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(54) HEAT EXCHANGER ASSEMBLY

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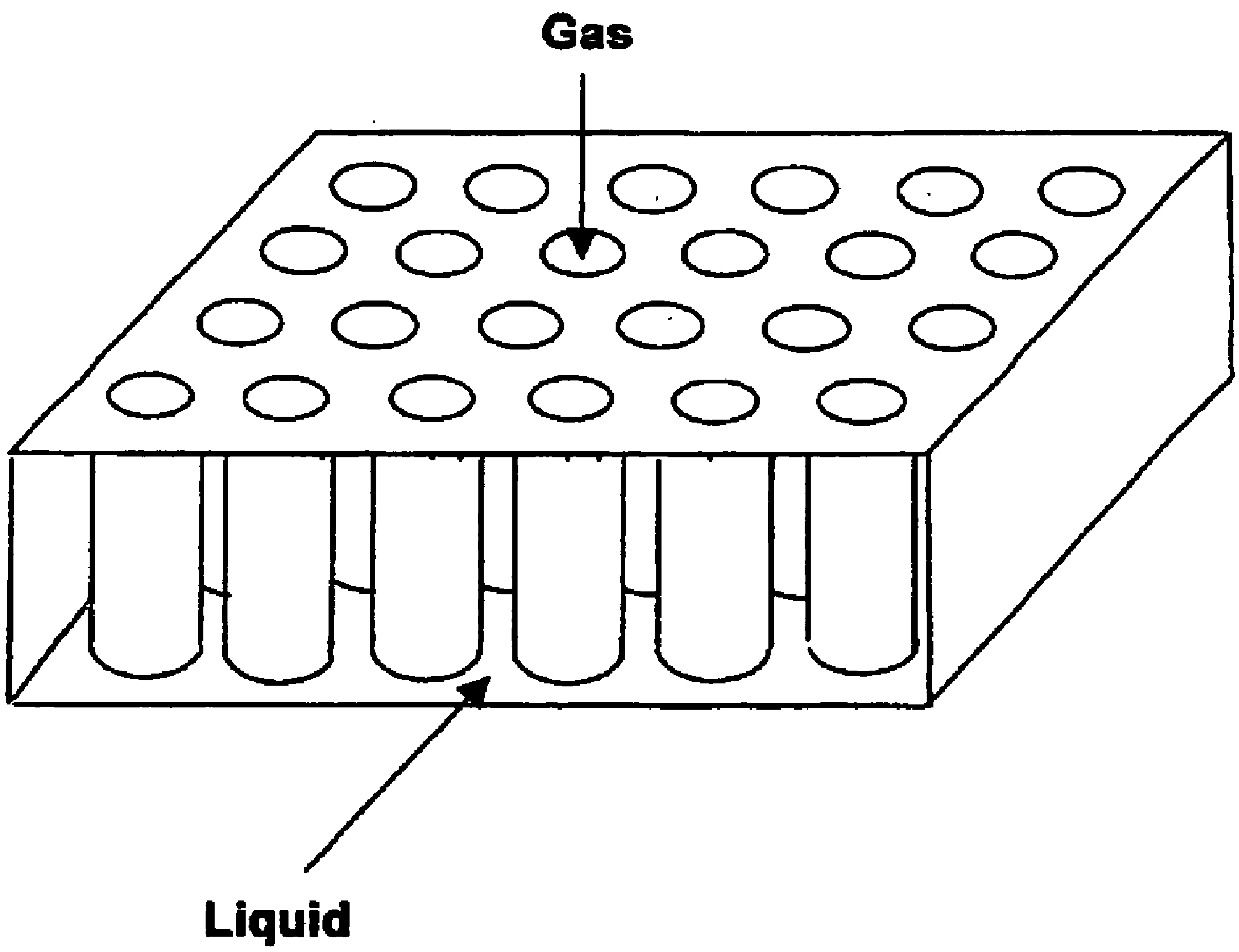
(57) **ABSTRACT**

An apparatus providing high efficiency heat exchange between two fluids is disclosed. The apparatus most commonly comprises multiple thin panels with fluid channels directing the flow of the two fluids, specifically: one or more flat panels aligned at some angle to the flow of the fluid traveling through the shortest channel of the thin panels. The panels are arranged in series and parallel, so that the hot fluid travels through multiple thin panels. The coolant is delivered to the thin panels through tubes or manifolds while the hot fluid is delivered through a duct or other piping.



