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(71) Applicant: **CHART HEAT EXCHANGERS Limited Partnership**
Wolverhampton WV10 6QB (GB)

(72) Inventors:
- **Symonds, Keith Thomas**
Codsall
Staffordshire WV8 2EN (GB)
- **Chatwin, Christopher John**
Penkridge
Stafford ST 19 5JG (GB)

(74) Representative: **Moore, Christopher Mark et al**
HLBBshaw
10th Floor, Metropolitan House
1 Hagley Road
Birmingham B16 8TG (GB)

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(54) **Heat exchangers**

(57) A heat exchanger or chemical reactor including a heat exchange body (500, 350) defining one or more fluid flow passages (507) and a removable insert (200, 201, 300, 301, 302). The insert includes a series of contacting plates (200, 201, 300, 301, 302) stacked along a common axis and is engaged in interference fit within at least one of the flow passages (507), thereby to provide secondary heat exchange surfaces in thermal contact with the primary wall surfaces.

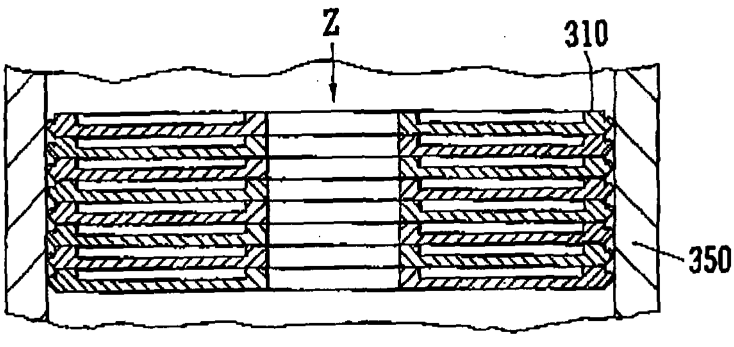

FIG. 16A

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Description

[0001] This invention relates to heat exchangers. It is particularly concerned with heat exchangers that are to be used as chemical reactors and, although not intended to be limited thereto, it will be more specifically described below with particular reference to catalytic reactors.

[0002] Heat exchanger constructions are well known in which passageways for fluid are provided between adjacent walls defined by parallel spaced plates which provide primary heat exchange surfaces, and in which the passageways contain secondary heat exchange surfaces In the form of fins, which may conveniently be in the form of a corrugated sheet or finning extending along the passageways.

[0003] It is conventional practice to braze or otherwise bond the corrugated finning to the passageway walls during brazing or otherwise bonding of the passageway walls to form the heat exchanger structure. In other words, the corrugated finning is bonded *in situ* during the manufacture of the heat exchanger body and it is conventional practice to utilise the presence of the corrugated finning to assist in transmitting the loads applied by jigging during the bonding/brazing process.

[0004] Where the heat exchanger is to be used as a chemical reactor, it is frequently required that passageways contain catalyst to catalyse the desired reaction in the fluids passing through those passageways. For an exothermic reaction, the reactor may be designed to have passageways to carry a cooling fluid across the opposite faces of the primary surfaces to the faces contacting the reacting fluid so that the heat of reaction can be carried away. If the reaction is endothermic, a heating fluid may be needed to transfer heat across those primary surfaces to initiate the desired reaction.

[0005] Two basic systems have hitherto been proposed to introduce catalyst into those passageways carrying the fluid to be reacted. In one, the internal surfaces of the passageways are coated with a catalyst, usually in finely divided form, e.g. of particle size 150 microns or less. In the second, the passageways are packed with catalyst, which may, for example, be of particle size 2 to 3 mm or greater. The second system is more suitable for use with relatively open, unobstructed passageways whereas the first system is more suitable for use with smaller passageways which may contain secondary finning. It is usual to coat the catalyst onto the primary and secondary surfaces after they have been bonded together to avoid damage to the catalyst and its adhesion properties during the bonding process. The catalyst is applied by well known coating techniques in which a solution or suspension of the catalyst is brought into contact with the passageway surfaces by dipping, and/or flowing with the solution or suspension and then stoving at the appropriate temperature.

[0006] Packed catalyst particles of the second system can be removed when spent or contaminated simply by being forced out of the passageways, e.g. by means of a rod, and the passageways can then be repacked with fresh catalyst. Spent or contaminated catalyst of the first system is much more difficult to remove from the relatively complex internal passageway surfaces and the reactor, therefore, may have only a short service life and have to be scrapped when the catalyst is spent.

[0007] It is, therefore, an object of the invention to provide an improved heat exchanger, particularly useful as a catalytic chemical reactor, in which the above-mentioned problem of coated catalytic reactors can be obviated.

[0008] Accordingly in one aspect the invention provides heat exchange apparatus comprising a plurality of passageways defined between primary wall surfaces, at least one passageway containing a removable member which defines a secondary heat exchange surface.

[0009] Preferably the member carries one or more catalytically active element or substance.

[0010] The removable member may take a variety of shapes. For example it may be in the form of fins and shaped from one component or it may be in the form of a bar having flat surfaces to carry the catalyst. It may be formed of a series of plates mounted on a common elongate element, e.g. a rod or tube, or on a common axis. The member may be engaged in the passageway as an interference fit or in any other convenient way.

[0011] In one preferred aspect the invention provides a heat exchanger comprising a plurality of passageways defined between parallel primary wall surfaces, at least one passageway containing secondary heat exchange surfaces in the form of corrugated finning, the corrugated finning being held as an interference fit and being thereby removable.

[0012] For example, the finning may be forced into place by means of a mechanical or hydraulic press. The force is preferably applied to the finning via an intermediate member of dimensions marginally less than those of the passageway entrance. This avoids damage to the corrugations by spreading the load and enables the finning to be inserted beyond the edge of the entrance of the passageway, i.e. it can be slightly recessed within the passageway.

[0013] The corrugated finning may conveniently be coated with catalyst before it is pressed into its passageway. It may be pressed out again when the catalyst is spent or contaminated and is preferably replaced by a new coated corrugated finning although it may be possible to clean the original finning and then coat it with fresh catalyst and re-use the original finning if it can still provide an adequate interference fit. The coating could be carried out after insertion but this is non preferred as it removes the possibility of inspecting the coating.

[0014] It is not essential that the replaceable corrugated finning be coated with catalyst, if it is desired to make a heat exchanger for other than catalytic reactor use but in which it is still desired to have replaceable finning. However, as indicated above, the Invention is particularly intended for use as a catalytic chemical reactor.

