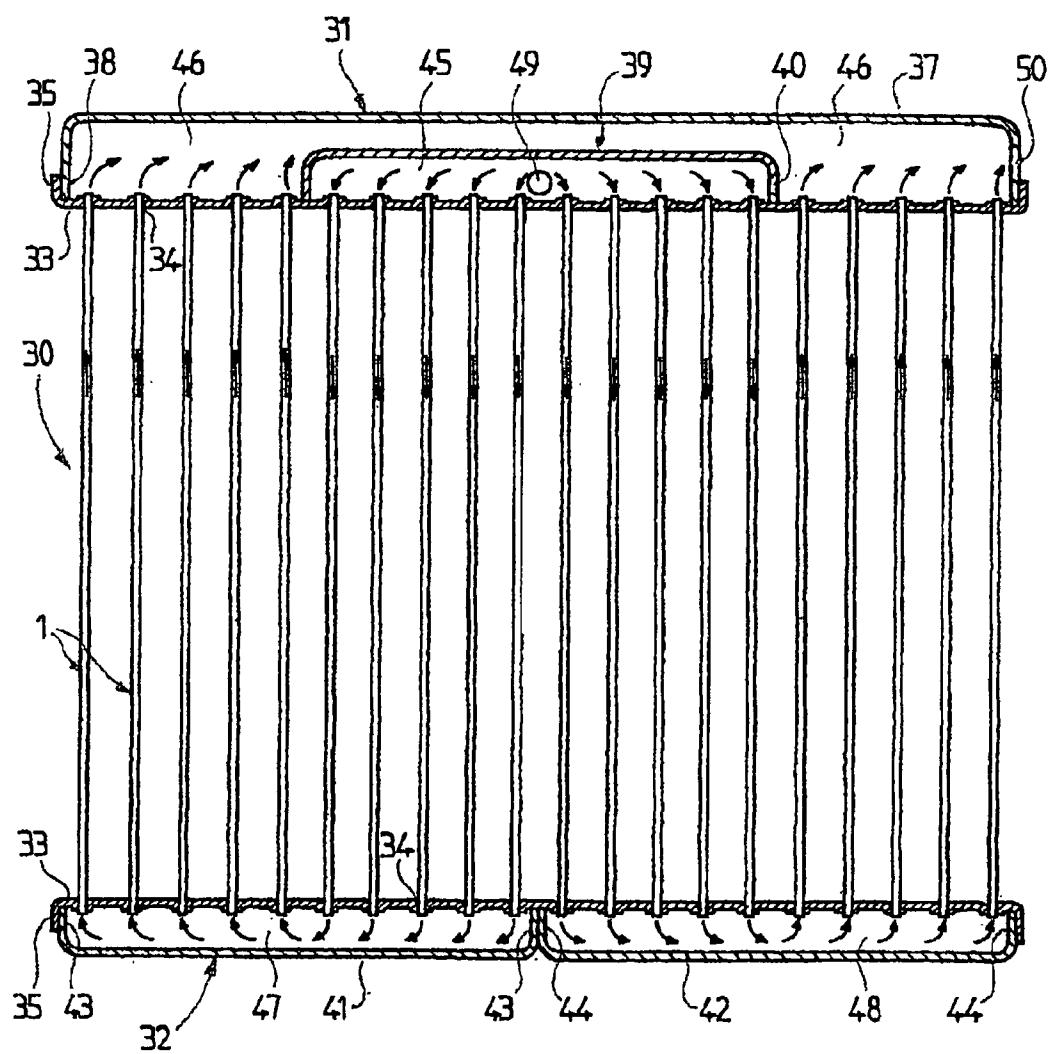
FIG.9
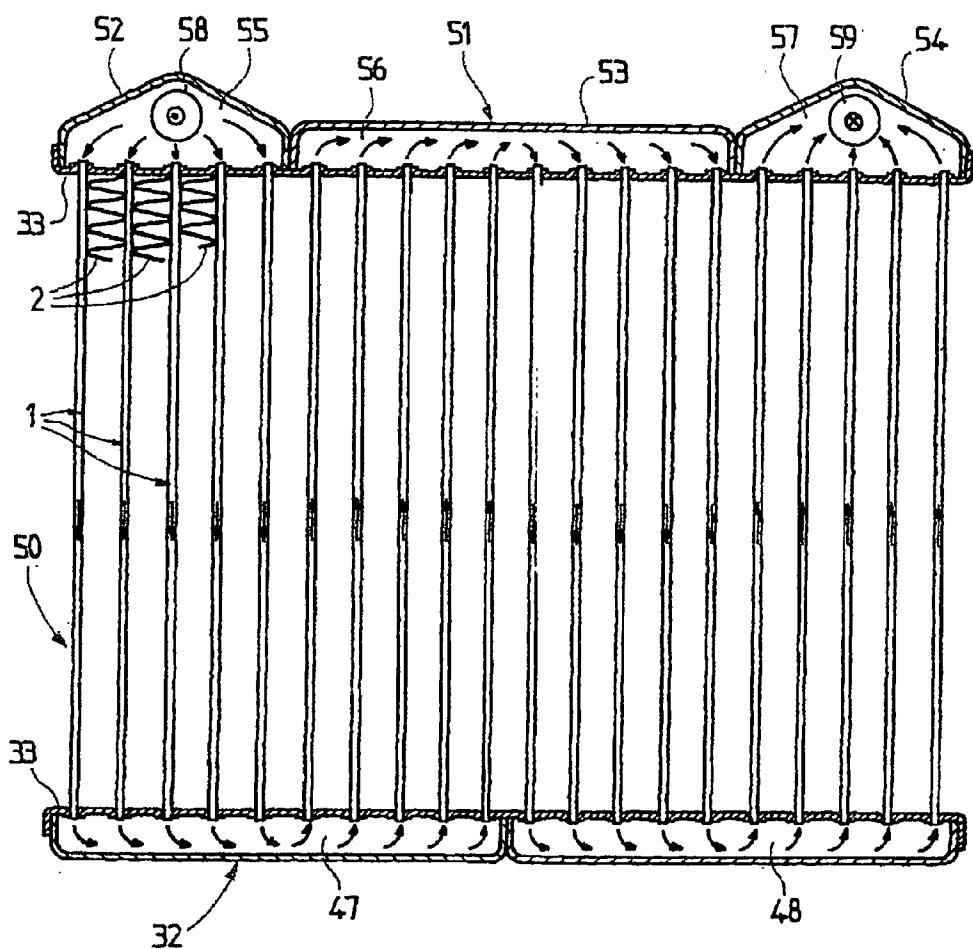
FIG.10