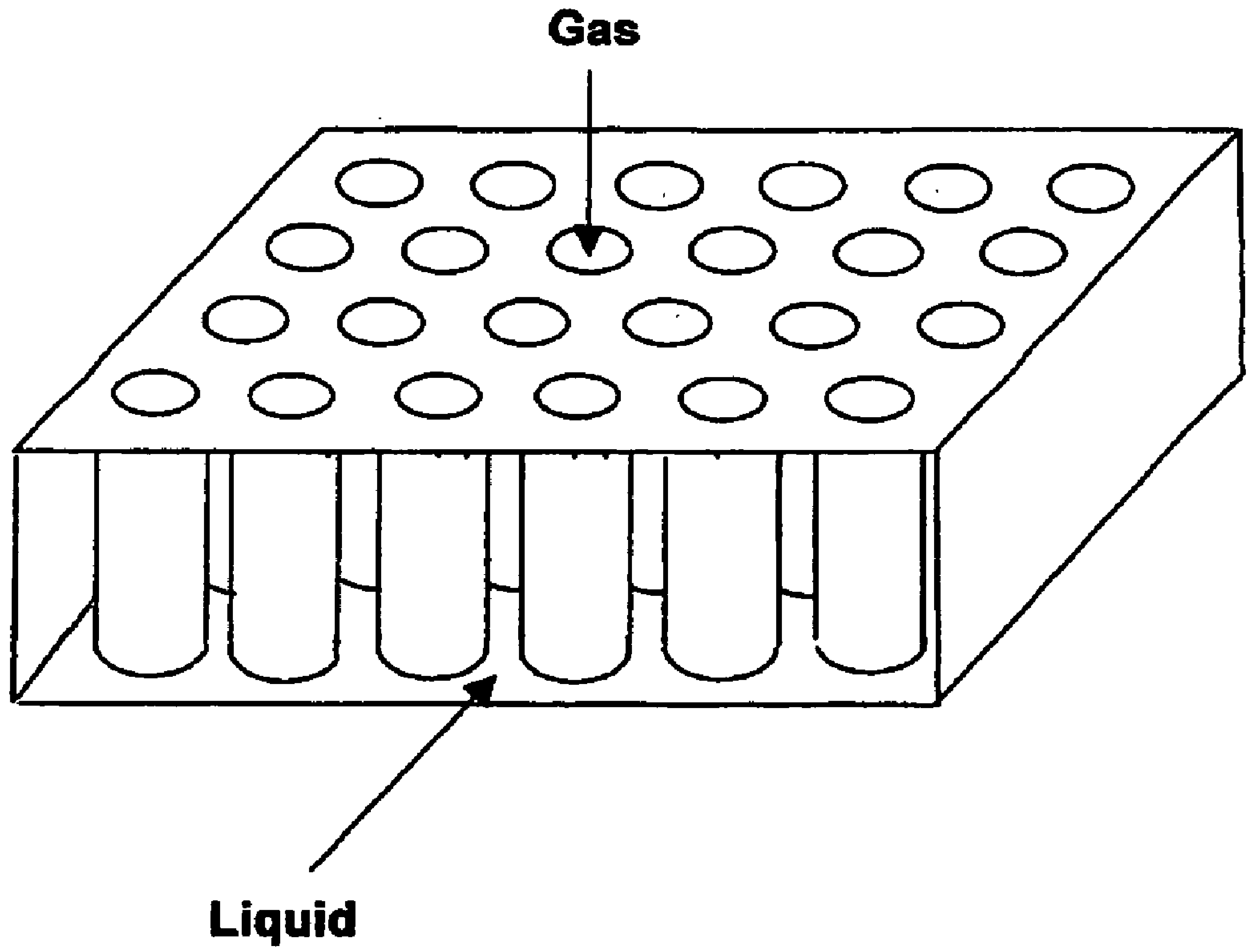


Figure 1

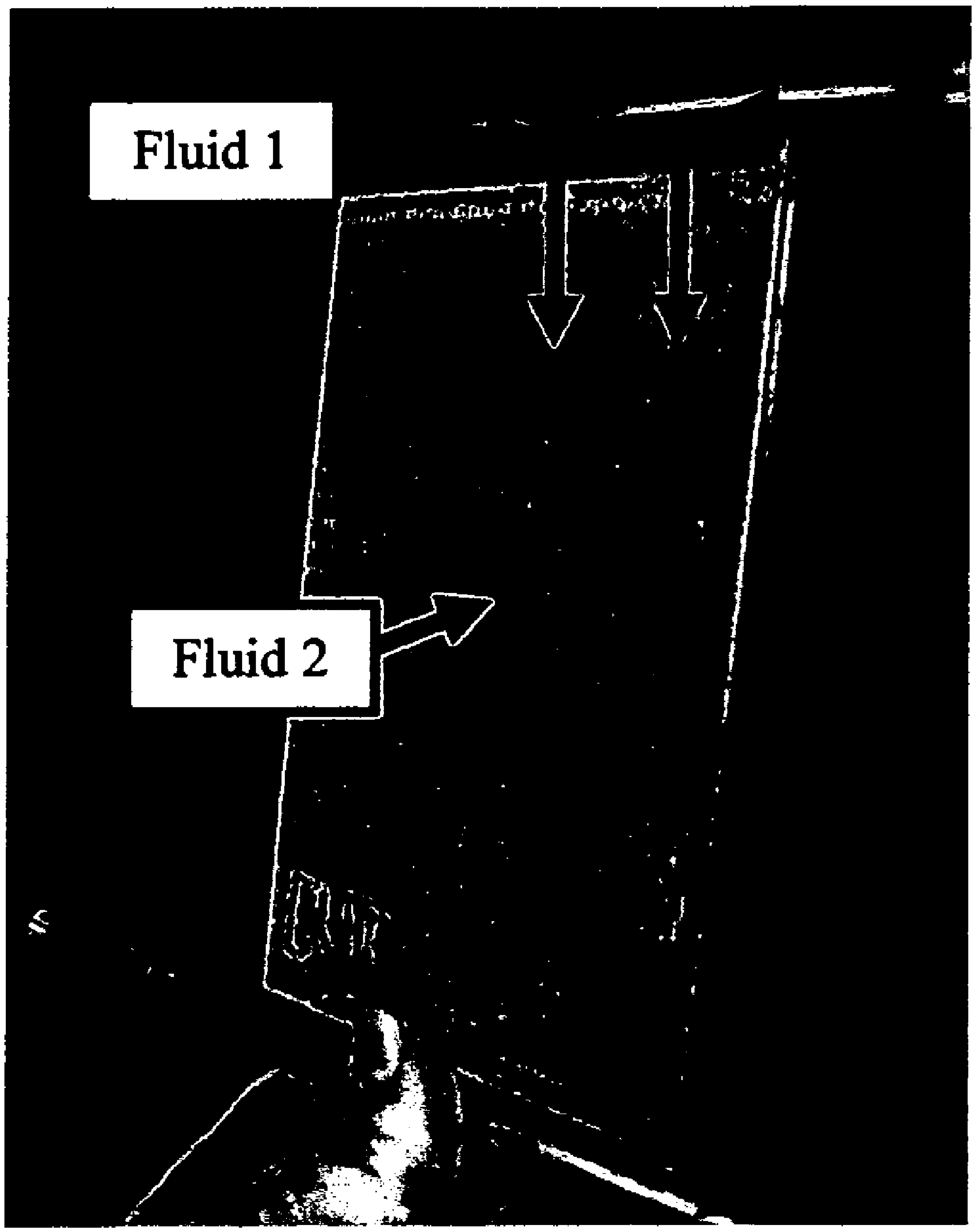


Figure 2

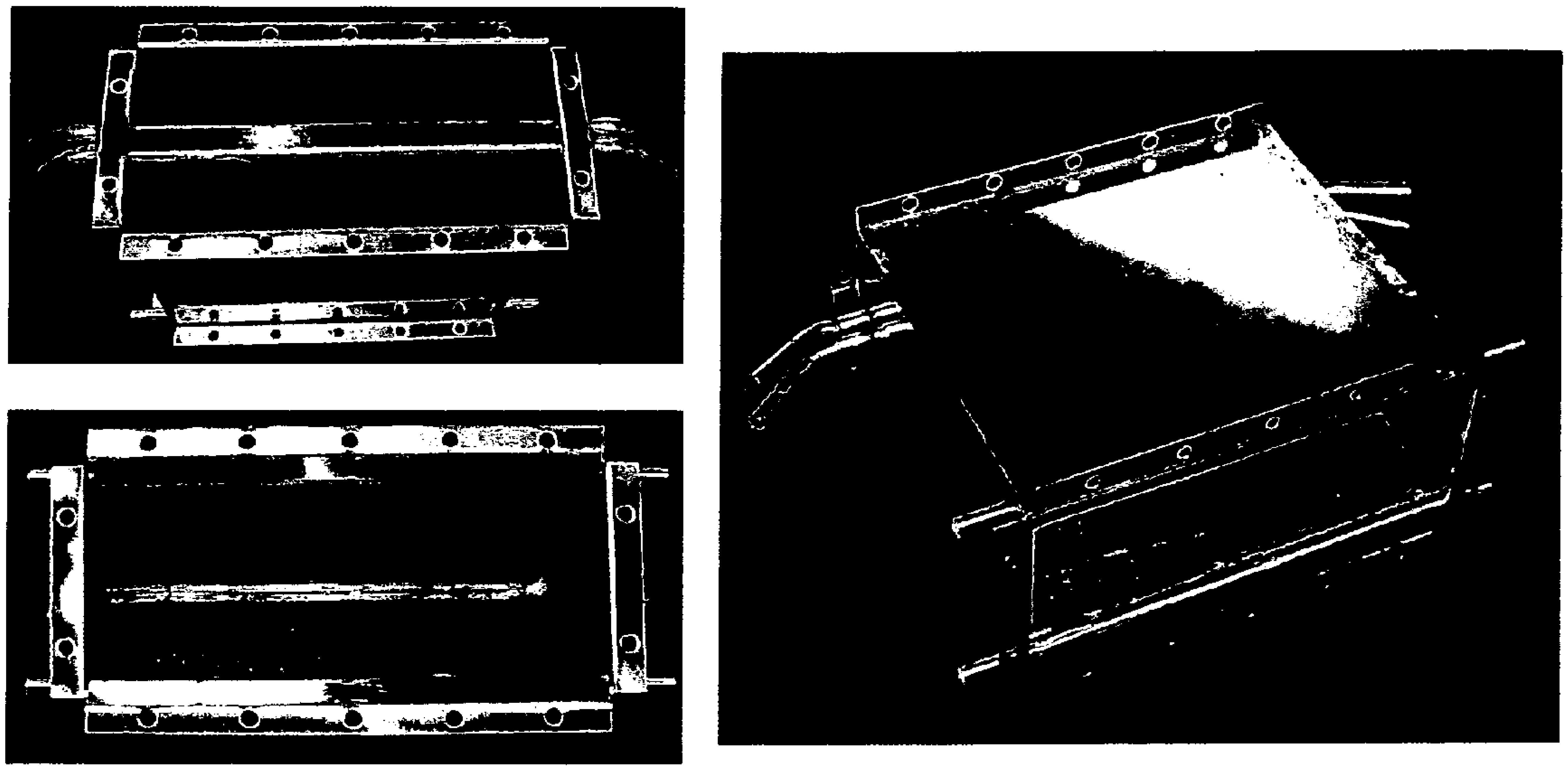


Figure 3

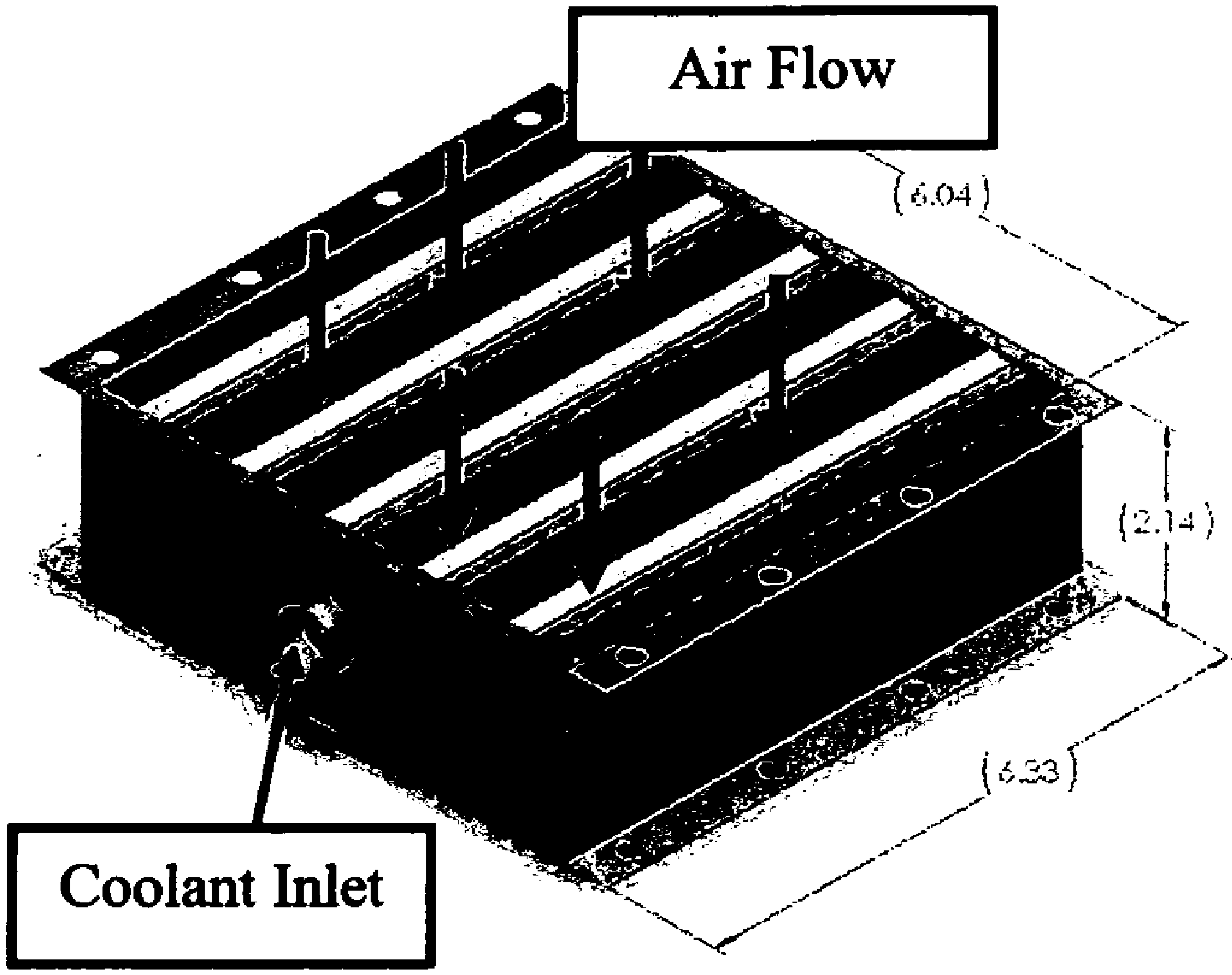


Figure 4

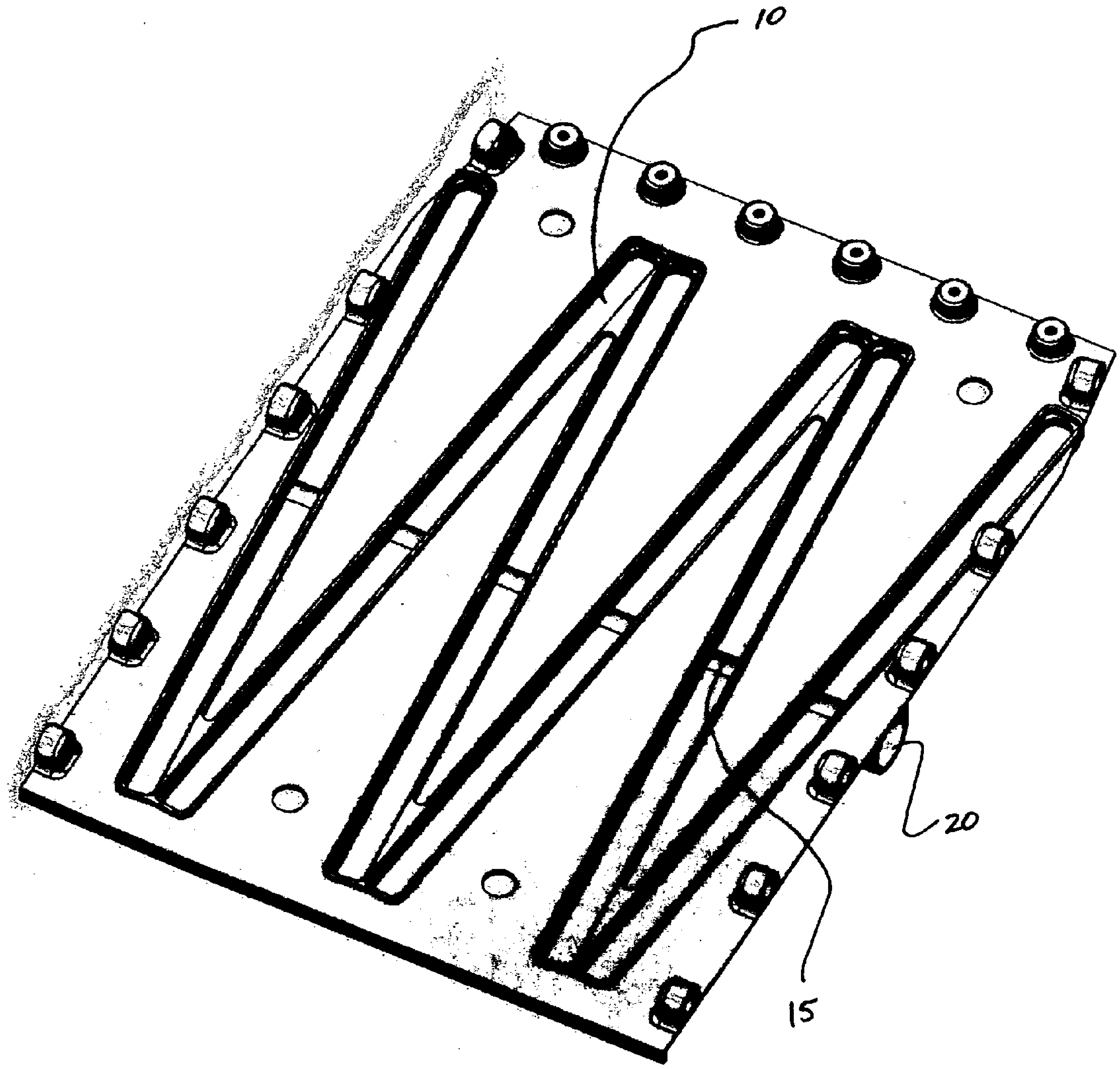


Figure 5

HEAT EXCHANGER ASSEMBLY

REFERENCE TO RELATED APPLICATIONS

[0001] This Application is a continuation-in-part of co-pending application identified as U.S. patent application Ser. No. 11/041,767, filed Jan. 24, 2005, the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to heat exchangers, particularly very high efficiency heat exchangers and heat exchanger systems.

SUMMARY OF THE INVENTION

[0003] Heat exchangers are used in a great many mechanical and electrical systems. Some of the most commonly known applications include the condenser of a refrigerator or the radiator of an automobile. Increasingly, customers have demanded high efficiency heat exchangers for cooling computer chips and other electronic components. This demand, among others, produces a continuing need for increased efficiency in a smaller volume.

[0004] Compact heat exchangers are used in applications which demand low overall mass or weight. Until recently, such a heat exchanger was incapable of transferring the amounts of heat necessary for certain applications, such as an automobile. It is desirable to reduce the size of the necessary heat exchanger while maintaining the rate of heat exchange. Unfortunately, the small features which allow for high heat transfer create correspondingly high pressure drops in the working fluids.