[0015] The passageways of the reactor may be defined by walls formed by adjacent pairs of parallel spaced plates in the manner indicated above but, in a particularly preferred embodiment of the Invention, they are defined In a stack of parallel plates, each plate having slots which are aligned In the stack to form passageways for the process and utility/service streams. The plates may be brazed or otherwise bonded together so that the slots align to form passageways perpendicular to the plane of the stacked, parallel plates.

[0016] The finning may be inserted in lengths that are, e.g. 0.0508 mm (0.020 inches) less than the distance between any injection ports that are provided in the heat exchanger so that a clear path exists across the width of the passageway to aid in the distribution of a secondary fluid into a first fluid passing along the passageway. This embodiment will of course necessitate intermediate members of different lengths so as to have the capability of inserting the finning to positions which do not interfere with the provision of points for injection of a secondary fluid into a first fluid passing along the passageways i.e. gaps between the items of finning will be provided by inserting the individual items of finning to different depths in the passageways.

[0017] A further aspect of the invention provides a heat exchanger comprising a heat exchange body defining one or more fluid flow passages and a removable insert defining secondary heat exchanger surfaces in interference fit within at least one of the flow passages.

[0018] The insert may comprise a metal sheet folded to form corrugations extending along an axis. Holes may be provided in the flanks of the corrugations.

[0019] The one or more fluid flow passage may be of an elongate cross section having a length (l') and a width (w') and the corrugations have a height (h) measured from peak to peak that is slightly greater than the width (w') of the slot.

[0020] The body may comprise a stack of plates each of which has one or more slots that when the plates are stacked define said one or more passages.

[0021] The stack of plates may have a depth (d) measured in a direction from one end of the stack to the other end, wherein the insert extends in a direction extending through the depth of the stack of plates.

[0022] One specific use of the present invention is in conjunction with the heat exchanger/catalytlc reactor constructions that are described and claimed in our international patent application no. PCT/GB99/04131, publication no. WO 00/34728. [Agents Ref: P03617PCT]. That describes and claims a stacked assembly of plates, the stack having an inlet and an outlet for a first fluid and an inlet and an outlet for a second fluid, a first portion of the length of the assembly being formed of one or more first perforated plates, each first perforated plate being perforated to define a first series of slots spaced across the plate and a second series of slots spaced across the plate, each slot of the first series being positioned between a pair of slots of the second series, whereby the slots of the first series define first passageways through the first portion of the length for a first fluid and the slots of the second series define second passageways through the first portion of the length for a second fluid, the first series of passageways being connected to said inlet and outlet for the first fluid, a second portion of the length of the assembly being formed of one or more second perforated plates, each second perforated plate being perforated to define a first and a second series of slots corresponding to the slots of the first plate(s) so as to provide continuing passageways in line with the first and second passageways of the first portion, each slot of the second series opening at one of its two ends into a feeder slot extending across the second plate, the feeder slot(s) being connected to an inlet or an outlet for the second fluid.

[0023] The corrugated secondary finning of the present invention may preferably be pressed into the first passageways of the assemblies described In WO 00/34728, i.e. the passageways for the first fluid, and, where it Is desired that the first fluid be subjected to a catalysed reaction, the secondary finning will be preferably coated with catalyst before insertion, or after Insertion, as described above.

[0024] The finning preferably contains a series of holes or slots through its thickness preferably in its flank regions to aid distribution of any second fluid Injected to mix with a first fluid flowing through the passageways.

[0025] In another aspect the invention provides a method of carrying out a chemical reaction; the method comprising carrying out a chemical reaction in apparatus as defined herein, and when the catalyst is spent, removing the removable insert and replacing it with a removable insert carrying fresh catalyst.

[0026] Preferably the insert is the original insert having an application of fresh catalyst.

[0027] Embodiments of the invention will now be described by way of example only, with reference to the accompanying diagrammatic drawings, in which:

> Figure 1 is a side view of a length of a removable insert in the form of a corrugated secondary finning for use in the present invention;
>
> Figure 2 is an elevation in enlarged scale of a portion of the length of the insert of Figure 1;
>
> Figure 3 is a plan view of a stack of plates having passageways formed by a row of elongated slots across each plate;
>
> Figure 4 is a similar view to Figure 3, but with the insert of Figure 1 inserted into the passageways of a heat exchanger constructed in accordance with the present invention;
>
> Figure 5 is a section on line V-V of Figure 4;

Figure 6 is an enlarged view of Figure 4;

Figure 7 is an elevation of another removable insert in the form of shim for use in the present invention;

Figure 8 is an elevation of another removable insert embodiment of shim;

Figure 9 is an elevation of a spacer to be located between alternating shims of Figures 7 and 8;

Figure 10 is a schematic plan view through a heat exchanger /chemical reactor constructed in accordance with the present invention made up of an assembly of the shims shown in Figures 7 to 9, showing the gas flow path:

Figure 11 is a plan view of two removable inserts for use in the present invention in the form of discs having wings, and a spacer ring therefor;

Figure 12 is an end elevation of an assembly of the Inserts of Figure 11 stacked along a common axis;

Figure 13 is a cross-sectional view of the assembly shown in Figure 12;

Figure 14 is a perspective view of a further removable insert system for use in the present invention;

Figure 15 is a perspective view of a stack of the inserts of Figure 14;

Figure 16A is a cross-sectional view of a heat exchanger assembly comprising the Inserts of Figure 15;

Figure 16B is a close-up view of the assembly of Figure 16A;

Figure 17 is a plan view of a spacer ring for use with the assembly of Figure 16A;

Figure 18A is a plan view of a further spacer ring for use with the assembly of Figure 16A; and

Figure 19 is an elevation of a composite shell and tube heat exchanger/reactor.

Figure 20 is an elevation of a composite shell and tube heat exchanger/reactor complete with inserts.

Figure 21 is a plan view of a plate used to construct the shell and tube heat exchanger/reactor as shown In figures 20 and 21.

Figure 22 is a plan view of a plate used to construct the shell and tube heat exchanger/reactor as shown in figures 20 and 21.

