(19) Europäisches Patentamt
European Patent Office
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(11) **EP 1 809 958 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
03.01.2018 Bulletin 2018/01

(21) Application number: **05817473.1**

(22) Date of filing: **04.11.2005**

(51) Int Cl.:
F25B 39/04 *(2006.01)* ***F25B 39/02*** *(2006.01)*
F28B 1/00 *(2006.01)* ***F28B 9/02*** *(2006.01)*

(86) International application number:
PCT/US2005/040164

(87) International publication number:
WO 2006/055297 (26.05.2006 Gazette 2006/21)

(54) PARALLEL FLOW EVAPORATOR WITH VARIABLE CHANNEL INSERTION DEPTH

PARALLELFLUSSVERDAMPFER MIT VARIABLER KANALEINSATZTIEFE

EVAPORATEUR A EQUICOURANT AVEC PROFONDEUR VARIABLE D'INSERTION DE CANAL

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

(30) Priority: **12.11.2004 US 987960**

(43) Date of publication of application:
25.07.2007 Bulletin 2007/30

(73) Proprietor: **Carrier Corporation**
Syracuse, NY 13221 (US)

(72) Inventors:
- **TARAS, Michael, F.**
  Fayetteville, NY 13066 (US)
- **KIRKWOOD, Allen, C.**
  Danville, IN 46122 (US)
- **CHOPKO, Robert, A.**
  Baldwinsville, NY 13027 (US)

(74) Representative: **Lees, Gregory Alexander et al**
Dehns
St Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

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EP 1 809 958 B1

Printed by Jouve, 75001 PARIS (FR)

Description

Background of the Invention

[0001] This invention relates generally to air conditioning and refrigeration systems and, more particularly, to parallel flow evaporators thereof.

[0002] A definition of a so-called parallel flow heat exchanger is widely used in the air conditioning and refrigeration industry now and designates a heat exchanger with a plurality of parallel passages, among which refrigerant is distributed and flown in the orientation generally substantially perpendicular to the refrigerant flow direction in the inlet and outlet manifolds. This definition is well adapted within the technical community and will be used throughout the text.

[0003] Refrigerant maldistribution in refrigerant system evaporators is a well-known phenomenon. It causes significant evaporator and overall system performance degradation over a wide range of operating conditions. Maldistribution of refrigerant may occur due to differences in flow impedances within evaporator channels, non-uniform airflow distribution over external heat transfer surfaces improper heat exchanger orientation or poor manifold and distribution system design. Maldistribution is particularly pronounced in parallel flow evaporators due to their specific design with respect to refrigerant routing to each refrigerant circuit. Attempts to eliminate or reduce the effects of this phenomenon on the performance of parallel flow evaporators have been made with little or no success. The primary reasons for such failures have generally been related to complexity and inefficiency of the proposed technique or prohibitively high cost of the solution.

[0004] In recent years, parallel flow heat exchangers, and brazed aluminum heat exchangers in particular, have received much attention and interest, not just in the automotive field but also in the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry. The primary reasons for the employment of the parallel flow technology are related to its superior performance, high degree of compactness and enhanced resistance to corrosion. Parallel flow heat exchangers are now utilized in both condenser and evaporator applications for multiple products and system designs and configurations. The evaporator applications, although promising greater benefits and rewards, are more challenging and problematic. Refrigerant maldistribution is one of the primary concerns and obstacles for the implementation of this technology in the evaporator applications.

[0005] As known, refrigerant maldistribution in parallel flow heat exchangers occurs because of unequal pressure drop inside the channels and in the inlet and outlet manifolds, as well as poor manifold and distribution system design. In the manifolds, the difference in length of refrigerant paths, phase separation, gravity and turbulence are the primary factors responsible for maldistribution. Inside the heat exchanger channels, variations in the heat transfer rate, airflow distribution, manufacturing tolerances, and gravity are the dominant factors. Furthermore, the recent trend of the heat exchanger performance enhancement promoted miniaturization of its channels (so-called minichannels and microchannels), which in turn negatively impacted refrigerant distribution. Since it is extremely difficult to control all these factors, many of the previous attempts to manage refrigerant distribution, especially in parallel flow evaporators, have failed.