[0005] The rate of heat transfer for a given heat exchanger is related to the surface area-to-volume ratio of the fluid channels. Advances in microfabrication allow the design of a heat exchanger to increase the amount of surface area in relation to the overall volume. As is well understood in the field, the overall heat transfer of a given fluid channel increases when the hydraulic diameter of that channel decreases. So-called microchannels provide the reduction in hydraulic diameter necessary to produce the required heat transfer performance.

[0006] Typically, the prior art defines a microchannel as any fluid flow channel with a smallest dimension less than 2.0 mm. See, e.g., WO 2004/017008 A1. Microchannels necessarily impose a significant increase in pressure drop over more conventional flow channels.

[0007] In further illustration, U.S. Patent Application 2002/0125001 A1 discusses, in detail, the history of so-called micro heat exchangers and highlights the high pressure drops created in those designs. The heat exchanger disclosed in that application consists of two sets of microchannels. The length of the first fluid channels, claimed for the first time, is less than 6.0 mm and preferably less than 1.0 mm. At the same time, that heat exchanger shows that the first fluid channels number at least 50 per square centimeter, preferably as much as 1000 per square centimeter.

[0008] These inventions describe and explain the need for thin panel heat exchangers, defined as a heat exchanger with shortest fluid channel less than 2.0 cm long.

[0009] The inventions described in existing Patents and patent applications such as U.S. Patent Application 2002/0125001 A1 demonstrate the utility of thin panels for high heat transfer performance in a small volume. Even these breakthroughs, however, are subject to limitations based on allowable pressure drops. In addition, sometimes a single thin panel heat exchanger cannot provide the required heat transfer because it does not provide enough surface area.

[0010] The current invention extends the utility of these thin panel designs by providing multiple orientations and other options which serve to increase the effective surface area without necessarily increasing the frontal area of the heat exchanger system.

[0011] For instance, a typical thin panel heat exchanger is oriented so that its shortest flow channels are parallel to the approaching external fluid flow (the impinging flow). This is intended to minimize the pressure drop for that external fluid. The current invention, however, contemplates a thin panel heat exchanger inclined so that the approaching external fluid flow is no longer parallel to the fluid channels in the panel. With an inclined panel, the ratio of surface area to frontal area increases dramatically.

[0012] Experimentation has proven that a thin panel of the sort contemplated by the inventions discussed above may be inclined eighty (80) degrees from perpendicular with no appreciable effect on pressure drop. If a system is amenable to some pressure drop, the thin panels may be inclined to eighty five (85) degrees from perpendicular.

[0013] Experimentation has also proven that inclination of such a panel does not adversely affect the heat transfer properties of the panel, assuming the eventual configuration of headers, manifolds or other components assures proper distribution of fluid through both the internal and external channels.

[0014] Once it is established that a panel may be inclined, two panels may be included in a heat exchanger system by making a 'v' shape. In fact, such a v-shape may be repeated many times to create a system with a great number of panels and still retain the advantages of a small frontal area.

[0015] A typical thin panel heat exchanger disclosed in the prior art contemplates the external fluid flow impinging perpendicular to the face of the panel, as if the panel is mounted in a duct. In that configuration, the panel may be plumbed so that an internal fluid passed from one side of the duct to the other. If such a panel is inclined away from the perpendicular, and especially if multiple v-shape configurations are included, plumbing the internal fluid flow requires new solutions.

[0016] The current invention also addresses this concern. Internal fluid flow may be plumbed through tubes which feed one or more panels. In addition, a manifold may feed internal fluid flow to all of the panels at one time. The manifold can be made integrally with structural members of the total heat exchanger system, providing for a savings in total weight by removing mass which does not facilitate heat transfer.

[0017] As an added bonus, once the thin panel cross flow micro heat exchanger is created, a person having ordinary skill in the art would be able to design heat exchanger systems which incorporate multiple panels in various alignments, such as stacking panels. One example of a heat exchanger system incorporates several thin panels in a corrugated pattern to increase thermal transfer as a factor of frontal area. If a single fluid flow passed through multiple panels, these panels are described as 'in series'. If a single fluid flow may pass through one panel without passing through a separate panel, these panels are described as 'in parallel'.

[0018] These and other embodiments and features of the present invention will become even more apparent from the following detailed description of preferred embodiments, the accompanying figures, and the appended claims. As used in this description, the term "microchannel" is used to mean a channel with at least one dimension on the scale of 2.0 mm or less. A "thin panel heat exchanger" is used to mean a heat exchanger with the shortest fluid flow channel less than 2.0 cm in length.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] **FIG. 1** illustrates a simple embodiment of a thin panel heat exchanger in accordance with the previously claimed invention.

[0020] **FIG. 2** is a picture showing a complete view of a heat exchanger panel, including tubes which provide the coolant-side flow to the panel. Fluid **1** flows through the tubes to the internal channels of the thin panel, while Fluid **2** impinges the panel normal to the plane of the panel.

[0021] **FIG. 3** contains three photographs of a heat exchanger system employing four thin panel heat exchangers. Each panel is set at an angle to the impinging flow to increase heat transfer as a function of frontal area. Coolant flow is delivered to the thin panels via the tubes extending from the housing. The air flow arrives via a rectangular duct which matches the housing shown.