[0028] In Figures 1 and 2 is shown length (l) of a thin sheet metal insert 10 in the form of a metal sheet folded to form a corrugated secondary finning having a height (measured from peak to peak) of h, and a width of w (see Figure2). By way of example only, the finning may have from 5 to 30 fins, or peaks, per 25 mm length. The metal sheet is typically made of stainless steel sheet of 0.05 to 0.5 mm thick or aluminium alloy 0.15 to 0.5 mm thick. The dimensions l, h and w of the insert 10 are selected to fit in flow passages of a heat exchanger or chemical reactor as described below. The fins 12 of the corrugations are provided with a series of holes 14 through the thickness of the fins if there is injection of a second fluid involved.

[0029] In Figure 3 there is shown a heat exchanger or chemical reactor comprising a body 11 constructed from a stack of plates 16. made of aluminium alloy typically 1.0 to 10 mm thick, or made of stainless steel 1.0 to 10 mm thick bonded together. In the case of aluminium plates, they are bonded together by soldering or brazing them together in a manner well known per-se. In the case of stainless steel plates they are either brazed or diffusion bonded together. Only the top plate 18 is visible in the drawing. The depth (d) of the stack of plates 16 (measured from top to bottom of the stack as seen in Figure 5) is slightly greater than the width (d) of the insert 10 if insert 10 is recessed within the passageway.

[0030] Each plate 16 has a row of elongate slots 20 through its thickness, the slots extend across each plate leaving a non-perforated peripheral margin 22 by which the stack of plates 16, 18 may be bonded together. The slots 20 in each plate are aligned with each other to define flow passages 20 through the stack. For plate 16 only, there will be an additional slot In-between each pair of slots 20 to allow the utility/service stream to flow and exchange heat with the process stream.

[0031] Each slot 20 has a width (h') a little less than the height (h) of the corrugations of insert 10, and a length (l') a little larger than length (l) of the insert 10.

[0032] As shown in Figures 4, 5 and 6, a length of insert 10 equal to, or preferably marginally less then, the length l of the slot 20, is pressed into place Into the passageways 20 formed by the slots. For reasons of clarity, the individual plates 16 making up the stack are not shown in Figure 5 and the stack is shown as if it were a monolithic block. In a passageway of length from 5.08 cm to 45.72 cm (2 inches to 18 inches) the finning may be, for example, from 0.0254 mm to 0.0772 mm (0.010 to 0.030 inches), that is to say 0.0508 mm (0.020 Inches) less in length than the slot. The finning of the insert 10 extends for almost the entire length of each slot 20 and for almost the entire depth (d) of the stack of plates. Each insert 10 is an interference fit in each slot 20 because the height (h) of the insert 10 is slightly more than the width (h') of the slot 20 by about 25 to 50 microns. As a consequence of the interference fit, the peaks of the corrugations will exert a considerable load at the contact areas with the walls of the passageways, thereby ensuring good thermal contact in those areas.

[0033] It will be appreciated that the excess height of the corrugated finning relative to the passageway it is to enter will determine the force of the interference fit with the passageway wall. Clearly such force must not be so great that the load required to insert the finning damages the finning but must be sufficient to cause adequate distortion to allow the Interference fit to take place and to retain sufficient lateral force to keep the inserted finning in position. The skilled man of the art will readily be able to determine appropriate dimensions for his particular circumstance.

[0034] Where the assembly is intended to be used as a chemical reactor, the finning may be coated in known manner with a catalyst. If the catalyst is of poor thermal conductivity, it may be preferable to prevent coating at the fin peaks, e.g. by masking, or to remove, e.g. by abrading, the coating from the peaks before the finning Is Inserted.

[0035] The insert 10 is fitted in a slot 20 by pushing it in to the slot, and can be removed by pushing it out of the slot when it is desired to remove it.

[0036] Once the catalyst has become depleted or poisoned from use of the reactor, the reactor can be removed from its installation and the member can then be removed, e.g. at an appropriate service depot. A new coated member may then be inserted, the reactor safety tested and then returned to service.

[0037] Figures 7 to 10 show an alternative design of removable insert 10 in the form of shims for insertion into circular cross-sectional slots 20 in the plates 16 or In the bores of tubes of a tube and shell heat exchanger of the type shown in Figures 19 and 20. Typically the shims will be made of thin sheets of stainless steel (typically 0.1 to 0.5 mm thick), aluminium, (typically 0.1 to 0.5mm thick) or similar thermally conductive materials. The shims 100,101 can be manufactured by means of photo-chemical etching, blanking tools or another convenient means, and have a series of castellations formed along two sides of each shim. The pitch (p) of the castellations along the shims are in the range of 0.1 mm to 10 mm. The width (h) of the shims will typically be within the range 1 mm to 10 mm, and the length (l) of the shims would be in the range of 25 mm to 250 mm, depending on the width (h') and length (l') of the slots 20 in the stack of-plates 16 of the heat exchanger or reactor. The exact width (h) of the shims is chosen so as to provide a 'force fit' within the slots 20.

[0038] The shims 100 and 101 are identical except that the castellations of one shim 101 is offset from those of the other shim 100 by one half pitch. This is achieved by providing each shim with two accurately positioned holes 102. If shims 100 and 101 are placed together with these holes 102 perfectly aligned, then the castellations of each shim would not be coincident.

[0039] The spacer shim 103 shown in Figure 9 is preferably manufactured from the same material as that used for shims 100 and 101 and will be of the same length (l) but the width (h) is typically only 25% of the widths (h) of shims 100 and 101. The spacer has two holes 104 identical in position and size to those in shims 1 and 2. The shim thickness will be selected in known manner to influence the flow characteristics of the fluid through the shim assembly. Where the insert 10 method is to be used in a chemical reactor the shims 100, 101, 103 are coated with catalyst before the assembly is made, but could be coated when assembled.

[0040] The insert 10 is made by sliding the shims 100, 101 and 103 onto two spaced temporary jig rods (not shown) which are a sliding fit in the holes 102,104 in the shims. The order of assembly is shim 100, spacer 103, shim 101, spacer 103 In sequence until the desired number have been loaded onto the tool, The length of the pins must be at least as long as the reactor is deep in the process stream flow direction.

[0041] The shim insertion into each slot 20 is accomplished by placing the reactor body formed by the stack of plates 16 on the base plate of a suitable press so that the slots 20 are vertical. The insertion tool with the stack of shims 100, 101, 103 is then placed on top of the reactor immediately above a slot 20 and perpendicular to the base plate. The press platen is then lowered onto the base of the intermediate member and the shim assembly forced into the slot 20. Once the base plate of the tool has reached the top of the reactor, the tool may be withdrawn leaving the insert 10 firmly located within the slot. The operation is then repeated for each slot 20. The overall assembly and the fluid flow paths are shown schematically in Figure 10.

