June 17, 1969 F. J. WARRELL 3,450,199

HEAT EXCHANGER

Filed July 10, 1967 Sheet 1 of 2

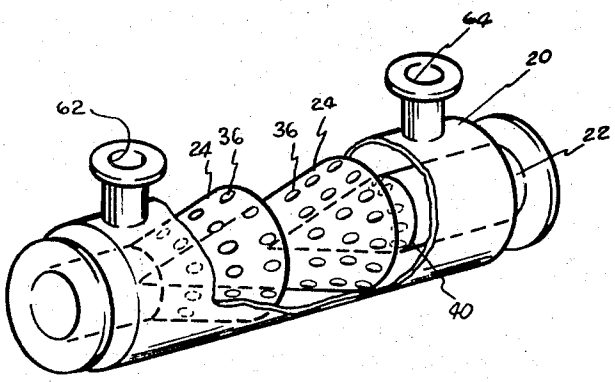


FIG. 1

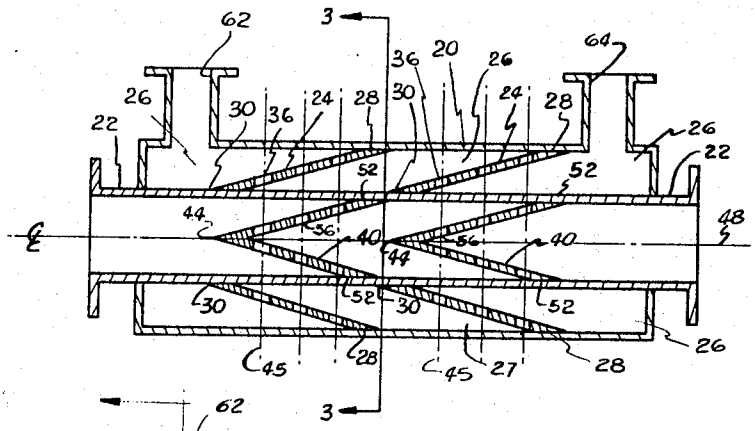


FIG. 2

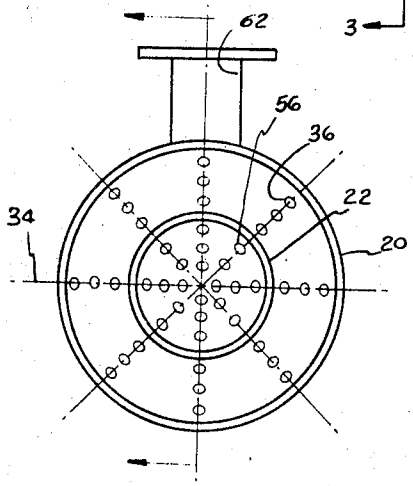


FIG. 3

INVENTOR
FRED J. WARRELL
BY
Hauke Kraus & Gifford
ATTORNEYS

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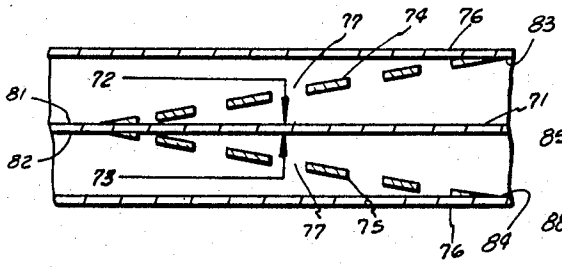