[0022] **FIG. 4** is a representation of a corrugated multi-panel heat exchanger, one of the applications of the current invention. It includes a coolant inlet. The water is then distributed among the separate panels by the integral manifold. After traveling through the panels, here arranged in parallel, the coolant is collected by another manifold and fed into piping or some other outlet path.

[0023] **FIG. 5** is a drawing of one of the manifolds used to both mount and plumb the thin panels in a corrugated arrangement such as that used in **FIG. 4**.

DETAILED DESCRIPTION OF THE INVENTION

[0024] A schematic illustration of an embodiment of a thin panel heat exchanger is shown in **FIG. 1** (not drawn to scale). In **FIG. 1**, the circular tubes are flow paths for a hot gas. The broad faces of the thin panel provide one large channel for the liquid flow path. This liquid flow path is broken up by the multitude of circular tubes. This arrangement creates a relatively large amount of primary surface area for heat transfer between the two fluids.

[0025] The flat panel illustrated in **FIG. 1** is only an example of a thin panel heat exchanger. Any heat exchanger which has a shortest fluid flow channel less than 2.0 cm can be used to take advantage of the current invention.

[0026] **FIG. 2** is a picture of a thin panel heat exchanger made part of a heat exchanger system which delivers coolant to the panel through tubes. Each tube has a slot in which the panel may be mounted. The panel is brazed or otherwise fixedly connected to the tubes. Fluid **1**, typically the coolant, is delivered to the interior of the panel through the upper tube and removed via the lower tube.

[0027] This figure does not illustrate the plumbing for the other fluid flow, but the entire panel may be mounted inside a duct or other piping to provide cooling for Fluid **2** flowing through that duct.

[0028] **FIG. 3** includes several pictures of a more complex heat exchanger system. In this system, four large thin panel heat exchangers are mounted in a v-configuration. This system allows greater thermal efficiency in a small frontal area than a single panel would allow. The cooling fluid is fed into the panels by means of an integral manifold at the top and the bottom of the heat exchanger assembly. The hot side fluid flows into the heat exchanger through the open area shown.

[0029] **FIG. 4** is a conceptual design using multiple thin panel heat exchangers in a corrugated arrangement. The dimensions shown are illustrative only. Persons having ordinary skill in the art will be able to array thin panel heat exchangers in a variety of configurations to take advantage of the unique qualities of the current invention.

[0030] **FIG. 5** illustrates a typical manifold used to create a corrugated arrangement similar to the one depicted in **FIG. 4**. The thin panels are mounted in slots (**10**), which provide structural support for the core of the heat exchanger assembly. Each slot (**10**) has an inlet port (**15**) which provides fluid flow to the panel. The ports (**15**) are all fed by a single inlet (**20**) made integral with the manifold. In this manner, multiple panels may be mounted at an angle to the impinging fluid flow and coolant delivered through a single fitting.

[0031] In order to increase the total amount of heat transfer between the working fluids, additional surface area may be added to the thin panel. This may be done by attaching fins, pins or expanded metal foam to one or more of the thin panels. Depending on the material comprising the body of the thin panel, additional structures may be plated, brazed, welded or otherwise attached. The most typical application is to attach fins to the downstream face of the thin panel, that is, away from the impingement of the fluid streams.

[0032] It is well understood by persons having ordinary skill in the art that the addition of secondary heat transfer surfaces such as fins, pins or expanded metal foam will cause additional pressure drop for the fluid encountering such secondary surfaces. This effect can be used by one skilled to adjust the flow through a panel. For instance, it is understood that a thin panel heat exchanger, when inclined away from perpendicular to the fluid flow, may see a maldistribution of fluid flow to the downstream portion of the panel. Secondary surfaces may be selectively mounted to redirect fluid flow to the upstream portion of the thin panel.

Fabrication of the Heat Exchanger Assembly

[0033] There are many ways to build a complete heat exchanger system using the current invention. A single thin panel may be plumbed with tubing to provide the internal flow (coolant flow). That tubing may be attached by brazing, welding or with an epoxy adhesive. The thin panel, with its plumbing in place, may be mounted in a duct or other piping system. That duct would be used to deliver the external flow to the thin panel heat exchanger. A potential mounting system is clamping the thin panel with gaskets to the duct or piping.

[0034] Multiple thin panels may be attached in a similar manner. Tubes can be used to deliver coolant flow, and the thin panels can be mounted in a duct, whether perpendicular to the flow through the duct, or inclined at some angle. Once again, the panels may be clamped to the duct using a gasket.

[0035] In the preferred embodiment, the thin panels are mounted first to a housing. This housing, such as that shown in **FIG. 4**, includes integral manifolds to both feed and remove the coolant to the heat exchanger panels. The manifold contains slots for mounting the thin panels. In each slot, there is a hole which allows fluid flow from piping or tubes to pass into the internal fluid channels of the thin panel. A typical manifold is depicted in **FIG. 5**.

[0036] In the preferred embodiment, the thin panel heat exchangers are fixedly connected to both the top and bottom manifold. If the panels are metal, typical brazing, soldering or welding techniques are appropriate methods of connection.

