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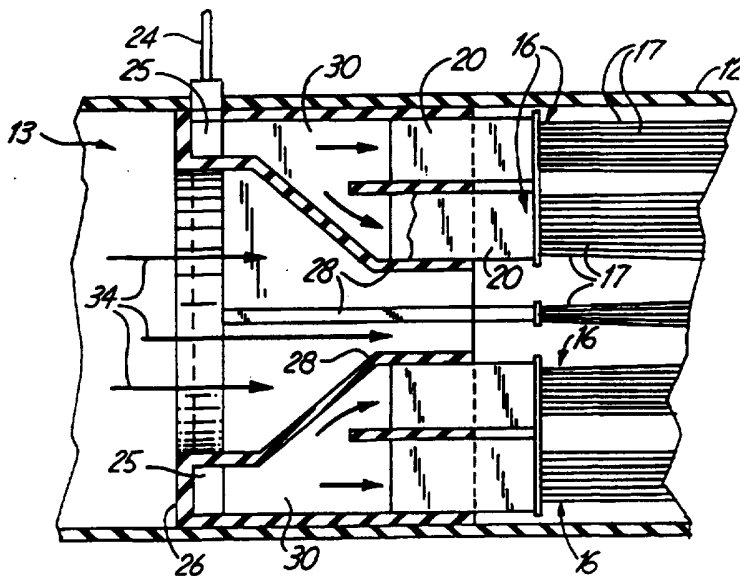
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(54) Title: GAS TRANSFER MANIFOLD AND METHOD OF CONSTRUCTION



(57) Abstract

A manifold (26, 26A, 26B, 81) for a plurality of microporous hollow fibers (17) used for transferring fluids into another fluid such as a gas to a liquid. The fibers (17) are formed into small packets (16, 16A, 16B), and secured into the manifold (26) in position to permit fluid under pressure to be introduced into the lumens of the fibers (17). The manifold (26, 26A, 26B, 81) has a plurality of hollow fins (28) forming pockets (28, 80) for receiving a molded block (20, 20B) of material, holding the fibers (17). A second fluid, such as a liquid, is introduced through the center of the manifold (26, 26A, 26B, 81) so that it flows over the fins (28) and the fibers (17) for permitting a gas to be transferred between the fibers (17) and the liquid. The modular construction makes molding and holding the fibers (17) easy.

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**GAS TRANSFER MANIFOLD AND
METHOD OF CONSTRUCTION**

BACKGROUND OF THE INVENTION

The present invention relates to the potting
5 or mounting of hollow-fiber membranes or tubing into
manifolds that can be used in gas-liquid, gas-gas, and
liquid-liquid membrane contactors for gas dissolution
and various separation applications including dissolved
gas removal, pervaporation, and filtration. These
10 contactors use sealed-end hollow fibers or flow-through
hollow fibers.

The manifolds in previous membrane contactors
had two functions: (1) the delivery of material to or
removal of material from the lumen of the hollow fibers
15 and (2) the containment of the hollow fibers and potting
agents during manufacture. Manufacture typically
employed centrifugation to force the potting agent or
uncured adhesive into the spaces between the individual
fibers and the spaces between the fibers and the walls
20 of the manifolds. Manifold design was constrained by
fiber-potting or fiber mounting requirements.

U.S. Patent No. 5,034,164 illustrates a
bubbleless gas transfer device and process, wherein
hollow fibers are supported in a housing or manifold and
25 carry a gas under pressure for transfer to a liquid.
All of the fibers that are used in the device shown in
Patent '164 are mounted in a single chamber of a
manifold. This mounting normally requires the use of a
centrifuge to force an uncured adhesive into spaces
30 between a fiber bundle and the walls of the manifold.
Centrifuging is a time consuming operation.

SUMMARY OF THE INVENTION

The present invention in one aspect relates to
a modular fiber packet used in a manifold for supporting

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hollow fibers for fluid transfer to or from a surrounding fluid. The mounting of small packets of fibers which can be formed in an efficient manner to simplify the manufacturing of the fluid transfer manifold. The fibers are assembled into individual packets of at least five, up to several hundred fibers potted or molded into a small block of material which fits into hollow fins or support pockets formed on the interior of the manifold. The hollow fins are open to the ends of the hollow fibers in each of the packets. The lumens of the fibers carry a fluid. The fluid from the interior or the exterior passes through the walls of the fibers in a desired manner, preferably through bubbleless transfer when gas is provided under pressure to the lumens and is transferred to a liquid. The outer ends of the fibers can be plugged to prevent bubbling from the ends.