[0006] In the refrigerant systems utilizing parallel flow heat exchangers, the inlet and outlet manifolds or headers (these terms will be used interchangeably throughout the text) usually have a conventional cylindrical shape. When the two-phase flow enters the header, the vapor phase is usually separated from the liquid phase. Since both phases flow independently, refrigerant maldistribution tends to occur.

[0007] If the two-phase flow enters the inlet manifold at a relatively high velocity, the liquid phase (droplets of liquid) is carried by the momentum of the flow further away from the manifold entrance to the remote portion of the header. Hence, the channels closest to the manifold entrance receive predominantly the vapor phase and the channels remote from the manifold entrance receive mostly the liquid phase. If, on the other hand, the velocity of the two-phase flow entering the manifold is low, there is not enough momentum to carry the liquid phase along the header. As a result, the liquid phase enters the channels closest to the inlet and the vapor phase proceeds to the most remote ones. Also, the liquid and vapor phases in the inlet manifold can be separated by the gravity forces, causing similar maldistribution consequences. In either case, maldistribution phenomenon quickly surfaces and manifests itself in evaporator and overall system performance degradation.

[0008] JP 2001-304775 discloses a single phase parallel flow heat exchanger including an inlet manifold into which channels extend a variable distance. However, the inlet manifold has a constant cross-sectional area, of which a large part is occupied by the channels. This introduces undesirable impedance to the refrigerant flow along the longitudinal axis of the inlet manifold.

Summary of the Invention

[0009] Briefly, in accordance with one aspect of the invention, the insertion depth of the individual parallel channels into the inlet manifold is varied so as to obtain a more uniform refrigerant distribution to the individual channels by way of the differential pressure drop that is created by the variable insertion depth. In this way, a two-phase refrigerant mixture is more uniformly distributed among the channels. The variable insertion depth of the individual channels is accommodated by appropriately enlarging the diameter of the inlet manifold. The enlargement is variable such that the portions immediately surrounding the individual channels are larger and the portions therebetween are smaller.

[0010] In accordance with another aspect of the invention, the insertion depth of the individual channels is progressively smaller toward the downstream end of the inlet manifold such that the hydraulic resistance to flow is progressively lower toward the downstream channels.

[0011] In accordance with yet another aspect of the invention, the insertion depth of the individual channels into the outlet manifold is also varied to compensate for variable flow impedance in the outlet manifold as well.

[0012] Thus the present invention provides the apparatus and method of claims 1 and 5.

[0013] In the drawings as hereinafter described, preferred and alternate embodiments are depicted; however, various other modifications and alternate constructions can be made thereto without departing from the scope of the invention.

Brief Description of the Drawings

[0014]

FIG. 1 is a schematic illustration of a parallel flow heat exchanger in accordance with the prior art.

FIGS. 2 and 3 are schematic illustrations of an example not part of the present invention.

FIGS. 4A, 4B and 4C are schematic illustrations of other examples, of which the embodiment shown in figure 4A is part of the present invention.

FIG. 5 is a schematic illustration of yet another embodiment of the present invention.

Description of the Preferred Embodiment

[0015] Referring now to Fig. 1, a parallel flow heat exchanger is shown to include an inlet header or manifold 11, an outlet header or manifold 12 and a plurality of parallel disposed channels 13 fluidly interconnecting the inlet manifold 11 to the outlet manifold 12. Generally, the inlet and outlet manifolds 11 and 12 are cylindrical in shape, and the channels 13 are usually tubes (or extrusions) of flattened or round shape. Channels 13 normally have a plurality of internal and external heat transfer enhancement elements, such as fins. For instance, external fins, disposed therebetween for the enhancement of the heat exchange process and structural rigidity, are typically furnace-brazed. Channels 13 may have internal heat transfer enhancements and structural elements as well.