[0042] Removal of the insert at the end of the useful life of the catalyst uses a similar process but the tool used would be a solid metal blank having a sliding clearance in the slot which is used to push the inserts out of the slots 20.

[0043] In an alternative embodiment to that shown In figures 3 to 6 the heat exchanger/reactor could be constructed from circular plates containing holes Instead of slots. Figure 19 shows this arrangement. The body 500 of the heat exchanger/reactor is constructed from a stack of plates 501,502 made of stainless steel and bonded together. The plates 501,502 (detailed in figures 21 and 22) consist of a series of rings 505 joined by half thick ligaments 504. The ligaments 504 are also attached to an outer ring 503. When plates 501, 502 are stacked together rings 505 form a series of tubes for the process fluid to flow through. The shell formed by the outer rings 503 allow the utility/services fluid to flow around the tubes and exchange heat with the process fluid. To enable the utility fluid to flow around the tube the ligaments of plates 501, 502 have different orientations. End plates 510 having the same hole pattern as plates 501, 502 are also included and are placed at the top and bottom of the stack to prevent the utility/service fluid escaping. A flange 509 is welded to the body 500 to allow the heat exchanger to be connected to the pipework delivering the process fluid to the heat exchanger/reactor. Unions 508 are welded to the body 500 to allow the utility/service fluid to enter and exit the exchanger/reactor.

[0044] The removable inserts 10 of Figures 11 to 18 are in the form of annular discs 200, 201 for insertion into circular cross-section slots 18, 20, 507 formed in the plates 16 (Figure 1) or plates 501, 502 (Figure 19), instead of the elongate slots 20 shown in Figures 1 to 4. Each disc has wings or vanes 203, and a keyhole central hole 204. Washers 205 hold neighbouring discs apart. When the discs are assembled in alternation they form a complete circle as shown in Figure 12.

[0045] The faces of the vanes are coated with a catalyst; either all of the faces are coated or just some. A rod or tube 206 is used to hold the discs in alignment for insertion into a passageway formed by the slots 507. The discs and the spacer ring sit on the outside of the tube 206. The rod or tube 206 may be left in situ or it may be removed. If a tube 206 is used and left in situ, the bore of the tube may form a passage for the flow of fluid therethrough.

[0046] Figure 14 shows further removable inserts in the form of member 300, 301, 302 for insertion into the circular cross-section slots 507 formed in the plates 501, 502 of Figures 19 and 20 or in the bores of tubes. Each member, for example 300, is made of aluminium sheet (typically 0.1 to 0.5 mm thick) or stainless steel (typically 0.1 to 0.5 mm thick) and has a pair of concentric rings 305, 306 interconnected by half thickness radial spokes 307. The inner ring 306 defines a generally circular aperture 304. Emending radially from circumference of each outer concentric ring 305 is a plurality of protrusions 308 that, in plan, appear as relatively large castellations extending around the circumference. The protrusions 308 are approximately one half of the thickness of the thickness of the outer ring 305. In a particularly preferred embodiment the protrusions 308 are or are about 0.25 mm thick, adjacent protrusions 308 being separated by a gap of or about 0.5 mm. The members 300, 301, 302 are formed by photo-chemical etching-or other convenient means.

[0047] The inner ring 306 of each member may have means (not shown), such as a protrusion extending into the aperture 304 (as shown in relation to spacer discs 400, 401), or a recess extending radially from the aperture (as shown In relation to discs 200, 201) to ensure that the members 300, 301, 302 are located with the correct or desired orientation when assembled in a stack along a common axis on a rod (not shown) that has a feature that engages the protrusion or recess on the members 300, 301, 302, to correctly orientate the members relative to each other. A stack of three members 300, 301, 302 is shown in Figure 15.

[0048] The spokes 307 may have either or both of their major surfaces coated with a catalyst. The coating operation may be completed before assembly of the members 300, 301, 302 Into a stack or once they have been located on the rod (not shown).

[0049] Once the members 300, 301, 302 have been located on a rod, the insert so formed (assembly 310) may be located within a circular cross section passage defined by circular cross section slots 507 in the plates 501, 502 as shown in Figures 19 and 20 or in the bores of tubes 350. Adjacent inner and outer rings 305, 306 of the members 300, 301, 302 are in abutting relations, thereby forming inner and outer cylindrical columns.

[0050] The protrusions 308 on each member 300, 301, 302 or slot 507, are sized such that their peripheries defines a circumference which is larger than the internal diameter of the tube 350. Consequently, as the assembly 310 is forced into the tube 350 in the direction indicated by the arrow 'Z' (figure 16A), the protrusions 308 are bent as is illustrated, providing an interference fit between the members 300, 301, 302 and the walls of the tube 350. The fit between the members 300, 301, 302 and the wall 350 ensures that there is good thermal conductivity between the members and the walls of the tube 350 and that the assembly 310 is firmly retained within the tube 350.

[0051] Once the assembly 310 is located within the tube 350 or the slot 507, the rod (not shown) is removed. A modified member (not shown), identical to the members 300, 301, or 302 but without a central aperture 304 may be placed over each of the assembly 310 to obturate the hole 304 to ensure that no fluid by-passes the assembly 310 via the aligned central apertures 304.

[0052] To remove the members 300, 301, 302 from the tube 350 or slot 507 for the purposes of replenishing the catalyst, cleaning or the like, they are pushed in the direction of arrow Z.

[0053] Figure 15 shows a preferred arrangement of members 300, 301, 302 wherein any fluid flowing passed the spokes 307 is encouraged to adopt a tortuous path. Such a motion increases the contact time between the fluid and the catalyst-coated surfaces of the spokes 307, increasing the reaction rate.

[0054] If a greater gap between the members 300, 301, 302 Is required, spacer rings 400, 401 can be used. As illustrated in Figures 17 and 18A, the spacer rings 400, 401 can have an inner ring 406, 406' and an outer ring 405, 405' with thin radial spokes 407, 407' extending therebetween. The inner rings 406, 406' define a generally circular aperture 404, 404'. Protruding into each is a tab 420, 420' to provide means for correct and desired orientation within the tube 350. The insertion rod will have a corresponding recess along its' length.

