(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 April 2008 (24.04.2008)

PCT

(10) International Publication Number
WO 2008/048251 A2

(51) International Patent Classification:
F28F 9/02 (2006.01)

(21) International Application Number:
PCT/US2006/040112

(22) International Filing Date: 13 October 2006 (13.10.2006)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

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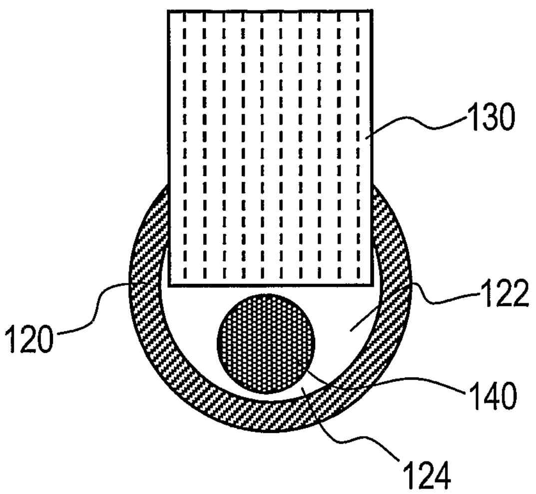
(54) Title: METHOD AND APPARATUS FOR IMPROVING DISTRIBUTION OF FLUID IN A HEAT EXCHANGER



(57) Abstract: A mini-channel heat exchanger or a micro-channel heat exchanger includes an insert (140, 240, 340, 440, 540, 640, 4, 940, 1040) having a volume. The insert is within a gap between a plurality of tubes (130, 230, 330, 430, 530, 630, 1 , 930, 1030) of the mini-channel heat exchanger or the micro- channel heat exchanger and a manifold inner wall of a manifold (120, 220, 320, 420, 520, 620, 2, 920, 1020).

WO 2008/048251 A2

Published:
— *without international search report and to be republished upon receipt of that report*

ABSTRACT OF THE DISCLOSURE

A mini-channel heat exchanger or a micro-channel heat exchanger includes an insert (140, 240, 340, 440, 540, 640, 4, 940, 1040) having a volume. The insert is within a gap between a plurality of tubes (130, 230, 330, 430, 530, 630, 1, 930, 1030) of the mini-channel heat exchanger or the micro-channel heat exchanger and a manifold inner wall of a manifold (120, 220, 320, 420, 520, 620, 2, 920, 1020).

METHOD AND APPARATUS FOR IMPROVING DISTRIBUTION OF FLUID IN A HEAT EXCHANGER

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This disclosure relates generally to mini- or micro-channel heat exchangers and, more particularly, to a method and apparatus for increasing uniformity in distribution of a fluid mixture into a micro-channel or mini-channel tube of mini- or micro-channel heat exchangers.

2. Description of the Related Art

[0002] In mini-channel or micro-channel heat exchangers (MCHX), the fluid flow is divided into many parallel tubes (circuits), where every tube and even every mini-channel should receive just a small and equal fraction of the total fluid flow. However, when two-phase fluid enters the heat exchanger, e.g., in an evaporator, condenser, gas cooler, or any other heat exchanger, the non-uniform distribution of two-phase mixture in parallel mini-channel tubes leads to certain tubes getting more liquid while the rest are getting more vapor, resulting in significant reduction in heat exchanger efficiency. This is called maldistribution and is a common problem in heat exchangers that utilize parallel fluid paths. Two-phase maldistribution problems are mainly caused by the difference in density of the vapor and the liquid phases.

[0003] Accordingly, there is a need to provide a method and apparatus for increasing uniformity in distribution of a two-phase fluid mixture into a micro-channel or mini-channel tube of mini- or micro-channel heat exchangers.

SUMMARY OF THE INVENTION

[0004] A mini-channel heat exchanger or a micro-channel heat exchanger is provided. The mini-channel heat exchanger or the micro-channel heat exchanger includes an insert having a volume. The insert is within a gap between a plurality of tubes of the mini-channel heat exchanger or the micro-channel heat exchanger and a manifold inner wall of a manifold.

[0005] A method for reducing maldistribution of fluid in a mini-channel heat exchanger or a micro-channel heat exchanger is also provided. The method includes reducing an internal volume of a manifold that distributes a flow including both a vapor and a liquid to a plurality of tubes of the mini-channel heat exchanger or the micro-channel heat exchanger.