FIG. 4

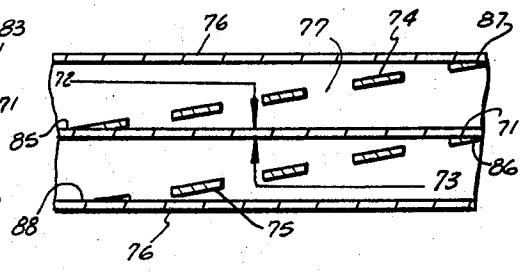


FIG. 5

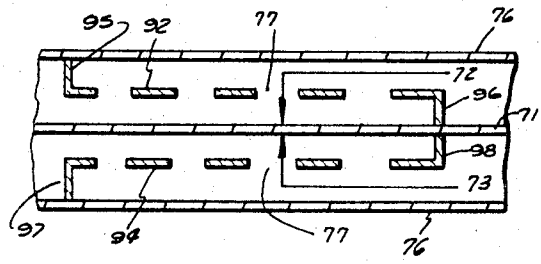


FIG. 6

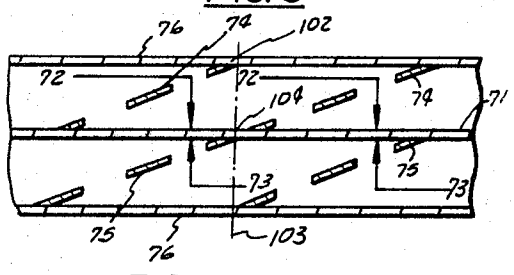


FIG. 7

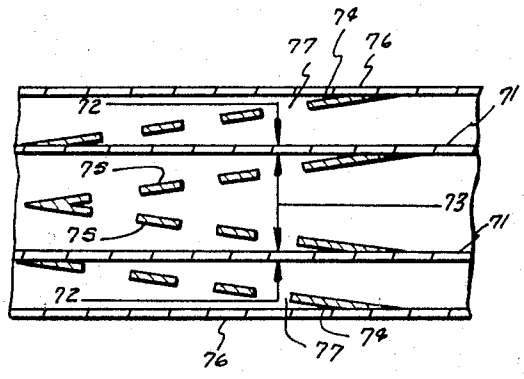


FIG. 8

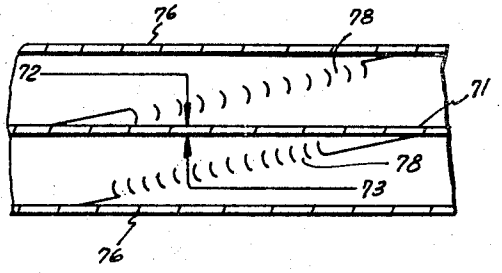


FIG. 9

INVENTOR
FRED J. WARRELL
BY
Hawke Kruss & Gifford
ATTORNEYS

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HEAT EXCHANGER

Fred J. Warrell, Mount Clemens, Mich., assignor to Continental Aviation & Engineering Corporation, Detroit, Mich., a corporation of Virginia

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Int. Cl. F28d 7/10; F28f 9/22, 13/00
U.S. Cl. 165—159 12 Claims

ABSTRACT OF THE DISCLOSURE

A heat exchange structure which prevents the formation of boundary layers of fluid along the exchange wall while attaining a transverse flow of fluid jets to impinge directly on the exchange walll.

BACKGROUND OF THE INVENTION

Field of the invention

The present inventon relates to heat exchangers and more particularly to jet impingement heat exchangers having a high rate of heat transfer through a surface or exchange wall in which the heat of a fluid is to be transmitted therethrough to a second fluid having a lower temperature.

Description of the prior art

In the employment of heat exchangers there is a tendency for an insulating boundary layer of fluid to form adjacent the exchange wall which moves at a reduced speed and can produce a stagnant condition along the wall. Various methods have been tried to disperse the fluid in the boundary areas to obtain a more turbulent flow and thus improve the efficiency of the heat exchanger. One such means is disclosed in U.S. Patent No. 3,034,769 wherein separate ducts are utilized for directing fluid in jet streams against the exchange wall to obtain a more turbulent flow. Still another method, as disclosed in U.S. Patent No. 2,659,392, has a series of secondary walls dispersed throughout the fluid flow to increase the efficiency of the heat exchanger. These and other methods, while achieving a certain amount of success, have proved costly to construct. Another drawback in the previous attempts to solve the problem have been a loss in the overall pressure of the system such that additional energy has to be supplied to the system. Other disadvantages of the prior art structure such as excess number of parts and high manufacturing costs will become apparent in the description of the present invention.