The present invention also relates to an improved manufacturing process which no longer uses the manifold in the potting or mounting of hollow fibers. Instead the hollow fibers are first assembled into packets or bundles held by a block of molded material. A small length of the block is cut away to expose the lumen of the hollow fibers. The block is then inserted and glued into place inside a support pocket or slot located on the manifold. The manifold can be almost any shape, because the manifold is not used in the potting of the hollow fibers. The minimum design requirements for the manifold are inclusion of a plenum for distributing gases or liquids to or from the lumen of the fibers and inclusion of one or more pockets to hold the blocks containing the potted fibers. The advantage of this process is reduced manufacturing costs compared

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to centrifugation, more flexibility in the design of manifolds, and greater quality control.

The fins and the manifold can be molded from plastic materials and assembled into a liquid carrying conduit. Water or other liquid is permitted to flow through the interior of the manifold, past the fins and through the conduit along the fibers. As the gas under pressure passes from the fibers into the liquid, the desired gas transfer takes place.

The packets of fibers are of size so injection of a quick setting potting material can be used without damaging the fibers and while insuring that the material fills the spaces between fibers. Several packets then are used to complete the manifold construction having several thousand total fibers.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of a gas transfer device having a manifold made according to the present invention installed therein;

Figure 2 is an enlarged vertical sectional view of the manifold of Figure 1;

Figure 3 is a sectional view taken as on line 3--3 in Figure 1;

Figure 4 is a schematic representation of a typical winding wheel used in a first step or forming the fiber packet in goods of the present invention;

Figure 5 is an enlarged schematic view of a typical corner of the wind-up wheel of Figure 4, showing schematically, the positioning of molds for molding blocks onto ends of fibers to form the fiber packets;

Figure 6 is a sectional view taken as on line 6--6 in Figure 5;

Figure 7 is a schematic side view of a partially finished fiber packet insert for a flow-

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through membrane contactor, after molding blocks of potting material on opposite ends of the fibers;

Figure 8 is a schematic side view of a typical fiber packet for a sealed and membrane contactor prior to insertion into a manifold;

Figure 9 is a sectional view of a flow pipe of a modified form of the invention having manifolds at each end of the flow pipe to support both ends of hollow fibers to create a flow-through membrane contactor; and

Figure 10 is a fragmentary part sectional view of a manifold that is elongated along a longitudinal axis, so that packets of hollow fibers are supported in pockets or fins along the longitudinal length of the manifold.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to Figure 1, a typical gas transfer device illustrated generally at 10 includes an outer conduit or tube 12 through which liquid will flow from an inlet end 13 to an outlet end 14, for purposes of illustration. A plurality of microporous, small hollow fibers 17 formed into fiber packets of bundles indicated at 16 are mounted on a manifold positioned on the interior of the tube 12. A liquid flow can be established with a pump illustrated at 18 if desired.

The small fiber packet inserts 16 are formed as shown in Figure 2 for example, and include the plurality of individual hollow fibers 17 mounted in a suitable molded on block 20 of a potting or molding compound molded around and between the end portions of the individual hollow fibers 17. The openings to the lumens of the hollow fibers 17 are kept open for receiving a fluid such as gas from a gas source 22 through a suitable conduit 24, that in turn connects through a fitting to an annular plenum passageway 25 of

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a manifold assembly 26. It should be noted that the exchange can be between two fluids, and there can be removal of gasses from a liquid as well as adding gas to a liquid as well as gas to gas transfer. The fiber lumens can carry a fluid, either a liquid or a gas.

The individual fiber packets 16 are installed in the manifold assembly 26, which as shown fits within the tube 12. The manifold 26 includes a plurality of pockets or fins 28 that extend radially around the center of the manifold 26.

The fin 28, as shown, are hollow pockets having end portions 30 adjacent the base of the manifold 26 fluidly connected to the plenum 25. Thus, the gas from source 22 under a suitable pressure is present in the pockets 28 and is introduced into open ends of the microporous tubular fibers 17 in each packet 16.

The fiber packet molded blocks 20 are suitably secured in the pockets or fins 28 of the manifold 26 so that the fins 28 are sealed at the ends facing downstream into the tube 12, to insure that gas does not bubble out around the packet insert molded block 20. This can be done by using suitable adhesives that will fill any voids between the walls of the fins 28 and the blocks 20, as well as serving to adhere and hold the fiber packets 16 in place in the individual fins 28.