[0006] The insert may be a solid cylinder having a solid cylindrical shape. The insert may be a tube-in-tube distributor that has a tubular shape with one or more orifices therethrough. At least one of the one or more orifices may be positioned on the insert having an angle greater than 0 degrees relative to a vertical axis parallel to the plurality of tubes. The one or more orifices may be positioned on the insert having an angle that is about +30° to about +330° relative to the axes of the mini-channel tubes. The insert may range from about 1/16 inch to about 3 inch in equivalent hydraulic diameter. The manifold and the insert may have a manifold to insert volume ratio that ranges from about 1.10 to about 5. The one or more orifices may have an orifice size that ranges from about 0.05 mm to about 4.0 mm. The one or more orifices may be sized so that a refrigerant experiences a partial or full expansion effect. The insert may be a D-shape tube insert having a curved portion adjacent to the manifold and a flat portion adjacent to the plurality of tubes. The flat portion may have the one or more orifices therethrough. The D-shape tube insert may have a pair of legs having the flat portion therebetween. The legs may abut the tubes. The insert may be a kidney shape tube insert with the one or more orifices on a concave side of the kidney shape tube insert. The kidney shape tube insert may have a first channel and a second channel that define an expanding volume. The one or more orifices can create a pressure drop from an interior volume of the insert to an internal volume of the manifold. The pressure drop may be greater than or equal to another pressure drop generated by flow through an internal volume to one of the plurality of tubes. The insert may be integrally formed with the manifold. The insert may form a first chamber separated from a second chamber in the manifold. The second chamber may have refrigerant flowing therethrough and the tubes may be inserted into the first chamber. The first chamber and the second chamber may be connected by the one or more orifices through the insert. The insert may be a propeller type insert having vanes.

[0007] The reducing may comprise reducing the internal volume by inserting an insert or shaping the manifold. The method may further comprise creating a pressure drop from an interior volume of an insert to the internal volume or mixing the vapor and the liquid in the internal volume.

[0008] The above-described and other features and advantages of the present disclosure will be appreciated and understood by those skilled in the art from the following detailed description, drawings, and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a schematic of a front cross-sectional view of a heat exchanger having a first exemplary embodiment of an insert of the present disclosure;

[0010] Figure 2 is a schematic of a front cross-sectional view of a heat exchanger having a second exemplary embodiment of an insert of the present disclosure;

[0011] Figure 3 is a schematic of a front cross-sectional view of a heat exchanger having a third exemplary embodiment of an insert of the present disclosure;

[0012] Figure 4 is a schematic of a front cross-sectional view of a heat exchanger having a fourth exemplary embodiment of an insert of the present disclosure;

[0013] Figure 5 is a schematic of a front cross-sectional view of a heat exchanger having a fifth exemplary embodiment of an insert of the present disclosure;

[0014] Figure 6 is a schematic of a front cross-sectional view of a heat exchanger having a sixth exemplary embodiment of an insert of the present disclosure;

[0015] Figure 7 is a schematic of a front cross-sectional view of a heat exchanger having a seventh exemplary embodiment of an insert of the present disclosure;

[0016] Figure 8 is a schematic of a side cross-sectional view of the heat exchanger having the insert of Figure 7;

[0017] Figure 9 is a graphical depiction of a scaled capacity to orifice angle of the insert of Figure 7;

[0018] Figure 10 is a representative infrared image for angle α shown in Figure 7 that equals 90°;

[0019] Figure 11 is a schematic of a front cross-sectional view of a heat exchanger having an eighth exemplary embodiment of an insert of the present disclosure; and

[0020] Figure 12 is a schematic of a front cross-sectional view of a heat exchanger having an ninth exemplary embodiment of an insert of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0021] It has been determined by the present disclosure that maldistribution in a MCHX heat exchanger, e.g., evaporator, condenser, gas cooler, or any other heat exchanger, may be reduced by reducing an internal volume of a manifold or header that distributes a multiple-phase flow, for example, a two-phase flow including both a vapor and a liquid, to parallel refrigerant paths, for example, tubes. Without wishing to be bound by any particular theory, it is believed that by reducing the total internal volume of the manifold, the velocity and mass flux of a two-phase fluid can be increased promoting internal mixing and also a volume over which a gas phase and a liquid phase of the two-phase flow separates is reduced as a result of these factors a relatively uniform and homogeneous mixture of vapor and liquid can be distributed to tubes that are parallel. Advantageously, it has been determined that an insert or shape of the manifold reduces the internal volume of the manifold. The insert or shape of the manifold may be of any shape or form that assists in forming a uniform and homogeneous mixture and can be used for inlet and/or intermediate length and/or outlet of the manifold.

[0022] A first exemplary embodiment of an insert is shown in Figure 1. A solid cylinder 140 having a solid cylindrical shape is introduced in a gap between mini-channel tubes 130 and a manifold inner wall 124 of a header or manifold 120. The solid cylinder 140 reduces a net internal open volume of an internal volume 122. The reduction of the net internal volume prevents separation of the vapor phase and the liquid phase of the two-phase flow of the refrigerant and results in mixing of the vapor phase and the liquid phase forming a homogeneous two-phase fluid. The homogeneous two-phase fluid improves distribution of the refrigerant to mini-channel tubes 130 that reduces maldistribution.