[0055] The rings 400, 401 may be mounted on the rod at any desired location to adjust the spacing between adjacent members 300, 301, 302. The rings 400, 401 are sized and shaped so that they do not adversely interrupt the flow of fluid through the heat exchanger. Preferably, the spokes 407, 407' are half the thickness of the inner 406, 406' and outer 407,407' circles.

[0056] It Is to be understood that the tube and shell heat exchanger of Figures 19 and 20 could be of a conventional design consisting of spaced tubes (not shown) corresponding in position to the slots 507 in the plates 501, 502 of Figure 19, extending between header plates (equivalent to the plates 509 of Figure 19) with the tubes located in an outer shell (not shown) so that heat exchange fluid flows around the tubes whilst process fluid flows through the bores of the tubes. In such an arrangement, the discs 10, 200, 201, 301, 302 of Figures 7 to 18 would be inserted in the bores of the tubes.

Claims

1. A heat exchanger or chemical reactor comprising a heat exchange body (500, 350) defining one or more fluid flow passages (507) and a removable insert (200, 201, 300, 301, 302), **characterised in that** the insert comprises a series of contacting plates (200, 201, 300, 301, 302) stacked along a common axis and engaged in interference fit within one of the flow passages (507), thereby to provide secondary heat exchange surfaces in thermal contact with the primary wall surfaces.

2. A heat exchanger according to claim 1, wherein the body (350, 500) comprises a stack of plates (16) each of which has one or more slots (20) that when the plates are stacked define said one or more passages (20).

3. A heat exchanger according to claim 1, wherein the body (350) comprises an elongate tube (350) with the bore of the tube constituting the flow passage.

4. A heat exchanger according to any one of claims 1 to 3, wherein the insert (10) carries a catalyst.

5. A heat exchanger according to any one of the preceding claims, wherein the series of contacting plates (200, 201, 300, 301, 302) include spacers (205, 400, 401).

6. A heat exchanger according to claim 5, wherein the plates (200, 201 or 300, 301, 302) are circular discs.

7. A heat exchanger according to claim 6, wherein the plates (200, 201) have radially extending vanes (203).

8. A heat exchanger according to claim 7, wherein the plates (200, 201) are stacked along the common axis with the vanes (203) of alternate plates (200, 201) aligned with each other and the vanes of one set of plates (200 or 201) offset circumferentially relative to the vanes of the other set of plates (200 or 201).

9. A heat exchanger according to any one of the preceding claims, wherein each plate (300, 301, 302) comprises two concentric rings (305, 306) interconnected by half thickness radial spokes (307).

10. A heat exchanger according to claim 9, wherein the plates (300, 301, 302) are stacked along the common axis with the spokes of alternate plates (300) aligned with each other and the spokes of one set of plates (300 or 301 or 302) offset circumferentially relative to the spokes of the other set of plates (300 or 301 or 302).

11. A heat exchanger according to claim 9 or claim 10, wherein the plates are provided with radially extending circumferentially spaced flanges (308) around the circumference of the outer ring (305).

12. A heat exchanger according to any one of the preceding claims, wherein the first fluid flow passages (507) are of a circular cross sectional shape.

13. A heat exchanger according to claim 11, wherein the flanges (308) project radially at a distance relative to the diameter of the slot (507) so as to constitute an interference fit when one of the inserts (10) is inserted in a slot (507).

14. A heat exchanger according to any one of claims 6 to 11, wherein the plates (200, 201, 300, 301, 302) are mounted on an elongate rod.

15. A heat exchanger according to any one of claims 6 to 11, wherein the plates (200, 201, 300, 301, 302) are mounted on an elongate tube (350).

16. A heat exchanger according to any one of claims 6 to 11, wherein the plates (200, 201, 300, 301, 302) have a central hole (404).

17. A heat exchanger according to claim 16, wherein the end plate (200, 201, 300, 301, 302) of the stack of plates (200, 201, 300, 301, 302) does not have a central hole (404) and serves to close off the central holes (304) of the other plates (200, 201, 300, 301, 302) in the stack.

18. A heat exchanger according to any one of the preceding claims, wherein the plates (200, 201, 300, 301, 302) are of a complementary shape to the cross sectional shape of the slot (507).