SUMMARY

According to the present invention, these difficulties are greatly reduced by means of applicant's simplified structure which lowers fabrication costs while attaining an efficient hydraulic flow for maximum dispersion of the fluid with a minimum of pressure loss. Applicant has conceived a heat exchanger structure for preventing the formation of an insulating layer on the heat exchange wall which utilizes orifice plates that initially direct the fluid in small jet streams to the heat exchange surface. The orifice plates are positioned such that the leading portion, with respect to the flow of the fluid, is secured to the heat exchange wall and the trailing portion is secured to the outer boundary of the passages provided on each side of the wall. By means of each small jet stream the fluid flow in each passage is controlled so that the fluid flowing adjacent to the heat exchange wall is prevented from continuing in a straight path along the heat exchange wall. This prevents the formation of a boundary layer along the heat exchange wall and also causes a pressure differential which assists in directing the fluid through the orifices to form jet streams that impinge on the heat exchange wall.

It is therefore an object of this invention to provide a heat exchanger matrix having a high heat transfer efficiency with low pressure loss characteristics.

It is a further object of the invention to provide a heat exchanger which is structurally strong and which has a high heat transfer efficiency and low pressure loss characteristics.

It is still another object of the present invention to provide a heat exchanger which will enable the device to be constructed from plates of like configuration so that the costs of producing the plates are reduced and for which a given heat transfer capacity will require less plate material then heretofore, thus further reducing the cost and also reducing the weight of the heat exchanger.

The exact nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawings and in which:

FIG. 1 is a perspective view of a preferred construction of a heat exchanger;

FIG. 2 is a longitudinal vertical section of the heat exchanger of FIG. 1;

FIG. 3 is a sectional view taken on line 3—3 of FIG. 2;

FIGS. 4–9 are all longitudinal sectional views of modified constructions for carrying out the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1, which illustrates a preferred embodiment, an opposed flow heat exchanger which comprises an outer tube **20** and concentric internal tube **22**. Surrounding the internal tube **22** and within the outer tube **20** are positioned a plurality of funnel shaped members **24**, for dividing the space between the tubes into a plurality of cells or chambers **26**. The large diameter end of the funnel members **24** are welded or otherwise fixedly secured in a fluid tight manner around its periphery indicated at **28**. The smaller diameter ends of the funnel member are in turn secured to the internal tube **22** around its inner periphery indicated at point **30**.

Each funnel member **24** is provided with a plurality of orifices **36**. Although the orifices **36** in the embodiment of FIG. 1 are shown as round holes and arrayed with their centers along trace lines **34** parallel with the principle axis of the tubes, it will be understood that the orifices could have various configurations such as slots, regular polygons, or irregular polygons and could be arrayed in another manner such as being in staggered relationship, for example.

Positioned within the tube **22** are a plurality of cone shaped members **40** with their apices **44** on the center line **48** and with their base portions fixedly attached to the inner wall of tube **22** by suitable means such as soldering or welding at point **52**. In the same manner as funnel members **24** the cone members **40** are provided with a plurality of orifices **56** which are of the same size and shape as the orifices **26** and arrayed wherein corresponding orifices in the plate members **24** and **40** are located in opposed relation. It will be further noted that the circumferential points **28** and **52** are located substantially in a common vertical plane, as are the apices **44** and the plane of the circumferential points **30**.

In the construction shown in FIG. 2 the outer tube **20** is provided with an inlet **62** and an outlet **64** which in the present embodiment are used to supply cold fluid to the

heat exchanger. The hot fluid enters at the right hand end of tube **22** and leaves through the left hand end of the tube so as to flow in opposed relation to the flow of cold fluid. Thus, as seen in FIG. 2, the fluid to be heated enters the inlet **62** and after flowing through the space defined between the tube **20** and tube **22** leaves through outlet **64**.