[0023] A second exemplary embodiment of the insert that is illustrated in Figure 2 has a tube-in-tube distributor 240. The tube-in-tube distributor 240 is a distributor type of device in a manifold 220 that causes a pressure drop from an interior volume 242 of tube-in-tube distributor 240 to an internal volume 222. The pressure drop, preferably, is higher or equal to the pressure drop in a mini-channel tubes 230 themselves. The pressure drop from interior volume 242 to internal volume 222 back pressurizes the two-phase flow entering manifold 220. The back pressure causes a majority or all of the two-phase flow to remain intact inside the internal volume 242 and hence internal volume 222. Without tube-in-tube distributor 240 in manifold 220, the liquid phase and the vapor phase of the two-phase flow would separate. Thus, tube-in-tube distributor 240 effectively reduces or eliminates two-phase separation and allows for the refrigerant flow to be efficiently distributed and/or regulated to the mini-channel tubes 230. Furthermore, tube-in-tube insert 240 reduces internal volume 222 of manifold 220 that results in a higher mass flux, defined as mass flow of refrigerant per unit flow cross-sectional area of open volume 222, and hence, improves mixing thereby reducing maldistrbituon inside manifold 220. Interior volume 242 of tube-in-tube insert 240 also has a higher mass flux which promotes mixing of the flow inside the internal volume 242.

[0024] Tube-in-tube distributor 240 has a hollow cylindrical or tubular shape with one or more orifices 244 therethrough. The two-phase refrigerant mixture is distributed into mini-channel tubes 230 through the one or more orifices 244. Each orifice 244 through tube-in-tube distributor 240 feeds one or more mini-channel tubes 230. Each of the one or more orifices 244 has an orifice size that is sized to produce a pressure drop that is equal to or greater than the pressure drop in mini-channel tubes 230 absent the tube-in-tube distributor 240.

[0025] The one or more orifices 244 may be sized so that the refrigerant experiences partial or full expansion effect that partially vaporizes at least a portion of the two-phase flow inside the one or more orifices 244. Preferably, one or more orifices 244 are 0.05 millimeters (mm) to 4.0mm in diameter and any subranges therebetween. As the orifice size decreases, the expansion effect increases. The expansion effect is in addition to expansion from an external device, such as, for example, an expansion valve. One or more orifices that are between 0.05mm and about 0.3mm create the expansion effect. One or more orifices having a sufficiently small diameter, such as, for example, 0.05mm to 0.1mm may provide enough expansion to eliminate a need for the expansion device. This allows liquid or low quality refrigerant to be fed to the MCHX heat exchanger and therefore minimizes the refrigerant maldistribution caused by a density difference between the liquid and vapor, and significantly improves heat exchanger efficiency.

[0026] Alternatively, the pressure drop in the manifold may be attained by an insert that is, but is not limited to, a tube-in-tube or plate type distributor with one or more orifices causing a pressure drop, a porous media, a shape of the manifold itself, one or more baffles with one or more orifices, or any combination thereof. The insert in the manifold or shape of the manifold that accomplishes such a pressure drop may be of any shape or form and can be used for an inlet and/or an intermediate length and/or an outlet of the manifold.

[0027] Figures 3 through 6 show different types of perforated tube/plate inserts inside the MCHX manifold with one or more orifices that function substantially the same as one or more orifices 244 in tube-in-tube distributor

240 described above. Figure 3 shows a D-shape tube insert 340 that has a curved portion 348 adjacent manifold 320 and a flat portion 346 facing tubes 330 of a MCHX heat exchanger. The flat portion 346 has one or more orifices 344 therethrough adjacent inlets of tubes 330. End caps (not shown) may be used to hold D-shape tube insert 340 in place in a manifold 320 before brazing D-shape tube insert 340 and manifold 320.

[0028] Figure 4 shows a kidney shape tube insert 440 with one or more orifices 444. The one or more orifices 444, preferably, are on a concave side 446 of kidney shape tube insert 440 adjacent to inlets of mini-channel tubes 430 of a MCHX heat exchanger. The kidney shape tube insert 440 has a first wall 448 and a second wall 449 that define a distributing volume 426. The channel comprising first wall 448 and the second wall 449 generate a secondary distribution of the two-phase flow from one or more orifices 444 to mini-channel tubes 430. The channel with walls 448 and 449 and distributing volume 426 therebetween may provide additional mixing of the two-phase mixture and may further prevent separation of the vapor phase and the liquid phase of the two-phase mixture to promote a uniform distribution of a homogeneous two-phase mixture to mini-channel tubes 430. The kidney shape tube insert 440 may sit on mini-channel tubes 430 before brazing kidney shape tube insert 440 and manifold 420 without using end caps.

[0029] Figure 5 shows an extruded manifold 520 with a first chamber 522 separated from a second chamber 524. The second chamber 524 can be D-shape or any shape, through which the refrigerant flows. Mini-channel tubes 530 of a MCHX heat exchanger may be inserted into first chamber 522. The first chamber 522 and second chamber 524 are connected to each other by a set of one or more orifices 544 for refrigerant distribution into mini-channel tubes 530. Extruded manifold 520 preferably has an integrally formed insert 540, although the present disclosure contemplates insert 540 being connected to or otherwise assembled with manifold 520 to define second chamber 524.

[0030] Figure 6 shows a D-shape insert 640 with a curved portion 648 connected to legs 647. The legs 647 have a flat portion 646 therebetween. One or more orifices 644 may be positioned on flat portion 646. The legs 647 may abut mini-channel tubes 630 of a MCHX heat exchanger for positioning before brazing to a manifold 620. Alternatively, legs 647 may abut mini-channel tubes 630 forming a friction fit to maintain D-shape insert 640 in proper position within manifold 620. The friction fit eliminates a need for brazing or other permanent attachment device.