[0016] The usual manner of attaching the parallel channels 13 to the inlet manifold 11 and the outlet manifold 12 is to insert the channels 13 so that they extend into the internal cavities of the inlet and outlet manifolds 11 and 12 as shown by the dotted lines. The usual practice is to have equal insertion depth for each of the channels 13. They are then fixed in position by way of brazing or the like.

[0017] In operation, two-phase refrigerant flows into the inlet opening 14 and into the internal cavity 16 of the inlet header 11. From the internal cavity 16, the refrigerant, in the form of a liquid, a vapor or a mixture of liquid and vapor (the most typical scenario) enters the tube openings 17 to pass through the channels 13 to the internal cavity 18 of the outlet header 12. From there, the refrigerant, which is now usually in the form of a vapor, passes out the outlet opening 19 and then to the compressor (not shown).

[0018] As discussed hereinabove, it is desirable that the two-phase refrigerant passing from the inlet header 11 to the individual channels 13 do so in a uniform manner (or in other words, with equal vapor quality) such that the full heat exchange benefit of the individual channels can be obtained and flooding conditions are not created and observed at the compressor suction (this may damage the compressor). However, because of various phenomena as discussed hereinabove, a non-uniform flow of refrigerant to the individual channels 13 (so-called maldistribution) occurs. In order to address this problem, the applicants have introduced design features that will create different pressure drop for flow of refrigerant from the inlet manifold to the individual channels to thereby bring about a more uniform flow of refrigerant into the channels 13. Additionally, increased velocity of the refrigerant flow in the inlet manifold promotes more homogeneous conditions through mixing and jetting effects.

[0019] Referring now to Fig. 2, the present invention is illustrated in accordance with one embodiment. Here, instead of the channels 13 penetrating equally into the internal cavity 16 of the inlet manifold 11, the penetration thereinto is variable, depending on the position along the longitudinal axis A. As shown, the channel 21 closest to the inlet 14 penetrates the furthest into the internal cavity 16 and those following (i.e. channels 22 and 23) are so placed and installed with respect to the inlet manifold 11 so as to have progressively smaller insertion depths as shown.

[0020] In operation, the two-phase refrigerant enters the internal cavity 16 by way of the inlet 14 and, because of the limited distance between the penetrating end 24 of tube 21 and the opposing wall 28 of the inlet manifold 11, there would be increased hydraulic resistance and therefore restricted flow into the channel 21. The next channel 22, with its reduced insertion depth, provides a greater distance between the end 26 and the wall 28. The next downstream channel 23 has its end 27 inserted an even smaller distance into the cavity, and any subsequent channels are progressively decreased in their insertion depth. Therefore, the problem of the more upstream tubes receiving a greater portion of the refrigerant is overcome by selectively varying the impedance to the flow at the entrance into each of the channels. Additionally, increased velocity of the refrigerant flow in the inlet manifold 16 may promote more homogeneous conditions through mixing and jetting effects.

[0021] It has to be noted that if it becomes difficult to control the insertion depth of the individual channels during the manufacturing processes due to a sufficiently

large number of channels, then the insertion depth can be controlled in sections with each section having equal insertion depth and with the insertion depth varying from section to section and decreasing in the downstream direction along the inlet manifold. In such case, each individual channel shown in Fig. 2 would represent a section of such channels for a sufficiently large heat exchanger.

[0022] The Fig. 2 illustration is presented in exaggerated form for demonstrative purposes. Therefore, in order to understand the magnitudes of the insertion depth for a typical design, exemplary measurements will be provided. Considering an inlet manifold 11 having a typical diameter D of 1", the insertion depth Li of the first tube 21 would preferably be in the range of 7/8". The next channel 22 would have an insertion depth Of(Li-L2) or (7/8"- 1/16"), and each succeeding tube would have a diminishing insertion depth by L2 1/16". It has to be understood the insertion depth Li of the individual channels depends on many parameters, including the heat exchanger size, channel size and number, typical operating range, refrigerant and oil type circulating through the system, etc.