EVAPORATOR CONSISTING OF STACKED FLAT TUBES HAVING TWO OPPOSITE FLUID BOXES

[0001] The invention relates to an evaporator for the exchange of heat between an airflow and a refrigerant fluid with the latter passing from the liquid state to the gaseous state, especially for air-conditioning the passenger compartment of a motor vehicle, comprising a tube bank consisting of a single row of flat tubes stacked alternately with corrugated spacers holding the tubes spaced apart from one another by a distance d and the corrugations of which define passages for the airflow in the direction of the width of the tubes, the two ends of each tube communicating respectively with two fluid boxes situated at opposite ends from one another with respect to the said tube bank, in such a way as to define a journey in at least two passes for the refrigerant fluid in the evaporator

[0002] Such an evaporator is said to be a "frontal circuitry" type evaporator, as opposed to an evaporator with "U circuitry" in which the refrigerant fluid circulates in U-shaped tubes the two branches of which communicate with respective chambers of a single fluid box. The number of passes is the number of individual journeys made by the refrigerant fluid, along a tube from one fluid box to the other, between the inlet and the outlet of the evaporator. This may be an odd number, if the inlet and the outlet are situated respectively on the two fluid boxes, or an even number, if they are situated on she same fluid box. Depending on the technology used, the fluid boxes may be affixed, that is to say assembled to the tubes, or not affixed, that is to say formed from the same pieces as the tubes.

[0003] The frontal circuitry exhibits the advantage, by comparison with the U-circuitry, of reducing the length of tubes traversed by the refrigerant fluid, for a given number of tubes used at each pass, thus reducing the loss of pressure head and the corresponding heating of the refrigerant fluid, as well as the separation of the liquid and gaseous phases. The thermal exchange with the airflow is therefore enhanced by virtue of a lower and more uniform refrigerant-fluid temperature between the various tubes of a single pass.

[0004] The frontal circuitry also allows economical manufacture of the evaporator, with tubes which are all identical allowing advanced automation of its manufacture.

[0005] The object of the invention is to propose dimensional characteristics which are suitable for optimizing the performance of this type of evaporator, more particularly when the number of passes is 4 or 6.

[0006] The invention especially envisages an evaporator of the type defined in the introduction, and provides for its dimension l in the said direction to lie between 20 and 55 mm and for the distance d to lie between 4.0 and 7.6 mm.