[0031] One or more orifices in an insert may be positioned adjacent to inlets of the mini-channel tubes as shown in Figures 2 through 6. Alternatively, at least one of the one or more orifices may have an angle greater than 0 degrees relative to a vertical axis A parallel to mini-channel tubes 1. Figure 7 shows a manifold 2 of a MCHX heat exchanger with an insert 4. The insert 4 may be any shape, such as, a cylindrical tube as shown in Figure 7. The insert 4 has a set of one or more orifices 3. Fluid flows along insert 3 and is fed to the mini-channel tubes 1 through one or more orifices 3. α is an angle between each of one or more orifices 3 and the flow into mini-channel tubes 1. Figure 8 shows a schematic of a mini-channel heat exchanger 10 with insert 4. End caps 5 may be used to seal manifold 2. Fluid flows into insert 3 identified by arrow 12 and fluid flows out of mini-channel tubes 1 identified by arrow 14.

[0032] Applicants conducted testing with a prototype coil having the height of 19 inch, header length of 36 inch and connecting 101 mini-channel tubes. From the experimental results, it was determined that a performance improvement would result if one or more orifices 3 are at an acute angle to a plane B perpendicular to the mini-channels. It was further discovered that preferably the angularity should be on the order of about $+30^{\circ}$ to about $+330^{\circ}$ and any subranges in between relative to the axes of mini-channel tubes. The insert 3, preferably, ranges from about 1/4 inch to about 1/2 inch in equivalent hydraulic diameter D, with a manifold to insert volume ratio that ranges from about 2 to about 3. Each of the one or more orifices 3, preferably, feeds about 1 mini-channel tube to about 10 mini-channel tubes. An orifice size, preferably, ranges from about 0.3mm to about 1.3 mm, as discussed above.

[0033] Figure 9 shows representative test results of various orifice angles. When the one or more orifices are perpendicular to the flow orientation in the mini-channel tubes 1, as shown in Figure 7, coil capacities, defined as the total amount of heat transferred from refrigerant flowing inside mini-channel tubes 1 to the air flowing over the external surfaces of mini-channel tubes 1 are significantly improved relative to different angles α. Figure 10 shows a representative infrared image for $\alpha = 90^{o}$. The fluid distribution shown in Figure 10 is improved relative to different angles α and manifolds without inserts. The orientation of the one or more orifices perpendicular to the mini-channel tubes 3 also creates a swirl effect whereby the fluid exiting the orifices has to travel around the periphery of the insert tube before entering the mini-channel tube promoting fluid mixing.

[0034] The insert may create turbulent and/or mixing conditions inside the manifold such that the liquid and vapor phases of the refrigerant do not separate as another way of reducing maldistribution in a MCHX heat exchanger. Mixing inside the manifold could be attained by several means including but not limiting to a mixer insert and/or modified shape of the manifold. The insert in the manifold or shape of the manifold to do such mixing could be of any shape or form and can be used for inlet and/or intermediate and/or outlet manifold 920. One such example is a propeller type insert 940 in a manifold as shown in Figure 11. The propeller type insert 940 has vanes 943. The vanes 943 may cause mixing of fluid in an open volume 922 of manifold 920 shown by arrow 901. The mixing prevents vapor and liquid phases from separating to reduce maldistribution to mini-channel tubes 930 and forms a more homogeneous mixture of vapor and liquid of the two-phase flow over the prior art.

[0035] An insert having any combination of features of the inserts described above may also improve uniformity of distribution of two-phase fluid from the manifold to the mini-channel tubes. For example, volume reduction and pressure drop can be combined and optimized to give overall distribution improvement greater than that obtained with volume reduction and pressure drop implemented independently. An example of optimization could be where the orifice size chosen for pressure drop may be increased when combined with volume reduction as compared to implementing only pressure drop. This may be beneficial especially for cases where the orifice size is limited by manufacturing and cost constraints.

[0036] An insert having volume reduction combined with mixing may be optimized to give overall distribution improvement greater than that obtained with either volume reduction and mixing implemented independently. An example of optimization could be where an insert that reduces the internal volume of the manifold or shape of the manifold may be designed/optimized, such as, for example option shown on Figure 13, where insert has a corrugated shape, to also assist in mixing rather than separating the liquid and vapor phases.

[0037] An insert generating a pressure drop and mixing may be optimized to give overall distribution improvement greater than that obtained with either the pressure drop or mixing implemented independently. An example of optimization may be where the insert or manifold shape may generate mixing and may also provide a pressure drop before the two-phase flow enters the mini-channel tubes. This could prove beneficial especially for the cases where the orifice size is limited by manufacturing and cost constraints.