[0023] As is seen in Fig. 3, because of increased insertion depths as compared with the prior art, the relatively wide channels 21, 22 and 23, which occupy a large part of the cross-section area of the inlet manifold 11, may each introduce undesired impedance to the refrigerant flow along the longitudinal axis of the inlet manifold 11. In this example, not part of the present invention, this may be accommodated by an increase in the diameter D of the inlet manifold 11.

[0024] Rather than increasing the diameter D of the inlet manifold 11 along its entire longitudinal axis, in the present invention, as shown in Fig. 4A, the cross-section area of a header 31 is enlarged only in the immediate vicinity of the insertion points of the channels 21, 22 and 23 into the header 31. In this way, the restriction to the refrigerant flow around the ends of the channels is avoided or limited so as to promote favorable uniform conditions to the refrigerant flow into the channels, as desired. Although the form and shape of the enlargements may vary, the wavy shape tends to provide a smoother, less disturbed motion of the refrigerant passing along the inlet header and would be preferred.

[0025] As shown in Fig. 4B and 4C, in examples not part of the present invention, an inlet manifold can be made of an oval or rectangular shape as shown by 37 and 38 respectively, without appreciably increasing its overall cross-section area. This will prevent refrigerant flow velocity reduction and potential undesired phase separation.

[0026] Furthermore, as shown in Fig. 5, a similar technique can be applied to the outlet manifold 41, with the downstream channels having higher insertion depths. Although the outlet manifold (typically having a single phase refrigerant vapor) has a less pronounced influence on the refrigerant distribution among the channels, such balancing of the flow impedances will further assist in the maldistribution problem resolution.

[0027] Furthermore, it should be noted that both vertical and horizontal channel orientations will take advantage from the teaching of the present invention, although higher benefits will be obtained for the latter configuration. Also, although the teachings of this invention are particularly advantageous for the evaporator applications, refrigerant system condensers may benefit from them as well.

[0028] While the present invention has been particularly shown and described with reference to preferred and alternate embodiments as illustrated in the drawings, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the scope of the invention as defined by the claims.

Claims

1. A parallel flow heat exchanger comprising:

   an inlet manifold (11) having an inlet opening for conducting flow of a two-phase fluid into said inlet manifold and a plurality of outlet openings for conducting the flow of fluid from said inlet manifold;
   a plurality of channels (13) aligned in a substantially parallel relationship and fluidly connected to said plurality of outlet openings for conducting the flow of fluid from said inlet manifold;
   an outlet manifold (12) fluidly connected to said plurality of channels for receiving the flow of fluid therefrom,
   wherein said plurality of channels extend into said inlet manifold at varying depths and are substantially flat in planes transverse to the longitudinal axis of the inlet manifold, **characterised in that** the cross-section areas of said inlet manifold are locally enlarged in the vicinities of those areas surrounding said flat channels to allow for the flow of fluid around said plurality of channels.

2. A parallel flow heat exchanger as set forth in claim 1, wherein the depths of extension into said inlet manifold for said plurality of channels decrease toward the downstream end of the inlet manifold.

3. A parallel flow heat exchanger as set forth in claim 2, wherein said parallel channels are divided into sections with each section having equal extension depths and the depths of extension into said inlet manifold decreasing from section to section toward the downstream end of the inlet manifold.

4. A parallel flow heat exchanger as set forth in any preceding claim, wherein said plurality of channels

extend into said outlet manifold at varying depths.

5. A method of operating a parallel flow heat exchanger comprising:

providing an inlet manifold (11) having an inlet opening and a plurality of outlet openings;
providing a plurality of channels (13) aligned in a substantially parallel relationship, fluidly connected to said plurality of outlet openings, and extended into said inlet manifold at varying depths; wherein said plurality of channels are substantially flat in places transverse to the longitudinal axis of the inlet manifold and
providing an outlet manifold (12) fluidly connected to said plurality of channels;
conducting a flow of a two phase fluid into the inlet manifold through the inlet opening;
wherein a pressure drop is varied at each of said plurality of channels extended into said inlet manifold at varying depths, and wherein the channels extended into said inlet manifold at varying depths mix and jet the two phase fluid to facilitate homogeneous conditions, **characterised by** providing cross-section areas of said inlet manifold which are locally enlarged in the vicinities of those areas surrounding said flat channels to allow for the flow of fluid around said plurality of channels.