[0037] Two manifolds make up the top and bottom of the main flow channel for the hot side flow. An entry manifold receives coolant flow and feeds it to the thin panels. The exit manifold collects coolant flow from the thin panels. In addition, sides may be attached to the manifold panels to complete a main flow channel. The housing, comprising two manifolds and the side panels, can be bolted or otherwise mounted to the duct, piping, or other flow path for the external fluid.

[0038] The preferred embodiment of the manifold is as depicted in **FIG. 5**. The thin panel heat exchangers are mounted with open faces in slots machined in the manifold (**10**). Each slot (**10**) has an inlet port (**15**) which provides fluid flow to the panel. The ports (**15**) are all fed by a single inlet (**20**) made integral with the manifold. In this manner, multiple panels may be mounted at an angle to the impinging fluid flow and coolant delivered through a single fitting.

[0039] Coolant flow may be delivered to the manifolds in any of a number of methods known to those having ordinary skill in the art. Most typical is rigid or flexible tubing from the coolant supply to the entry manifold and from the exit manifold back to the coolant supply.

[0040] Once the assembly is complete, it can be placed in the flow path of the external fluid flow, such as the air duct of a vehicle or air conditioner. Persons having ordinary skill in the art will be able to design appropriate interfaces, such as flanges and gaskets, to properly attach the heat exchanger assembly to such a duct.

[0041] Each and every patent, patent application and printed publication referred to above is incorporated herein by reference in toto to the fullest extent permitted as a matter of law.

[0042] This invention is susceptible to considerable variation in its practice. The forgoing description, therefore, should not be construed as limiting the invention to the particular embodiments presented hereinabove. Rather, what is intended to be covered is as set forth in the ensuing claims and the equivalents thereof permitted as a matter of law.

We claim:

1. A heat exchanger for transferring heat between a first fluid and a second fluid, comprising:

a. A core made up of one or more thin panel heat exchangers; and

b. An apparatus for directing the first fluid to the core, such as tubes or an integrated manifold; and

c. An apparatus for directing the second fluid to the core, such as ducts or piping.

2. The heat exchanger of claim 1 in which the core is made up of more than one thin panel heat exchanger.

3. The heat exchanger of claim 2 in which the thin panels are in series such that the second fluid flow must pass through each panel successively.

4. The heat exchanger of claim 3 in which the series of thin panels in the core are placed so that the second fluid flow impinges the panels normal to their largest face.

5. The heat exchanger of claim 4 in which the series of thin panels in the core are aligned so that the second fluid flow channels match up in successive panels.

6. The heat exchanger of claim 4 in which the series of thin panels in the core are aligned so as to stagger the inlets of the second fluid flow channels.

7. The heat exchanger of claim 3 in which the series of thin panels in the core are placed to that the second fluid flow impinges the panels at some angle other than normal to their largest face.

8. The heat exchanger of claim 7 in which the series of thin panels in the core are aligned so that the second fluid flow channels match up in successive panels.

9. The heat exchanger of claim 7 in which the series of thin panels in the core are aligned so as to stagger the inlets of the second fluid flow channels.

10. The heat exchanger of claim 2 in which the thin panels in the core are arranged in parallel such that the second fluid flow may pass through any of the panels.

11. The heat exchanger of claim 10 in which the thin panels in the core are arranged so that the second fluid flow impinges the panels normal to their largest face.

12. The heat exchanger of claim 10 in which the thin panels in the core are placed so that the second fluid flow impinges the panels at some angle other than normal to their largest face.

13. The heat exchanger of claim 12 in which the thin panels are placed in a corrugated arrangement which results in a series of v-shapes.

14. The heat exchanger of claim 2 in which the core is made up of thin panels placed in a series and parallel configuration.

15. The heat exchanger of claim 14 in which the core is a stack made up of multiple v-shapes in series.

16. The heat exchanger of claim 14 in which the core is made up of multiple stacks of v-shapes in parallel.

17. The heat exchanger of claim 2 in which the thin panels contain microchannels.

18. The heat exchanger of claim 14 in which the thin panels contain microchannels.

19. The heat exchanger of claim 15 in which the thin panels contain microchannels.

20. The heat exchanger of claim 16 in which the thin panels contain microchannels.

21. The heat exchanger of claim 2 also comprising some additional material attached to the thin panels so as to provide secondary heat transfer surfaces for the second fluid, such as fins, pins or expanded foam.

22. The heat exchanger of claim 14 in which the thin panels have secondary heat transfer surfaces for the second fluid, such as fins, pins or expanded foam.

23. The heat exchanger of claim 15 in which the thin panels have secondary heat transfer surfaces for the second fluid, such as fins, pins or expanded foam.

24. The heat exchanger of claim 16 in which the thin panels have secondary heat transfer surfaces for the second fluid, such as fins, pins or expanded foam.

25. The heat exchanger of claim 21, in which the secondary heat transfer surfaces are arrayed so as to control the distribution of flow for the second fluid through the thin panel.

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