[0007] The proposed dimension in the direction of the airflow ensures a reduced bulk of the evaporator in this direction, and a saving of material. It tends, however, to reduce the surface area for exchange between the two fluids. This tendency is compensated for by the choice of a distance d which is also reduced. The combination of these two dimensional characteristics makes it possible to reconcile the reduction in bulk and the saving in material which are mentioned above with a level of performance comparable to that of the evaporators usually used for air-conditioning the passenger compartment of motor vehicles.

[0008] Optional characteristics of the invention, which are complementary or alternative, are set out below:

[0009] the total thickness of a tube lies between 1.0 and 2.7 mm.

[0010] the wall thickness of a tube lies between 0.2 and 0.45 mm, and between 0.2 and 0.7 mm in the case of the nose of the tube.

[0011] the internal thickness of a tube lies between 0.6 and 1.8 mm.

[0012] the half-period of corrugation of the spacers lies between 1.0 and 1.8 mm.

[0013] the wall thickness of the spacers lies between 0.05 and 0.1 mm.

[0014] the tubes and the fluid boxes are in the form of a stack of pouches each formed from two sheet-metal plates stamped into cup shape, the concavities of which are turned towards one another and which are brazed together so as to be leaktight at their periphery, each pouch defining one of the said tubes and featuring, at each of its ends, an increased thickness so as to define a segment of fluid box.

[0015] the fluid boxes are independent components featuring apertures through which penetrate the ends of the tubes, the latter being brazed so as to be leaktight to the edge of the apertures.

[0016] each tube is formed from two stamped sheet-metal plates which are brazed together for leaktightness along their lateral edges and for stiffening in intermediate regions projecting towards the inside of the tube.

[0017] each tube is formed from two stamped sheet-metal plates which are brazed together so as to be leaktight along their lateral edges, the tube being stiffened by an insert brazed onto the inner faces of the plates.

[0018] the tubes are extruded tubes.

[0019] the tubes are formed from metal sheets which are folded and closed by longitudinal brazed joints.

[0020] at least one fluid box is formed from two elements delimiting an internal volume, one of which features the said apertures, and at least one affixed internal partition separating the said internal volume into different chambers each of which communicates with one subset of the tubes.

[0021] at least one fluid box is formed from a manifold plate featuring the said apertures, and of at least two tank-shaped elements interacting with the manifold plate, each over a part of the extent of the plate, so as to delimit respective chambers each of which communicates with a subset of the tubes.

[0022] at least one fluid box is formed from at least one stamped sheet-metal element defining, on either side of a fold line, a manifold plate featuring the said apertures and a tank which are brought edge to edge by folding and brazed together so as to delimit a chamber of the fluid box.

[0023] The characteristics and advantages of the invention will be set out in more detail in the description below, by referring to the attached drawings.

[0024] FIGS. 1 and 2 are partial sectional views of an evaporator.

[0025] FIGS. 3 to 7 are graphs showing the influence of the dimensional characteristics on the functioning of an evaporator.

[0026] FIGS. 8 to 10 are views in longitudinal section of different embodiments of an evaporator.

[0027] FIG. 11 is a view in perspective of a component intended for the production of an evaporator fluid box.

[0028] FIG. 1 is a partial view in section of the tube bank of an evaporator of the type to which the invention is applied, showing two adjacent flat tubes 1, in transverse section, and the corrugated spacer 2 interposed between them. A few of the dimensions which the invention aims to optimize are indicated here, namely the width l of the tubes, that is to say the dimension of the evaporator in the direction of flow of the airflow, represented by the arrow F1, the distance d between the tubes, fixed by the corrugations of the spacer, the total thickness E_e of a tube, that is to say its bulk in the direction of the stack of the tube bank, the wall thickness e_1 of a tube, and the internal thickness E_i of a tube, equal to $E_e - 2e_1$.

[0029] FIG. 2 is a partial side view of a spacer 2, showing its corrugated profile substantially in sinusoidal shape. The distance d between the two planes P containing the corrugation crests is seen again here. The wall thickness e_2 of the spacer, and its corrugation half-period p/2, are also seen.

[0030] According to the invention, the abovementioned dimensions ideally lie in the intervals as below:

20 mm ≦ l	≦55 mm
4.0 mm ≦ d	≦7.6 mm
1.0 mm ≦ E_e	≦2.7 mm
0.2 mm ≦ e_1	≦0.7 mm
0.6 mm ≦ E_i	≦1.8 mm
1.0 mm ≦ p/2	≦1.8 mm
0.05 mm ≦ e_2	≦0.1 mm.