6. The method of claim 5, wherein the depths of extension into said inlet manifold for said plurality of channels decrease toward the downstream end of the inlet manifold.

7. The method of claim 5, wherein said parallel channels are divided into sections with each section having equal extension depths and the depths of extension into said inlet manifold decreasing from section to section toward the downstream end of the inlet manifold.

Patentansprüche

1. Parallelflusswärmetauscher, umfassend:

ein Ansaugrohr (11) mit einer Einlassöffnung zum Leiten eines Flusses eines Zwei-Phasen-Fluids in das Ansaugrohr und eine Vielzahl von Auslassöffnungen zum Leiten des Fluidflusses aus dem Ansaugrohr;
eine Vielzahl von Kanälen (13), die in einer im Wesentlichen parallelen Beziehung aneinandergereiht und mit der Vielzahl von Auslassöffnungen flussverbunden sind, um den Fluidfluss aus dem Ansaugrohr zu leiten;
ein Auslassrohr (12), das mit der Vielzahl von Kanälen flussverbunden ist, um den Fluidfluss aus diesem zu empfangen, wobei sich die Vielzahl von Kanälen in verschiedenen Tiefen in das Ansaugrohr erstreckt und in Ebenen quer zu der Längsachse des Ansaugrohrs im Wesentlichen flach sind, **dadurch gekennzeichnet, dass** die Querschnittsflächen des Ansaugrohrs in der Umgebung der Bereiche, die die flachen Kanäle umgeben, örtlich vergrößert sind, um den Fluidfluss um die Vielzahl von Kanälen herum zu erlauben.

2. Parallelflusswärmetauscher nach Anspruch 1, wobei sich die Erstreckungstiefen in das Ansaugrohr der Vielzahl von Kanälen in Richtung des nachgelagerten Endes des Ansaugrohrs verringern.

3. Parallelflusswärmetauscher nach Anspruch 2, wobei die parallelen Kanäle in Abschnitte unterteilt sind, wobei jeder Abschnitt gleiche Erstreckungstiefen aufweist und sich die Erstreckungstiefen in das Ansaugrohr von Abschnitt zu Abschnitt in Richtung des nachgelagerten Endes des Ansaugrohrs verringern.

4. Parallelflusswärmetauscher nach einem der vorherigen Ansprüche, wobei sich die Vielzahl von Kanälen in verschiedenen Tiefen in das Auslassrohr erstrecken.

5. Verfahren zur Bedienung eines Parallelflusswärmetauschers, umfassend:

Bereitstellen eines Ansaugrohrs (11) mit einer Einlassöffnung und einer Vielzahl von Auslassöffnungen;
Bereitstellen einer Vielzahl von Kanälen (13), die in einer im Wesentlichen parallelen Beziehung aneinandergereiht sind, mit der Vielzahl von Auslassöffnungen flussverbunden sind und sich in verschiedenen Tiefen in das Ansaugrohr erstrecken;
wobei die Vielzahl von Kanälen an Stellen quer zu der Längsachse des Ansaugrohrs im Wesentlichen flach sind, und
Bereitstellen eines Auslassrohrs (12), das mit der Vielzahl von Kanälen flussverbunden ist;
Leiten eines Flusses von Zwei-Phasen-Fluid in das Ansaugrohr durch die Einlassöffnung;
wobei ein Druckabfall an jedem der Vielzahl von Kanälen, die sich in verschiedenen Tiefen in das Ansaugrohr erstrecken, variiert wird, und wobei die sich in verschiedenen Tiefen in das Ansaugrohr erstreckenden Kanäle das Zwei-Phasen-Fluid mischen und ausstoßen, um homogene Bedingungen zu fördern, **gekennzeichnet durch** Bereitstellen von Querschnittsflächen des Ansaugrohrs, die in der Umgebung der Bereiche, die die flachen Kanäle umgeben, örtlich

vergrößert sind, um den Fluidfluss um die Vielzahl von Kanälen herum zu erlauben.