[0038] An insert may have volume reduction, a pressure drop, and mixing may be optimized to possibly achieve an overall distribution improvement greater than that obtained with volume reduction, a pressure drop, and mixing implemented independently. An example of optimization could be an insert or manifold shape that optimizes volume reduction, pressure drop and mixing before the two-phase flow enters the mini-channel tubes. This could prove beneficial especially for the cases where the orifice size is limited by manufacturing and cost constraints. One example which combines all three methods is a tube-in-tube type of distributor 1040 with one or more orifices 1044 directed away from a plane A of mini-channel tubes 1030 as shown in Figure 12. The presence of tube-in-tube distributor 1040 inside manifold 1020 reduces an open internal volume 1022 of manifold 1020 which feeds mini-channel tubes 1030, thereby improving maldistribution as discussed above. The one or more orifices 1044 on tube-in-tube distributor 1040 provides significant enough pressure drop resulting in even flow distribution as discussed above. Off-setting flow coming out of one or more orifices 1044 and going into mini-channel tubes 1030 provides a rotation/mixing inside a remainder of open internal volume 1022 shown by arrow 1001 thus preventing liquid vapor separation and reducing maldistribution as discussed above.

[0039] Additionally, one or more of the inserts described above may be implemented in conjunction with a multi-pass MCHX (evaporator or condenser or gas cooler or any other heat exchanger) wherein refrigerant traverses an entire tube length more than one time before exiting the heat exchanger. A multi-pass MCHX offers additional benefit that a net length of manifold that witnesses two-phase flow is reduced with increasing number of passes but in-turn adds maldistribution complexity in intermediate manifolds.

[0040] The particular type, including materials, dimensions and shape, of the insert can vary according to the particular needs of the MCHX heat exchanger. Preferably the insert is aluminum. The present disclosure has described a number of exemplary embodiments having one or more features described therewith. It should be understood that these features are interchangeable between the number of exemplary embodiments.

[0041] While the instant disclosure has been described with reference to one or more exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope thereof. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the disclosure without departing from the scope thereof. Therefore, it is intended that the disclosure not be limited to the particular embodiment(s) disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A mini-channel heat exchanger or a micro-channel heat exchanger comprising:

an insert (140, 240, 340, 440, 540, 640, 4, 940, 1040) having a volume, said insert being within a gap between a plurality of tubes (130, 230, 330, 430, 530, 630, 1, 930, 1030) of the mini-channel heat exchanger or the micro-channel heat exchanger and a manifold inner wall of a manifold (120, 220, 320, 420, 520, 620, 2, 920, 1020).

2. The apparatus of claim 1, wherein said insert (140) is a solid cylinder having a solid cylindrical shape.

3. The apparatus of claim 1, wherein said insert (240, 340, 440, 540, 640, 4, 1040) is a tube-in-tube distributor that has a tubular shape with one or more orifices (244, 344, 444, 544, 644, 3, 1044) therethrough.

4. The apparatus of claim 3, wherein at least one of said one or more orifices (244, 344, 444, 544, 644, 3, 1044) are positioned on said insert (240, 340, 440, 540, 640, 4, 1040) having an angle greater than 0 degrees relative to a vertical axis (B) parallel to said plurality of tubes (130, 230, 330, 430, 530, 630, 1, 930, 1030).

5. The apparatus of claim 3, wherein said one or more orifices (244, 344, 444, 544, 644, 3, 1044) are positioned on said insert (240, 340, 440, 540, 640, 4, 1040) having an angle that is about +30° to about +330° relative to axes of mini-channel tubes (130, 230, 330, 430, 530, 630, 1, 930, 1030).

6. The apparatus of claim 1, wherein said insert (140, 240, 340, 440, 540, 640, 4, 940, 1040) ranges from about 1/16 inch to about 3 inches in equivalent hydraulic diameter, and wherein said manifold and said insert have a manifold to insert volume ratio that ranges from about 1.10 to about 5.

7. The apparatus of claim 3, wherein said one or more orifices (244, 344, 444, 544, 644, 3, 1044) have an orifice size that ranges from about 0.05 mm to about 4.0 mm.

8. The apparatus of claim 3, wherein said one or more orifices (244, 344, 444, 544, 644, 3, 1044) are sized so that a refrigerant experiences a partial or full expansion effect.

9. The apparatus of claim 3, wherein said insert is a D-shape tube insert (340, 640) having a curved portion (348, 648) adjacent said manifold and a flat portion (346, 646) adjacent to said plurality of tubes (330, 630), and wherein said flat portion (346, 646) has said one or more orifices (344, 644) therethrough.

10. The apparatus of claim 9, wherein said D-shape tube insert (640) has a pair of legs (647) having said flat portion (646) therebetween, and wherein said legs (647) abut said tubes (630).

11. The apparatus of claim 3, wherein said insert is a kidney shape tube insert (440) with said one or more orifices (444) on a concave side (446) of said kidney shape tube insert (440), and wherein said kidney shape tube insert (440) has a first channel (448) and a second channel (449) that define an expanding volume (426).

12. The apparatus of claim 3, wherein said one or more orifices (244, 344, 444, 544, 644, 3, 1044) creates a pressure drop from an interior volume of said insert to an internal volume of said manifold (120, 220, 320, 420, 520, 620, 2, 920, 1020).

13. The apparatus of claim 12, wherein said pressure drop is greater than or equal to another pressure drop generated by flow through an internal

volume to one of said plurality of tubes (130, 230, 330, 430, 530, 630, 1, 930, 1030).