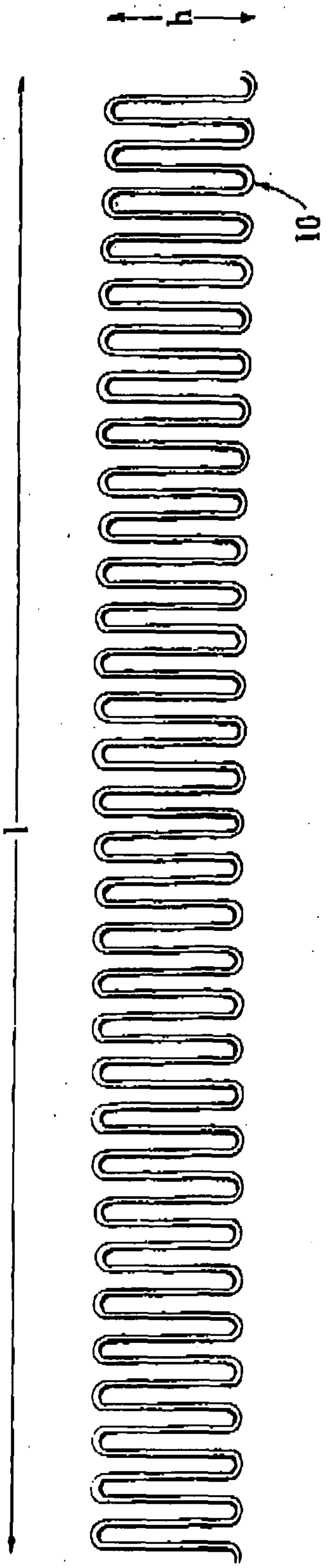

FIG. 1

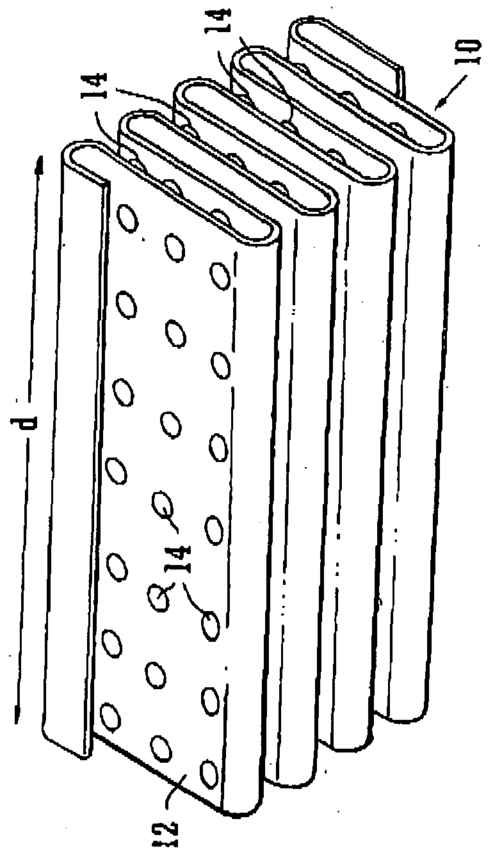

FIG. 2

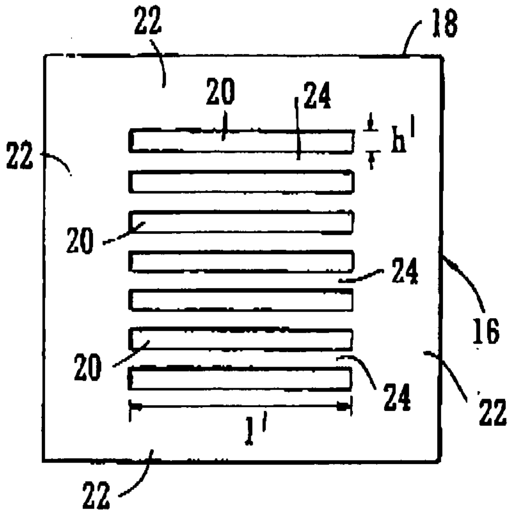

FIG. 3

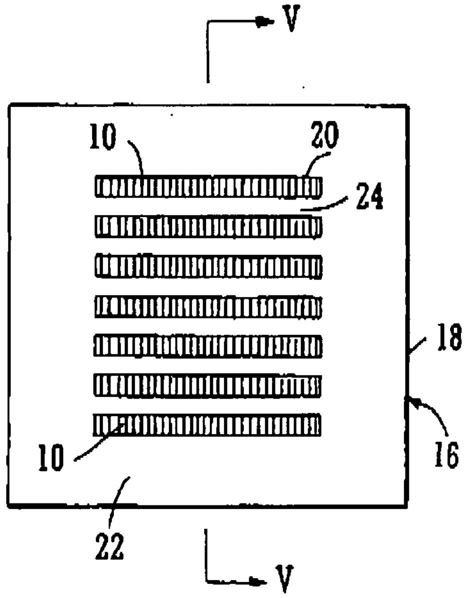

FIG. 4

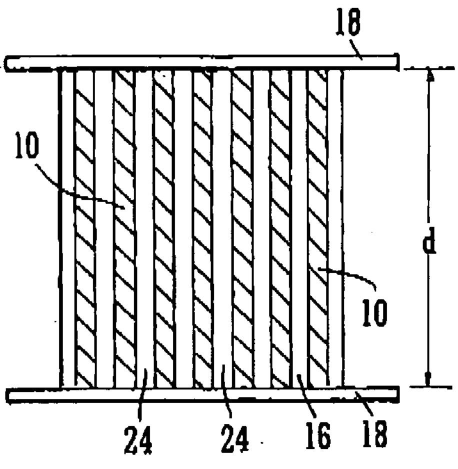

FIG. 5

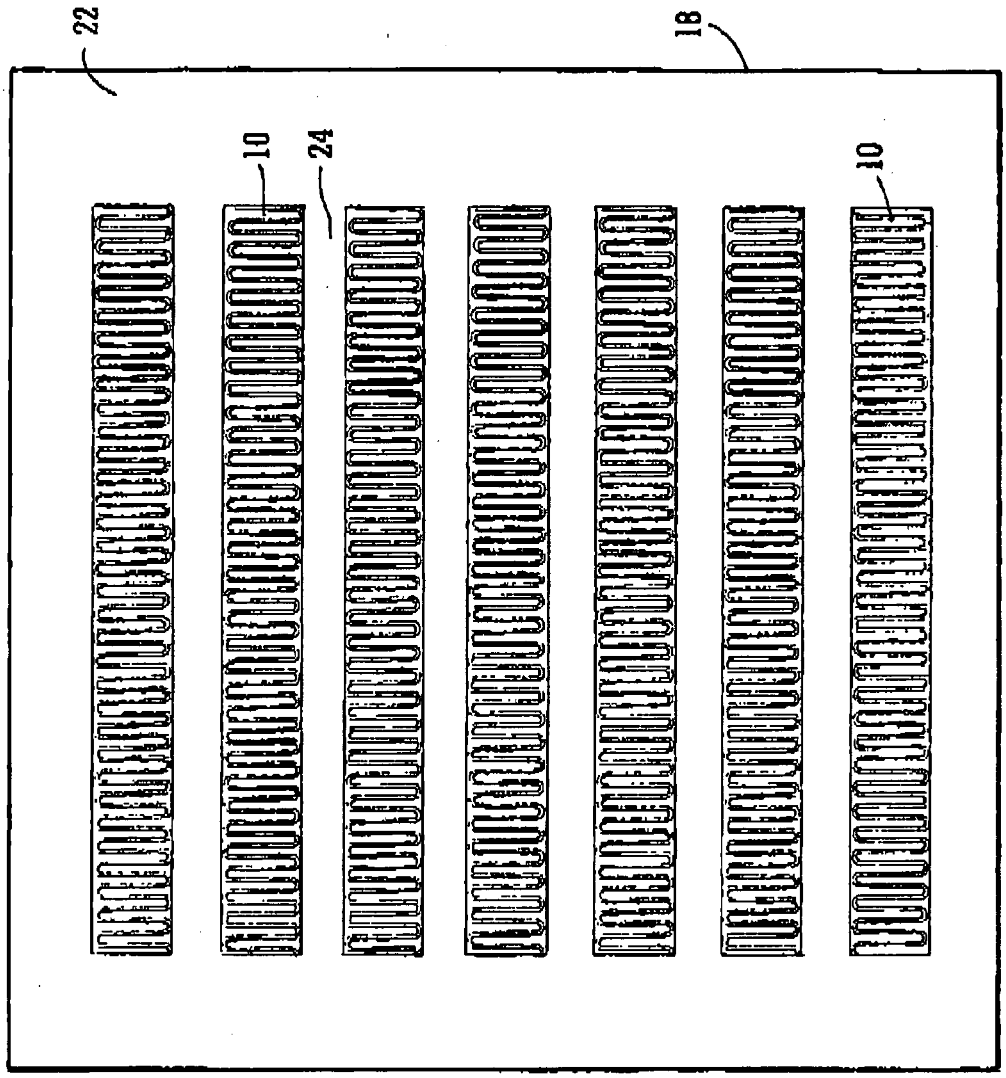

FIG. 6

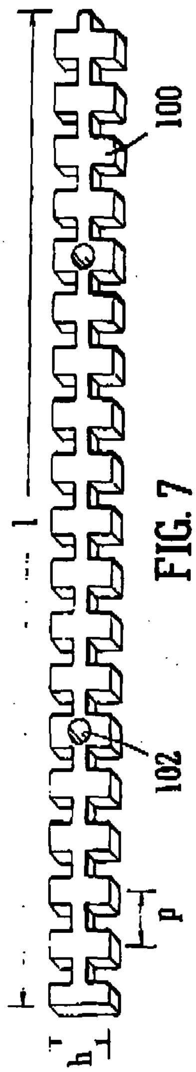

FIG. 7