6. Verfahren nach Anspruch 5, wobei sich die Erstreckungstiefen in das Einlassrohr für die Vielzahl von Kanälen in Richtung des nachgelagerten Endes des Ansaugrohrs verringern.

7. Verfahren nach Anspruch 5, wobei die parallelen Kanäle in Abschnitte unterteilt sind, wobei jeder Abschnitt gleiche Erstreckungstiefen aufweist und sich die Erstreckungstiefen in das Ansaugrohr von Abschnitt zu Abschnitt in Richtung des nachgelagerten Endes des Ansaugrohrs verringern.

Revendications

1. Échangeur thermique à équicourant comprenant :

un collecteur d'admission (11) ayant une ouverture d'admission permettant de conduire un courant d'un fluide diphasique dans ledit collecteur d'admission et une pluralité d'ouvertures de sortie permettant de conduire le courant de fluide en provenance dudit collecteur d'admission ;
une pluralité de canaux (13) alignés dans une relation sensiblement parallèle et reliés de manière fluidique à ladite pluralité d'ouvertures de sortie permettant de conduire le courant de fluide en provenance dudit collecteur d'admission ;
un collecteur de sortie (12) relié de manière fluidique à ladite pluralité de canaux permettant de recevoir le courant de fluide en provenance de ceux-ci,
dans lequel ladite pluralité de canaux s'étendent dans ledit collecteur d'admission à des profondeurs variables et sont sensiblement plats dans des plans perpendiculaires à l'axe longitudinal du collecteur d'admission,
caractérisé en ce que les sections transversales dudit collecteur d'admission sont élargies localement à proximité de ces sections entourant lesdits canaux plats pour permettre l'écoulement du fluide autour de ladite pluralité de canaux.

2. Échangeur thermique à équicourant selon la revendication 1, dans lequel les profondeurs d'extension dans ledit collecteur d'admission pour ladite pluralité de canaux diminuent vers l'extrémité en aval du collecteur d'admission.

3. Échangeur thermique à équicourant selon la revendication 2, dans lequel lesdits canaux parallèles sont divisés en sections, chaque section ayant des profondeurs d'extension égales et les profondeurs d'extension dans ledit collecteur d'admission diminuant d'une section à une autre section en direction de l'extrémité en aval du collecteur d'admission.

4. Échangeur thermique à équicourant selon une quelconque revendication précédente, dans lequel ladite pluralité de canaux s'étendent dans ledit collecteur de sortie à des profondeurs variables.

5. Procédé de mise en oeuvre d'un échangeur thermique à équicourant consistant à :

utiliser un collecteur d'admission (11) ayant une ouverture d'admission et une pluralité d'ouvertures de sortie ;
utiliser une pluralité de canaux (13) alignés dans une relation sensiblement parallèle, reliés de manière fluidique à ladite pluralité d'ouvertures de sortie, et s'étendant dans ledit collecteur d'admission à des profondeurs variables ;
dans lequel ladite pluralité de canaux sont sensiblement plats dans des plans perpendiculaires à l'axe longitudinal du collecteur d'admission
et
utiliser un collecteur de sortie (12) relié de manière fluidique à ladite pluralité de canaux ;
conduire un courant d'un fluide diphasique dans le collecteur d'admission à travers l'ouverture d'admission ;
dans lequel une chute de pression varie pour chaque canal de ladite pluralité de canaux qui s'étendent dans ledit collecteur d'admission à des profondeurs variables, et dans lequel les canaux qui s'étendent dans ledit collecteur d'admission à des profondeurs variables mélangent et éjectent le fluide diphasique pour faciliter des conditions homogènes, **caractérisée par** l'utilisation de sections transversales dudit collecteur d'admission qui sont élargies localement à proximité de ces sections entourant lesdits canaux plats pour permettre l'écoulement du fluide autour de ladite pluralité de canaux.