14. The apparatus of claim 1, wherein said insert (540) is integrally formed with said manifold (520).

15. The apparatus of claim 14, wherein said insert forms a first chamber (522) separated from a second chamber (524) in said manifold, wherein said second chamber (524) has refrigerant flowing therethrough and said tubes (530) are inserted into said first chamber (522), and wherein said first chamber (522) and said second chamber (524) are connected by said one or more orifices (544) through said insert.

16. The apparatus of claim 1, wherein said insert is a propeller type insert (940) having vanes (943).

17. A method for reducing maldistribution of fluid in a mini-channel heat exchanger or a micro-channel heat exchanger, the method comprising:

reducing an internal volume of a manifold (120, 220, 320, 420, 520, 620, 2, 920, 1020) that distributes a flow including both a vapor and a liquid to a plurality of tubes (130, 230, 330, 430, 530, 630, 1, 930, 1030) of the mini-channel heat exchanger or the micro-channel heat exchanger.

18. The method of claim 17, wherein said reducing comprises reducing said internal volume by inserting an insert (130, 230, 330, 430, 530, 630, 1, 930, 1030) or shaping said manifold.

19. The method of claim 17, further comprising creating a pressure drop from an interior volume of an insert (130, 230, 330, 430, 530, 630, 1, 930, 1030) to said internal volume or mixing said vapor and said liquid in said internal volume.

20. An apparatus or method for reducing two-phase flow separation as herein before described with reference to Figures 1 through 12 of the accompanying drawings.