[0031] FIG. 3 shows the variation in the heat-exchange capacity of an evaporator envisaged by the invention as a function of the distance d, other things being equal, and keeping the air throughput constant. It is seen that the maximum effectiveness under these conditions is reached for a value of 4 mm. However, a reduction in the distance d increases the loss of pressure head of the airflow and consequently reduces the air throughput for a given speed of the blower. This is why the values chosen are at least equal to this apparent optimum, that is to say that they lie between 4.0 and 7.6 mm.

[0032] The wall thickness e_1 is chosen so as to ensure an appropriate resistance to pressure and to corrosion, without excessive consumption of material.

[0033] The graph of FIG. 4 shows the variation in the heat-exchange capacity of an evaporator as a function of the internal thickness e_i of the tubes. When this thickness value is low, this results in a loss of pressure head of the refrigerant fluid and a rise in its temperature impeding the thermal exchange. In contrast, a substantial thickness has the effect of a lower speed of the fluid, limiting the heat exchange with the walls of the tubes. The chosen range provides optimized results.

[0034] The graphs of FIGS. 5 and 6 respectively represent the variation in the thermal-exchange capacity of an evaporator and that of the loss of pressure head which it causes the airflow to undergo, as a function of the half-period p/2 of the spacers, the air throughput being kept constant.

[0035] In FIG. 7, the curve depicted by the symbol o and that depicted by the symbol ▼ represent the variation in the loss of pressure head suffered by the air in an air-conditioning apparatus as a whole, as a function of the throughput, respectively for p/2=1.4 mm and p/2=1.7 mm. The curve depicted by the symbol ■ represents the variation in the back-pressure produced by the blower as a function of the throughput. The intersection of a curve of loss of pressure head and of the curve of back-pressure represents the operating point for the air of the evaporator/blower combination. Thus the air throughput passing through the evaporator is obtained, and the performance delivered by it is deduced therefrom. By repeating the approach for various values of p/2, the optimal value for a given blower is determined. By proceeding thus for various blowers and various air-conditioning boxes, the values proposed according to the invention were arrived at.

[0036] The tubes 1 shown in FIG. 1 are each produced by the brazing-together of two plates 1a and 1b, stamped so as each to form two marginal longitudinal ribs 1c and a multiplicity of intermediate longitudinal ribs 1d. The marginal ribs 1c of one of the plates are brazed to the marginal ribs of the other plate so as to achieve leaktightness of the tube with respect to the outside. Each intermediate rib 1d of a plate is brazed to a rib 1d of the other plate so as to stiffen the tube and to delimit circulation channels 1e for the fluid within the tube. The intermediate ribs 1d can be replaced, wholly or partly, by stiffening projections which do not extend from one end to the other of the tube and which do not delimit circulation channels.

[0037] FIG. 8 represents, in longitudinal section, an embodiment of an evaporator 10 according to the invention, in which the tubes and the two fluid boxes are formed by a multiplicity of pouches 11 which are stacked together from the left to the right of the figure, each consisting of two sheet-metal plates stamped into the shape of cups 12 and 13. The latter are identical to each other and have their concavities turned towards one another, i.e. respectively to the right and to the left. Each cup exhibits a peripheral edge situated in a vertical plane, and the peripheral edges of the two cups forming a pouch are assembled together so as to be leaktight to the fluid by brazing, in order to delimit the internal volume of the pouch. Each cup includes an upper region 14 and a lower region 15 of a greater depth than that of the intermediate region 16. The regions 16 of two associated cups together constitute one tube of the tube bank. The upper regions 14 of the same cups define between them an individual volume 17 forming part of the internal volume of the corresponding pouch and communicating with the upper end of the tube. The set of the regions 14

forms an upper fluid box **18**, each individual volume **17** communicating with at least one adjacent volume **17**, via apertures **19** formed in the bottom of the cups, so as to form one chamber of the fluid box. Likewise, the lower regions **15** of the cups define between them individual volumes **20** communicating with the lower ends of the tubes, and together form a lower fluid box **21** including at least one chamber. The two fluid boxes have to possess at least three chambers in total in order to ensure a circulation of the fluid in at least two passes. In the example illustrated, the inlet **22** and the outlet **23** for the fluid are provided respectively on the lower fluid box and on the upper fluid box, in such a way that the number of passes is an odd number and at least equal to three. The corrugated spacers **2** are brazed to the outer faces of the intermediate regions **16** of the cups **11**, **12**.