6. Procédé selon la revendication 5, dans lequel les profondeurs d'extension dans ledit collecteur d'admission pour ladite pluralité de canaux diminuent vers l'extrémité en aval du collecteur d'admission.

7. Procédé selon la revendication 5, dans lequel lesdits canaux parallèles sont divisés en sections, chaque section ayant des profondeurs d'extension égales et les profondeurs d'extension dans ledit collecteur d'admission diminuant d'une section à une autre section en direction de l'extrémité en aval du collecteur d'admission.

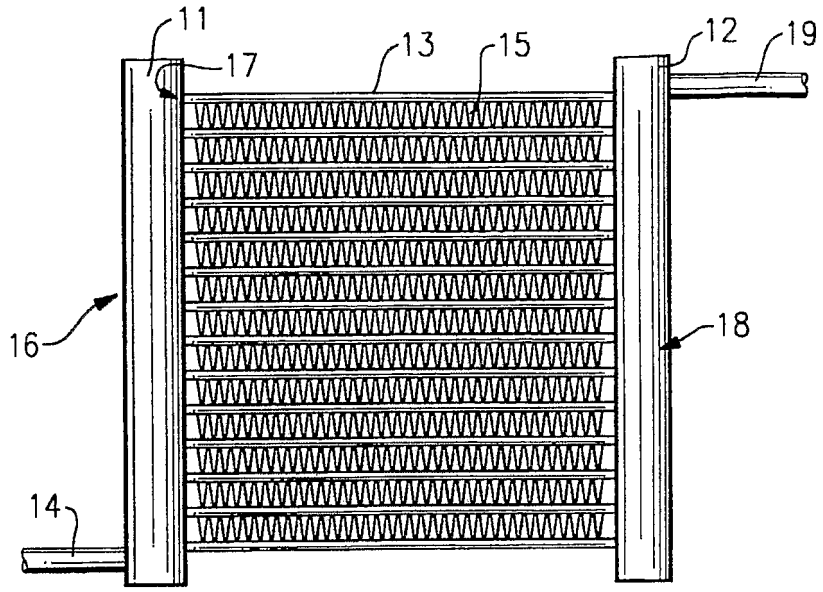


FIG.1
Prior Art

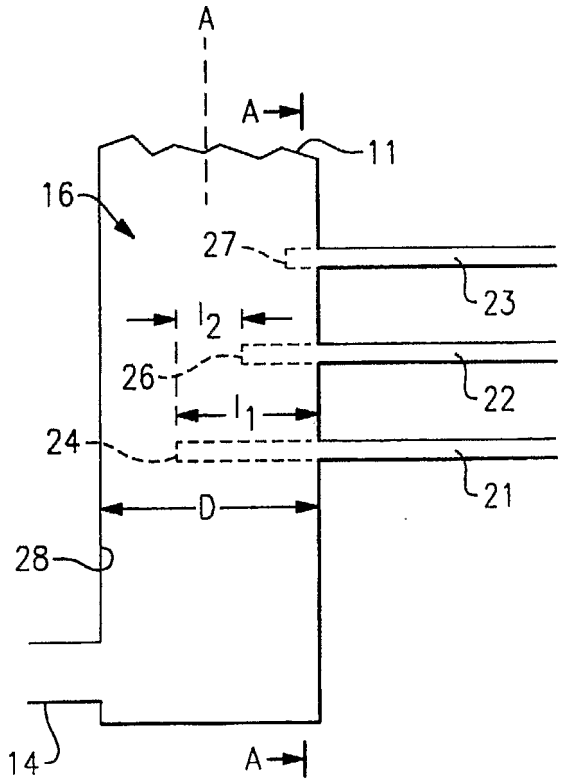


FIG.2

FIG.3

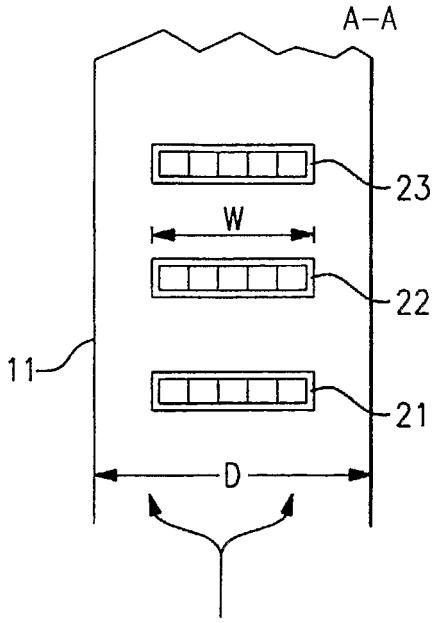
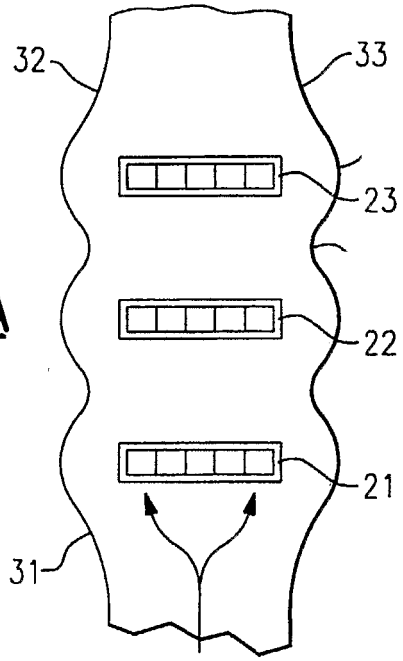


FIG.4A



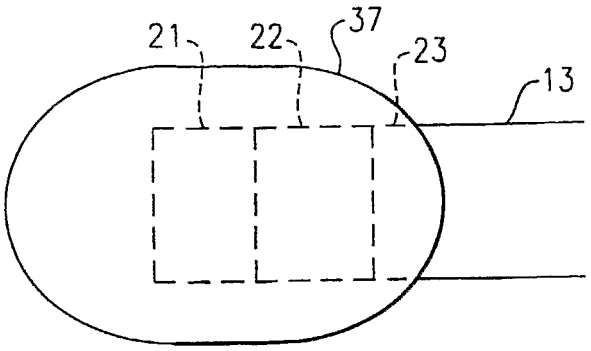


FIG.4B

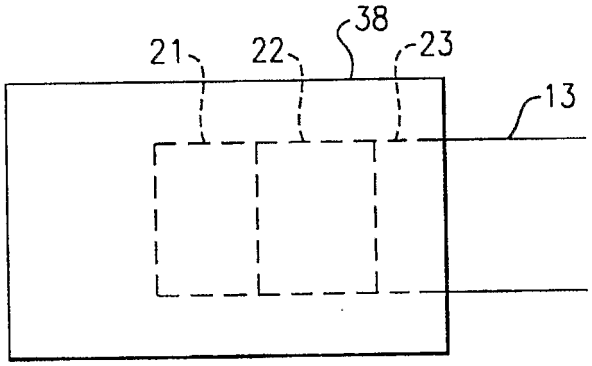


FIG.4C

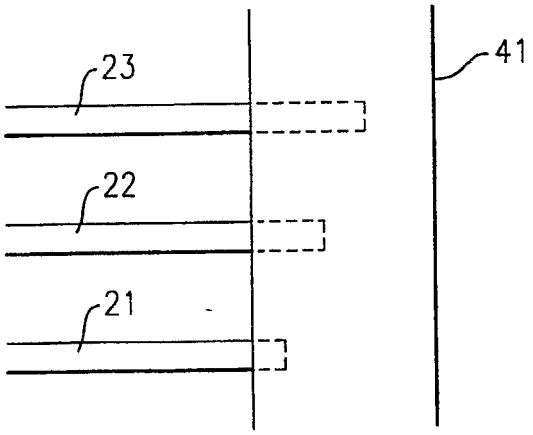


FIG.5

REFERENCES CITED IN THE DESCRIPTION

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