From the various disclosures of the different heat exchanger arrangements in the drawings illustrated in FIGS. 4–9, it is obvious that numerous modified constructions of the orifice plates may be presented for carrying out the objects of the present invention and a considerable number thereof have been illustrated. Any one of the diagramatic arrangements shown in FIGS. 4–9 may be used in the heat exchanger structure of the general type shown in FIG. 1. As only one type of heat exchanger has been illustrated in detail the invention will be first explained as it relates directly to the various basic orifice plate arrangements and modifications. In this way the operation of the heat exchanger structure of FIG. 1, when described subsequently, will be understood to function in accordance with the basic principles of the invention shown in FIGS. 4–9. In the various units illustrated in the figures the numeral **71** represents the heat transfer surface or exchange wall separating fluids **72** and **73** while the cooperating pair of deflecting plates are indicated at **74** and **75**, and the outer boundary walls at **76**. Orifice **77** are provided in plates **74** and **75** for directing the fluid flow in a manner to be explained.

The overall relative flow direction may be parallel flow, as illustrated in FIGS. 4 and 6 or opposed flow as shown in FIGS. 5 and 7. The orifice plates **74** and **75** may be at any independent angle or arranged with the orifice plates parallel to the heat transfer surface **71** as shown in the modification of FIG. 6.

As shown at FIG. 7 any number of the units may be arranged in series so that each unit carries the total fluid flow. FIG. 8 shows that any number of the basic units may further be arranged in parallel so that each unit carries a portion of the total fluid flow. It will be noted in FIG. 8 that the units are arranged in opposed flow pattern as also shown in FIG. 2. FIG. 9 shows an alternative form in which turning vanes **78** are employed to accomplish the function of the orifices **77** in plates **74** and **75**.

While applicant discloses that exchange of fluid by jet streams of opposed temperatures at coaxial points on the heat exchange plate by orifices of substantially equal sizes it should be understood that a still satisfactory heat exchange of fluids can be arrived at by non-coaxial opposed fluid streams hitting at a substantially normal angle with the heat exchange plate and by a distribution of hole sizes in the overall spacing. Such a variation of hole sizes and spacing are, of course, arranged in a predetermined design providing an interdependent relationship.

In the parallel flow arrangement of FIG. 4 the cold fluid, represented at **72**, is diverted by plate **74**. In like manner the plate **74** diverts the flow of the hot fluid **73** to form a plurality of small fluid jets, indicated by the opposed arrows in the figure. In this manner, pairs of jets are directed toward the exchange wall **71** in opposed relation to impinge directly thereon and to produce maximum heat exchange between the fluids.

The heat exchange is optimum due to the prevention of stagnant boundary layers along the portion of the exchange wall coextensive with the plates by the diversion effect of the plates. This, together with the transverse movement of the fluid from the central core of both the hot and cold fluid flow, having the maximum temperature of each of the fluids, produces a highly efficient heat exchange at the wall **71**. It will be seen in FIG. 4, that the plates **74** and **75** are positioned at equal acute angles to the direction of fluid flow. While in the particular embodiment disclosed the walls **74** and **75** are located at substantially 10 degrees with the exchange wall **71** it is to be understood that the plates could be positioned at various acute angles. Applicant has found that orifice plates **74** and **75** positioned at acute angles within the range of 10 degrees to 20 degrees to the exchange wall **71** have proved most satisfactory in attaining the optimum exchange between the fluids while producing a minimum of pressure drop through the system.

The arrangement shown in FIG. 5 is similar to FIG. 4 except in this embodiment the fluids are in opposed relation rather than parallel. It will be noted that in this figure the plates **74** and **75** are located so as to be in substantially parallel relation to each other while being coextensive in relation to the exchange wall. This form of the invention operates so that the cold fluid **72** is diverted by the plate **74** at the point indicated at **85** while the plate **75** diverts the flow of the hot fluid **73** at the point **86**. It will be noted that the trailing edge portions of the plates **74** and **75** are joined to the boundary walls **76** at points **87** and **88** respectively. Thus, in this form of the invention the corresponding leading and trailing edges of the plates are located in common plane extending transverse to the plane of the exchange wall **71**.