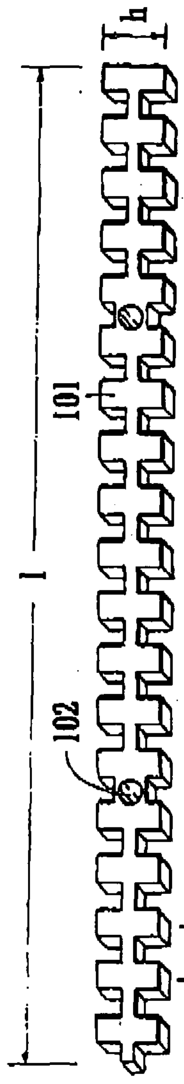

FIG. 8

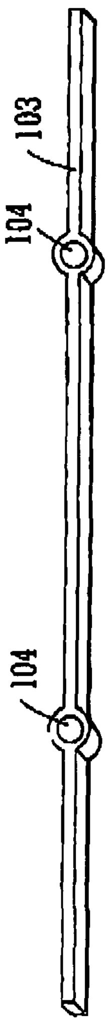

FIG. 9

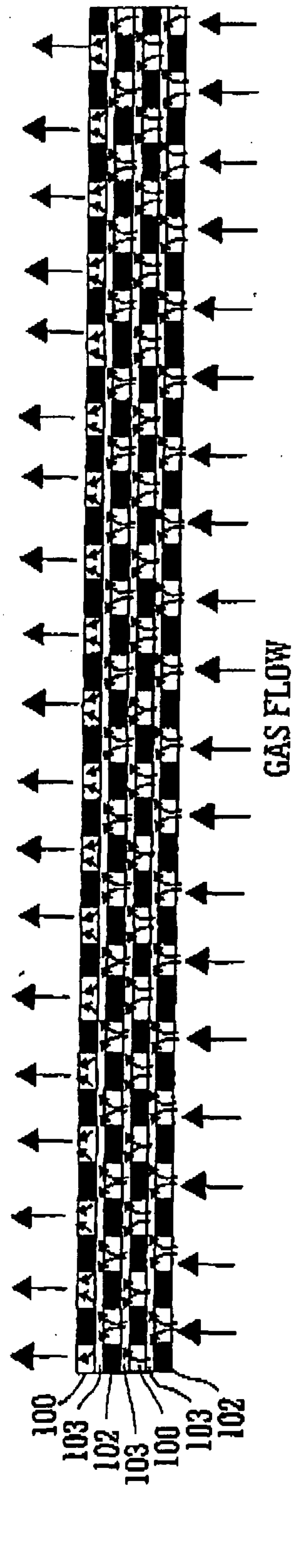

FIG. 10

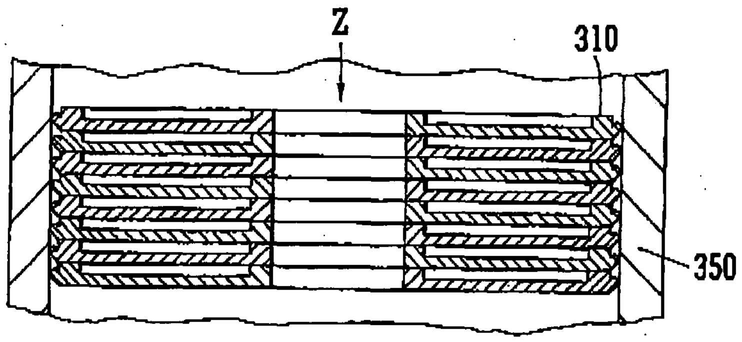

FIG. 16A

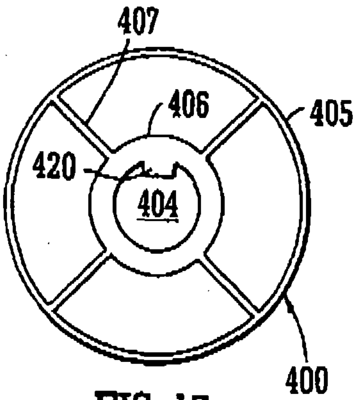

FIG. 17

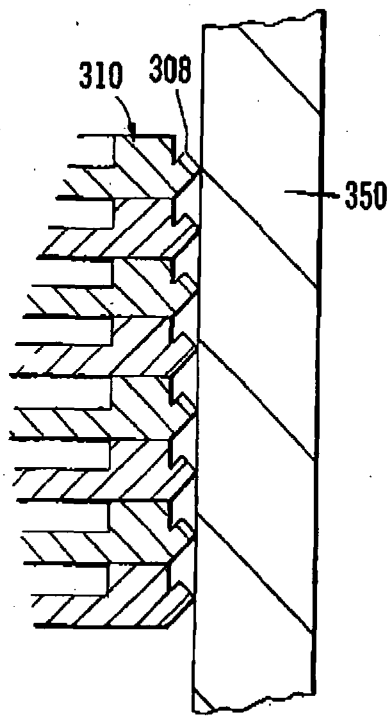

FIG. 16B

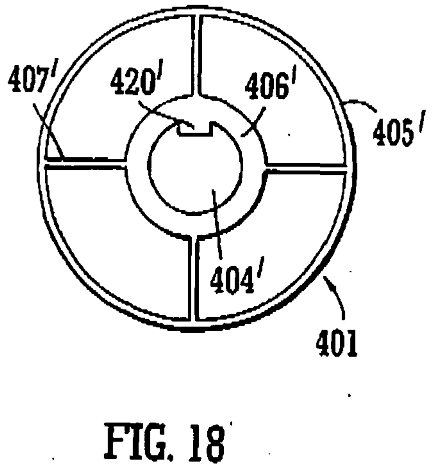

FIG. 18

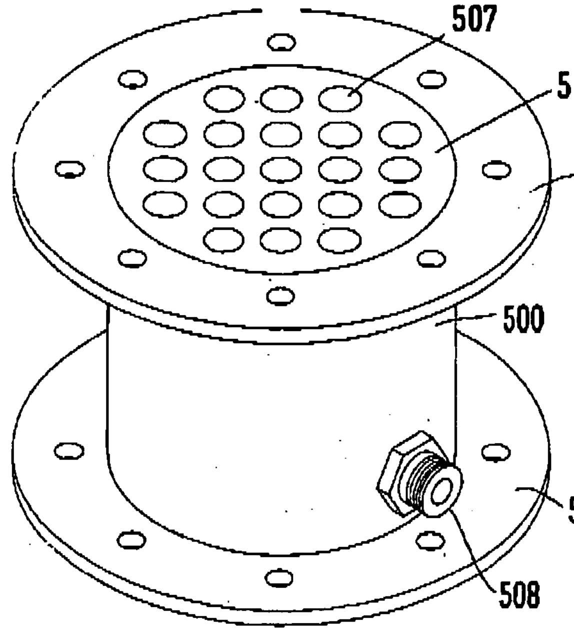