[0038] **FIGS. 9 and 10** are views similar to **FIG. 8**, relating to evaporators including tubes **1** produced independently of the fluid boxes, for example by assembling cups similar to the cups **12**, **13** of **FIG. 8**, but not including the regions **14** and **15** of increased depth, or in the form of extruded tubes, or, in a known way, by folding sheet metal and forming longitudinal brazed joints.

[0039] The upper fluid box **31** and the fluid box **32** of the evaporator **30** of **FIG. 9** each comprise a manifold plate **33** featuring a multiplicity of apertures **34** into which penetrate the ends of the tubes **1** and equipped with a peripheral rim **35** turned away from the bank of tubes. The upper manifold plate serves as a cover for a tank-shaped piece **37**, the peripheral edge **38** of which is brazed to the rim **35**, the two pieces delimiting the internal volume of the fluid box. Within this internal volume is found another tank-shaped piece **39** the peripheral edge **40** of which s brazed to the plate **33**. The lower manifold plate **33** serves as a cover common to two tank-shaped pieces **41** and **42** which are mutually juxtaposed in the direction of stacking of the bank of tubes. The peripheral edges **43**, **44** of the tanks **41**, **42** are brazed to one another in their area of mutual contact and, moreover, to the peripheral rim **35** of the plate **33**. The tank **39** separates the internal volume of the fluid box **31** into two chambers **45** and **46** situated respectively inside and outside the tank **39**, and communicating respectively with a central subset of the tubes and with the rest of them. The tanks **41** and **42**, with the manifold plate **33**, respectively delimit two chambers **47** and **48** of the lower fluid box, which communicate respectively with two subsets of the tubes following each other in the direction of stacking of the tube bank. The fluid penetrates into the chamber **45** through an aperture **49** formed in the side walls of the tanks **37** and **39**, and circulates from top to bottom in the central subsets of the tube so as to reach, in part, the chamber **47** and, in part, the chamber **48**. From them, it travels the other tubes from bottom to top and arrives in the chamber **46**, which it leaves through an aperture **50** of the piece **37**. The circulation of the fluid in the evaporator thus takes place in two passes.

[0040] The evaporator **50** of **FIG. 10** possesses a lower fluid box **32** identical to that of **FIG. 9** and which will not be described again. The upper fluid box **51** features a structure similar to that of the box **31**, with a manifold plate **33** identical to those of the boxes **31** and **32**, and three tanks **52**, **53**, **54**, instead of two in the case of the box **32**, which are juxtaposed in the direction of stacking and delimiting respectively with the plate **33** chambers **55**, **56** and **57**. The fluid penetrates into the chamber **55** through an aperture **58**

provided in the tank **52**, and circulates from top to bottom in a first subset of tubes so as to reach the chamber **47** of the lower box. From there, it circulates from bottom to top in a second subset of tubes so as to arrive in the chamber **56**. It leaves the latter by running from top to bottom through a third subset of tubes which lead it into the chamber **48**. It finally runs from bottom to top through a fourth and final subset of tubes so as to pass from the chamber **48** to the chamber **57** after which it leaves the evaporator through an outlet aperture **59** provided in the tank **54**. The circulation takes place here in four passes.

[0041] **FIG. 11** represents a stamped sheet-metal piece **60** intended to be associated with a bank of tubes and of spacers such as those represented in **FIGS. 9 and 10**, by forming at least a part of a fluid box. The piece **60** comprises two regions **61** and **62** situated respectively to right and to left, as seen in the figure, of a horizontal line L, and stamped respectively upwards and downwards with respect to the horizontal plane containing the line L, so as to form, on the one hand, a tank, and, on the other hand, a manifold plate pierced by apertures **63** and equipped with a peripheral rim **64**. By a rotation of 180° about the line L, as indicated by the arrows F2, the plate **62** comes to fit into the tank **61**, the rim **62** coming into contact over its entire perimeter with the peripheral wall **65** of the tank, to which it is brazed so as to be leaktight. The piece thus fashioned may by itself constitute a single-chamber fluid box, or several similar pieces can be juxtaposed so as to form a fluid box with multiple chambers. An inlet or outlet aperture **66**, as the case may be, for the fluid is provided in the peripheral wall **65**.