The operation of the form of the invention shown in FIG. 5 is identical to that as described for the FIG. 4. It is evident therefore that by merely reversing one plate member, end for end, the heat exchanger of applicant's present invention could be fabricated to accommodate either parallel flow or cross flow with a minimum of fabrication of parts.

In the form of the invention shown in FIG. 6, applicant shows a structure for obtaining heat exchange between parallel flows of fluids by means of orifice plates **92** and **94** which have a double L-shape in cross section. In this form of the invention the orifice plates are positioned parallel to the heat transfer surface or exchange wall **71** and are secured to the outer boundary walls **76** by means of substantially right angle flange members **95**, **96**, **97** and **98**. In this modification the flanges at the leading edge of the orifice plates, **96** and **98**, function to divert the fluid away from the exchange wall to break up the formation of boundary layers at a transverse common plane along the exchange wall. Here again orifices **77** are arranged in the plates **92** and **94** so as to be in opposed relations so that the fluid jets formed by the fluid flow will impinge directly on the exchange wall **71** to obtain the maximum heat exchange. It will be seen in this form of the invention that an increased turbulent flow will be created which will produce a greater heat exchange effect while on the other hand the pressure loss will be greater than that disclosed in the form of the invention shown in FIGS. 4 and 5.

As explained above the arrangement of the heat exchange structure shown in FIG. 7 utilizes the basic concept of the opposed flow arrangement shown in FIG. 5 and demonstrates, by means of applicant's unique arrangement of parts, a plurality of the units of FIG. 5 can be stacked to provide a series type heat exchanger.

In reference to the series arrangement shown in FIG. 7 it should be noted that the trailing edge portion of plate **74**, indicated at **102**, is arranged to lie in the transverse plane of trace line **103** so as to include the leading edge **104** of the plate which is the next most plate downstream in the fluid flow **72**. In this manner applicant has devised a symmetrical heat exchanger which provides for a maximum interchange while forming a rigid structure when constructed as shown in FIG. 1.

FIG. 8 shows the basic unit described in FIG. 5 employed in an opposed flow form of the invention wherein the individual units are stacked in a parallel relationship. As this form of the invention is similar to the embodiment shown in FIG. 1 the description of its operation will follow below.

While for most applications the use of orifice plates has proved satisfactory other means for inhibiting the formation of boundary layers and for attaining a transverse flow of the fluid are considered within the scope of the invention. FIG. 9 thus discloses an embodiment

wherein turning vanes are used to accomplish the functions of the orifices **77**. While this embodiment is, of course, more costly to construct its use in a plate type exchange structure is considered advantageous to reduce the pressure drop through the system.

Turning now to the operation of the exchange structure of FIGS. 1–3 it can be seen that applicant has provided an opposed flow unit wherein the orifice plates **24** and **40** are in a series arrangement. It can be seen that by using a concentric tube structure applicant has formed the orifice plates **24** in identical funnel shaped or frustocone type members which allow the tubes **20** and **22** to be easily and quickly positioned in concentric relationship for ease of fabrication. Also, by positioning the large end **28** of one member **24** substantially in the transverse plane of the small end **30** of the subsequent member **24**, the plane defined by section line **3—3**, the resultant sandwich core type arrangement produces a structure that has a high strength to weight ratio both under axial and bending stresses.

It will be seen that the orifices **36** and **56** of the orifice plates are aligned on trace lines **45** to attain applicant's opposed direct jet impingement on the exchange wall **22**. The orifices of applicant's structure could, of course, be substantially the same size or progressively increasing in size without departing from the principle of the invention. Further, in this structure the acute angle formed by the orifice plate members with respect to principal counter-line **48** is approximately **15** degrees, which provides a heat exchanger having properties of efficient heat exchange with a minimum of pressure loss while achieving a rigid unitary structure.