FIG. 19

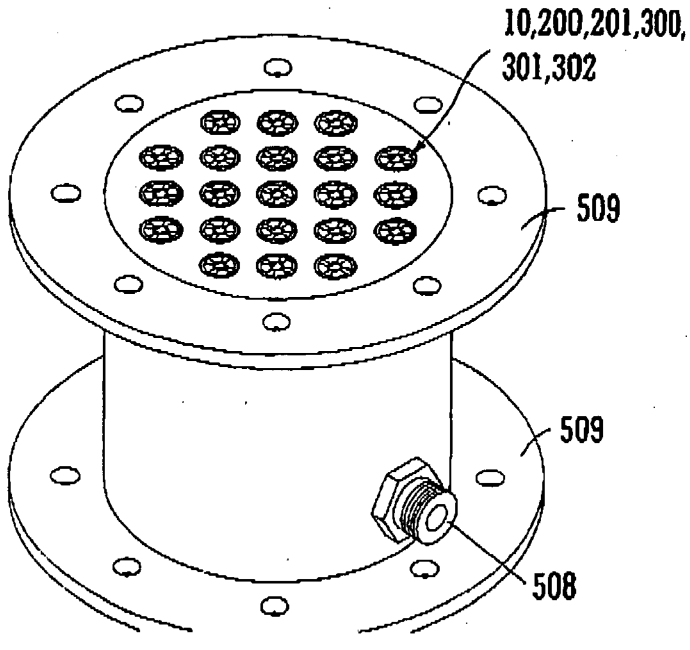

FIG. 20

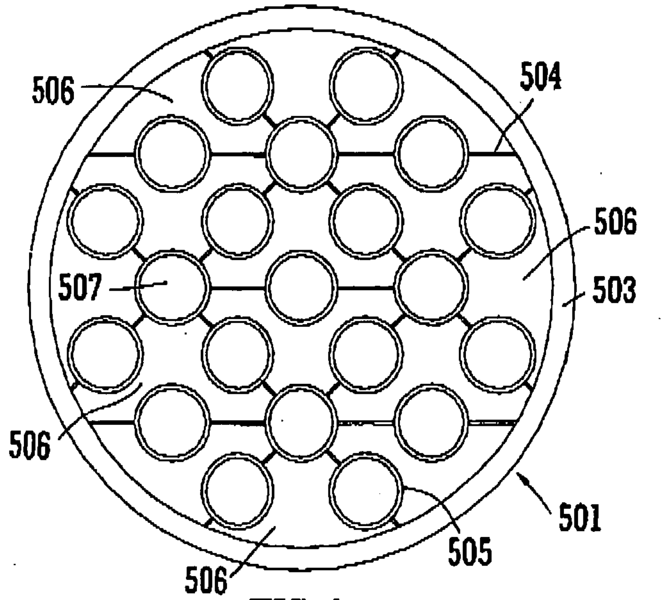
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FIG. 21

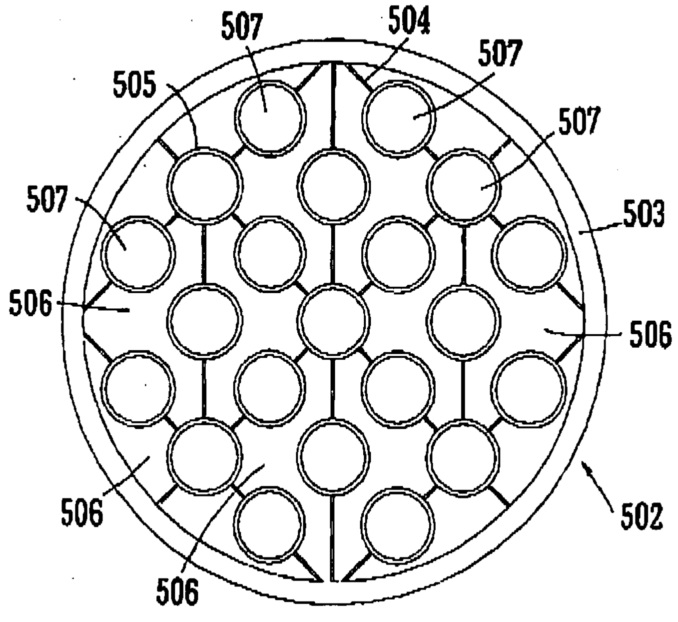
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FIG. 22

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- WO 0034728 A **[0022] [0023]**