[0042] Needless to say, in the case in which the internal volume of a fluid box is delimited by two elements such as a manifold plate and a tank-shaped piece, and subdivided into two or more chambers, this separation can be achieved in a known way by virtue of transverse partitions.

[0043] Another means, known in itself, for stiffening the tube consists in inserting into it an insert brazed to the inner faces of the plates, for example a corrugated insert brazed by its corrugation crests.

1. An evaporator for the exchange of heat between an airflow and a refrigerant fluid with the latter passing from the liquid state to the gaseous state, especially for air-conditioning the passenger compartment of a motor vehicle, comprising a tube bank consisting of a single row of flat tubes (**1**) stacked alternately with corrugated spacers (**2**) holding the tubes spaced apart from one another by a distance d and the corrugations of which define passages for the airflow in the direction (**F1**) of the width of the tubes, the two ends of each tube communicating respectively with two fluid boxes (**31**, **32**), affixed or not affixed, situated at opposite ends from one another with respect to the said tube bank, in such a way as to define a journey in at least two passes for the refrigerant fluid in the evaporator, wherein its dimension l in the said direction lies between 20 and 55 mm and wherein the distance d lies between 4.0 and 7.6 mm.

2. The evaporator as claimed in claim 1, wherein the total thickness (E_e) of a tube lies between 1.0 and 2.7 mm.

3. The evaporator as claimed in one of claims **1** and **2**, wherein the wall thickness (e_1) of a tube lies between 0.2 and 0.7 mm.

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4. The evaporator as claimed in one of the preceding claims, wherein the internal thickness (E_2) of a tube lies between 0.6 and 1.8 mm.

5. The evaporator as claimed in one of the preceding claims, wherein the corrugation half-period (p/2) of the spacers lies between 1.0 and 1.8 mm.

6. The evaporator as claimed in one of the preceding claims, wherein the wall thickness (e_2) of the spacers lies between 0.05 and 0.1 mm.

7. The evaporator (**10**) as claimed in one of the preceding claims, wherein the tubes and the fluid boxes (**18, 21**) are in the form of a stack of pouches (**11**) each formed from two sheet-metal plates (**12, 13**) stamped into the shape of cups, the concavities of which are turned towards one another and which are brazed together so as to be leaktight at their periphery, each pouch defining one of the said tubes and featuring, at each of its ends, an increased thickness so as to define a segment of fluid box.

8. The evaporator (**30**) as claimed in one of claims 1 to 6, wherein the fluid boxes are independent components (**31, 32**) featuring apertures (**34**) through which penetrate the ends of the tubes (**1**), the latter being brazed so as to be leaktight to the edge of the apertures.

9. The evaporator as claimed in claim 8, wherein each tube is formed from two stamped sheet-metal plates (**1a, 1b**) which are brazed together for leaktightness along their lateral edges (**1c**) and for stiffening at intermediate regions (**1d**) projecting towards the inside of the tube.

10. The evaporator as claimed in claim 8, wherein each tube is formed from two stamped sheet-metal plates which are brazed together so as to be leaktight along their lateral edges, the tube being stiffened by an insert brazed onto the inner faces of the plates.

11. The evaporator as claimed in claim 8, wherein the tubes are extruded tubes.

12. The evaporator as claimed in claim 8, wherein the tubes are formed from metal sheets which are folded and closed by longitudinal brazed joints.

13. The evaporator (**30**) as claimed in one of claims 8 to 12, wherein at least one fluid box (**31**) is formed from two elements (**33, 37**) delimiting an internal volume (**45, 46**), one of which (**33**) features the said apertures (**34**), and at least one affixed internal partition (**39**) separating the said internal volume into different chambers (**45, 46**) each of which communicates with one subset of the tubes.

14. The evaporator (**30**) as claimed in one of claims 8 to 13, wherein at least one fluid box (**32**) is formed from a manifold plate (**33**) featuring the said apertures (**34**), and of at least two tank-shaped elements (**41, 42**) interacting with the manifold plate, each over a part of the extent of the plate, so as to delimit respective chambers (**47, 48**) each of which communicates with a subset of the tubes.

15. The evaporator as claimed in one of claims 8 to 14, wherein at least one fluid box is formed from at least one stamped sheet-metal element (**60**) defining, on either side of a fold line (L), a manifold plate (**62**) featuring the said apertures (**63**) and a tank (**61**) which are brought edge to edge by folding and brazed together so as to delimit a chamber of the fluid box.

16. The evaporator as claimed in one of the preceding claims, in which the number of passes is chosen between 4 and 6.

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