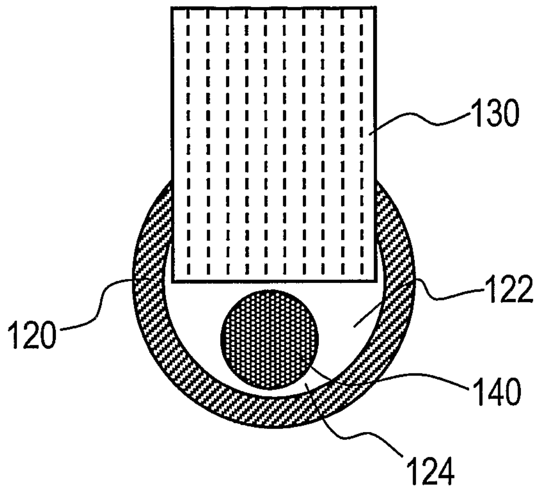


Fig.1

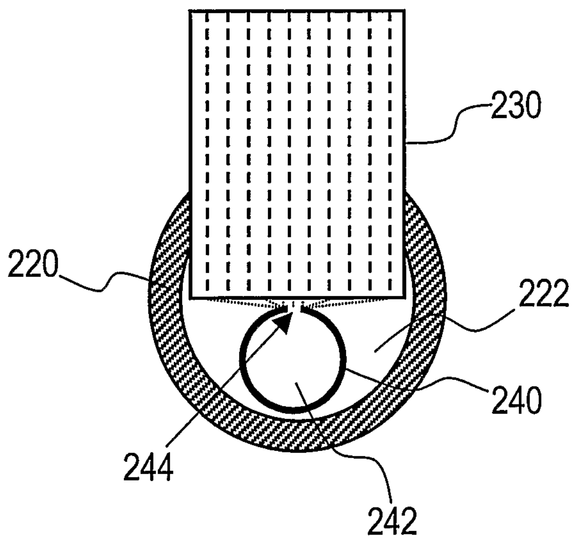


Fig. 2

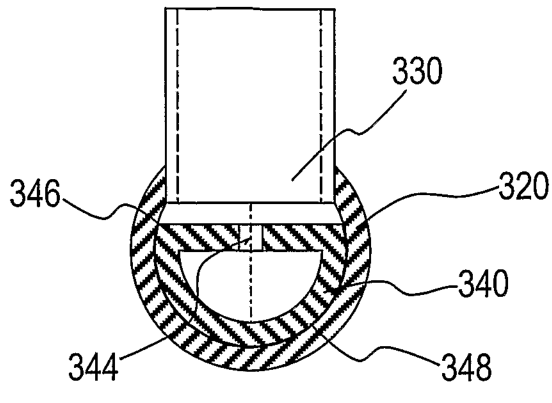


Fig. 3

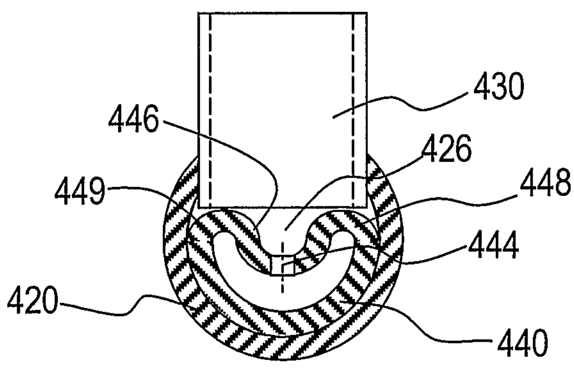


Fig. 4

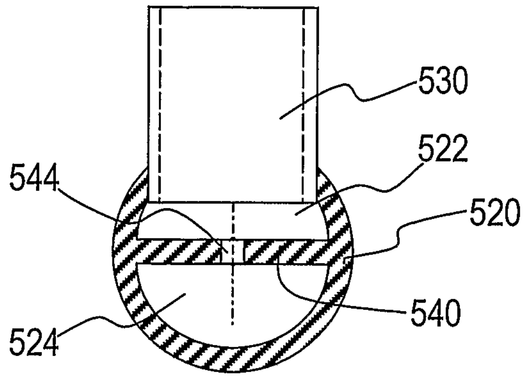


Fig. 5

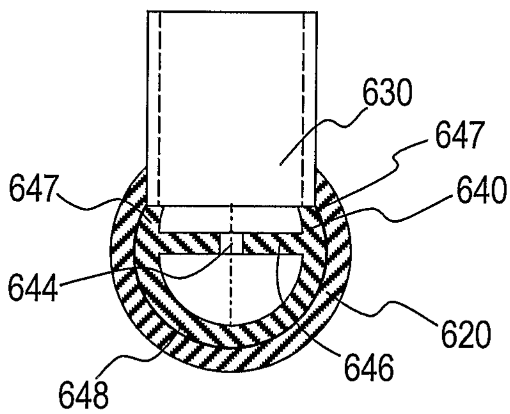


Fig. 6

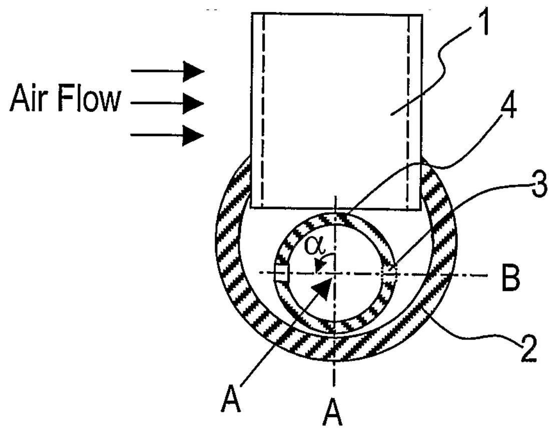