It is also evident that a further modification of the invention could be attained by rotating one plate member substantially 90 degrees with respect to the opposite plate member in a skewed relationship so that the heat exchanger could be fabricated to accommodate overall cross-flow.

It should be understood, of course, that the foregoing disclosure relates to only preferred embodiments of the invention and that numerous modifications or alterations may be made therein without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A heat exchange structure comprising:

(a) a heat exchange wall member spaced between boundary members providing fluid passages on either side thereof,

(b) diverting means disposed on either side of said wall means in opposed paired relation so as to be coextensive in the direction of fluid flow,

(c) each said diverting means positioned with respect to the direction of fluid flow in its associated passage wherein the fluid is directed away from said exchange wall, and

(d) each diverting means of said pair having a plurality of orifice means therein arranged so that fluid jets created thereby impinge directly on said exchange wall.

2. The structure as defined in claim **1**, wherein:

(a) said diverting means are orifice plates inclined toward the direction of fluid flow to form acute angles with said wall means, and

(b) said orifice means comprise a plurality of holes in said plates wherein each hole in one plate is in axial alignment with a corresponding hole in said opposed plate.

3. The structure as defined in claim **2**, wherein said acute angles are equal and have a value in the range of 10 degrees to 20 degrees.

4. The structure as defined in claim **1**, wherein:

(a) each of said diverting means are plates having a double L cross section whose central portions are positioned parallel to the exchange wall member, and

(b) the orifice means are holes in said central portions.

5. The structure as defined in claim **2**, wherein the fluid flow in said passages is in parallel relation so that said pair of orifice plates form equal acute angles with said exchange wall member.

6. The structure as defined in claim **2**, wherein the fluid flow in said passages is in opposed relation and said orifice plates are arranged in parallel relation so that the leading and trailing edges thereof form equal acute angles with said exchange wall member.

7. The structure as defined in claim **1**, wherein said diverting means are plate members having turning vanes that direct the fluid in said passages to impinge substantantially normal to said exchange wall.

8. A heat exchange structure comprising, in combination:

(a) coaxially-disposed outer and inner tubes,

(b) said inner tube providing a heat-transfer partition adapted to contain a first flowing stream of fluid and to have a second flowing stream of fluid at a different temperature contained between said outer and inner tubes,

(c) said heat exchanger further comprising a first fluid diverting means disposed between said outer tube and said inner tube, and a second fluid diverting means disposed within said inner tube,

(d) said first and second fluid diverting means arranged in opposed paired relation so as to be coextensive in the direction of fluid flow, and

(e) each diverting means of said pair having a plurality of orifices arranged therein such that each orifice in said first diverting means is in alignment with a corresponding orifice in said second diverting means wherein fluid jets created thereby impinge directly on either side of said inner tube.

9. The structure as defined in claim **8**, wherein:

(a) said first diverting means is a funnel-shaped orifice plate having its small diameter end positioned around said inner tube and its large diameter end encircled by said outer tube, and

(b) said second diverting means is a cone-shaped orifice plate having its apex positioned in the plane of said funnel-shaped orifice plate small diameter end and its base positioned in the plane of said funnel-shaped orifice plate large diameter end.

10. The structure as defined in claim **9** wherein said funnel-shaped orifice plate and said cone-shaped orifice plate are concentrically positioned wherein they form equal angles with said inner tube.

11. The structure as defined in claim **10** wherein the angle formed is of the order of ten degrees to twenty degrees.

12. The structure as defined in claim **10** wherein a plurality of paired orifice plates are arranged in series such that the base of each cone-shaped orifice plate is positioned substantially in the plane of the small diameter end of the next succeeding funnel-shaped orifice plate.

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ROBERT A. O'LEARY, *Primary Examiner.*

T. W. STREULE, *Assistant Examiner.*

U.S. Cl. X.R.

165—135, 154