Fig. 7

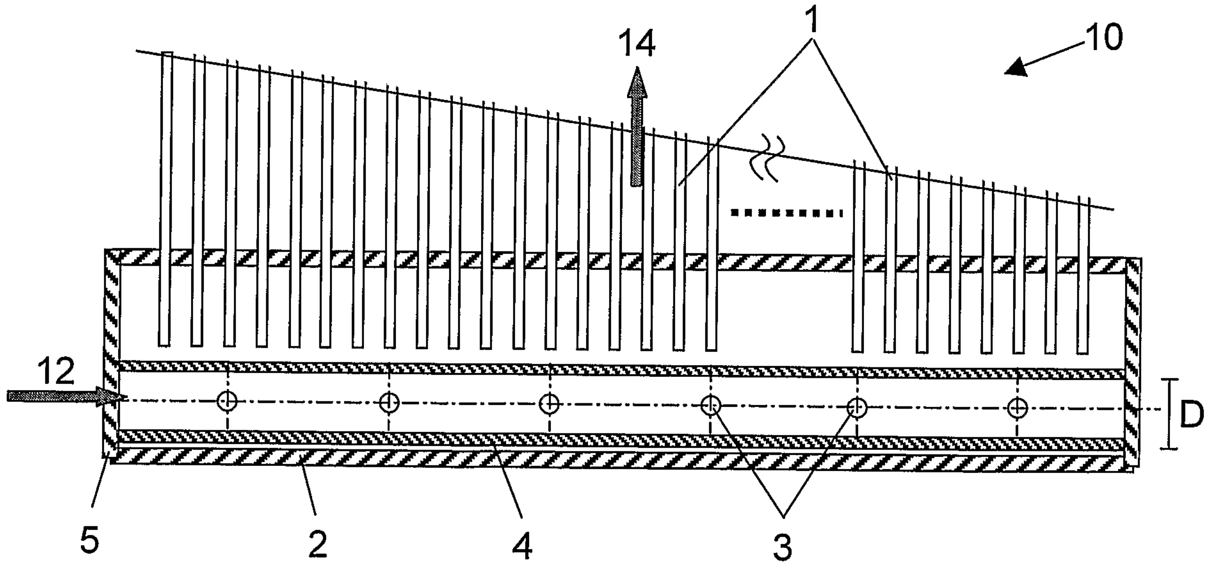


Fig. 8

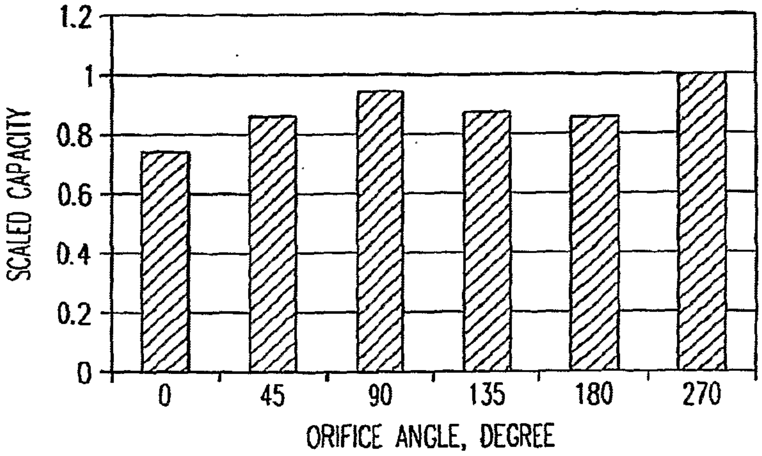

1.2
1
0.8
0.6
0.4
0.2
0
SCALED CAPACITY
0
45
90
135
180
270
ORIFICE ANGLE, DEGREE

FIG. 9

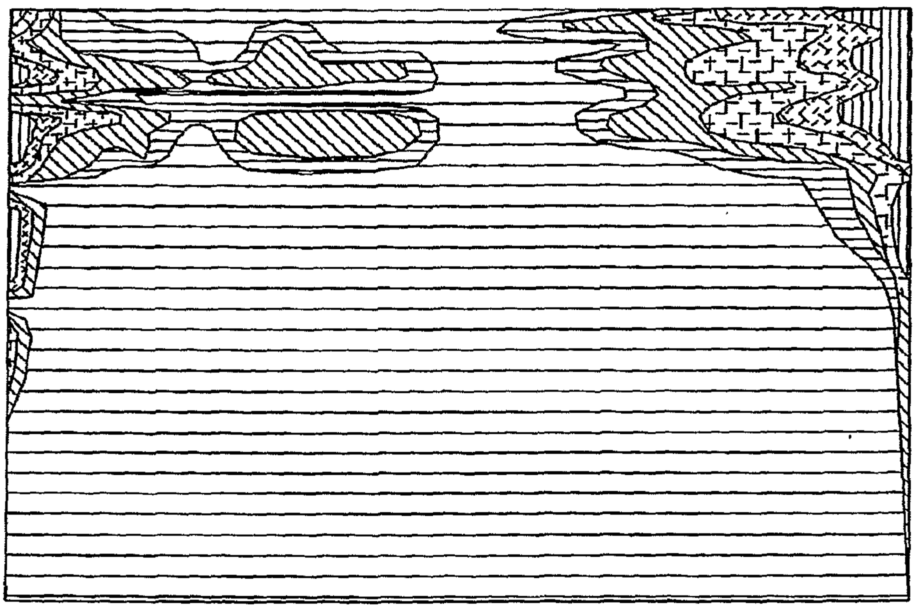


FIG. 10

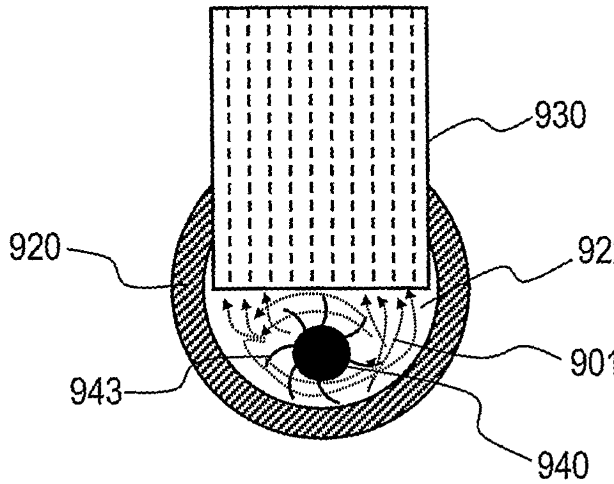


Fig. 11

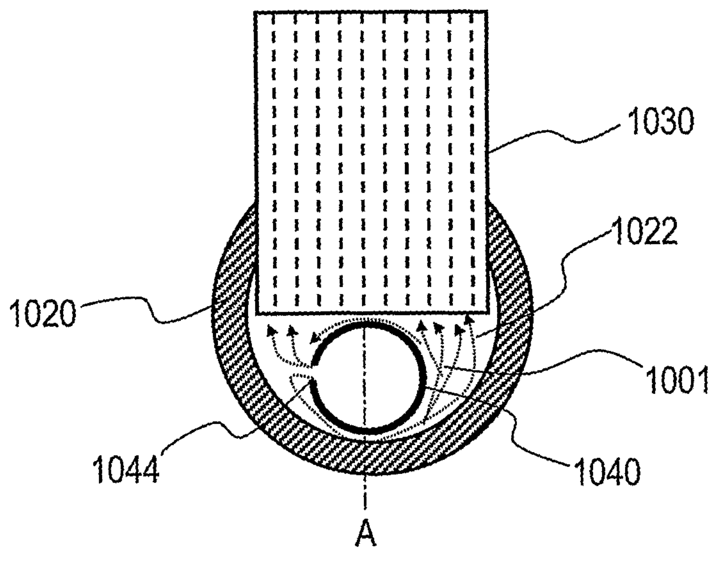


Fig. 12