There are a plurality of the hollow fins 28 around the interior periphery of the manifold 26. The number of fins 28 can be changed to suit conditions as desired. Note that there are eight fins 28 shown in Figure 3. For clarity all of the fins 28 are not shown in Figure 2.

The hollow fibers 17 are made to be relatively long in relation to the size of the molded blocks 20, and extend along the length of the tube 12 as desired.

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The hollow fibers 17 will spread out from the effects of fluid flow past the fibers 17. Flow passes through the interior of the manifold 26 into the tube 12 and is shown by the arrows 34, in Figure 2.

5 The transfer of gas (oxygen) takes place by providing pressure differentials between the fluids. For example, pressurized gas from the source 22 applied to the lumens of the hollow fibers 17. The individual hollow fibers 17 have their remote ends plugged for
10 bubbleless gas transfer, as described in U.S. Patent 5,034,164. The sealed end fibers can also be pressurized so that small bubbles are generated along the length of the fiber. The walls of the hollow fibers 17 preferably are microporous membrane walls, and can be
15 manufactured of high polymer material such as polypropylene, polyethylene, polytetrafluorethylene, and other similar microporous materials made by known processes. The hollow fibers 17 typically are between 100 and 400 microns in diameter and the walls may be 25
20 microns in thickness. The wall pores are very small, for example, between 0.02 and 0.2 microns. Typically, the hollow fibers 17 shown will be in the range of 1 meter long.

 If the ends are to be plugged, it can be done
25 as will be described in connection with the process for making the fiber packet inserts 16. The pressure of the gas from the gas source 22 can be maintained below the bubble pressure of the membrane walls of the hollow fibers 17, for example between 40 and 60 psi. If
30 desired, the hollow fibers 17 can be wetted or treated at selected locations for permitting liquid that may form on the interior to escape outwardly, also as taught in U.S. Patent No. 5,034,164.

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5 Microporous fibers that are sold under the trademark CELGARD by Hoechst Celanese of Charlotte, North Carolina, USA are suitable and can be used with the present invention as can gas permeable membranes manufactured by Mitsubishi Rayon Company Ltd. of Tokyo, Japan.

10 Gas is continuously supplied to the lumens of each of the hollow fibers 17, through the manifold assembly 26, and in particular through the hollow fins 28 at the base end of the hollow fibers 17.

15 A valve 24A can be provided and used to switch to a vacuum source 25. Then the pressure differential would cause a removal of gas from the liquid in tube 12. Also, liquid (a fluid) can be passed through the fiber lumens for exchange with a gas on the outside of the fiber.

20 It also can be noted that while the tube 12 is illustrated as being horizontal, the orientation of the hollow fibers 17 can be as desired, either vertical, at a selected standard size having molded on blocks 20 at the support ends.

25 The use of individual fiber packet inserts 16 greatly aids in molding the hollow fibers 17 without crushing them, and making the molding process relatively rapid with relatively fast drying potting materials. The individual fiber packet inserts 16 are modules that then can be slid into the individual pockets formed by fins 28. There are two such modular fiber packet inserts 16 in the pocket formed by each fin 28, as shown. Fins 28 that hold only one packet insert 16 can also be used. As can be seen in Figure 3, a fin 28 for one packet insert 16 could be placed between adjacent fins 28 extending radially inward from the outer support rim 29 about one-half of the radial distance of the fins

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28 that are shown. The manifold 26 can be formed by suitable molding techniques if the manifold 26 is made of plastic, as is preferred.

Individual fiber packet inserts 16 can be positioned to provide an adequate flow through area in the center of the manifold 26 for liquid to be pumped directly through the tube 12 from the inlet end 13. The tube 12 can be placed in a waste water treatment facility, or other areas where the fluid transfer is to take place and is easily done.

Forming the fiber packet inserts 16, or fiber modules can be carried out using relatively simple fixturing can be used. For example, as shown in Figures 4-8, a method of manufacturing can essentially comprise a winding wheel shown at 40 that has corner frame segments 44 held on spokes 41 extending from a hub and rotatably supported on a suitable shaft 42. The spokes 41 form a spider assembly 46 that is shown only schematically.

The wheel 40 can be rotated in direction as indicated by the arrow 48 about the axis of the shaft 42 either by manual movement or by a power drive. One or more hollow fibers 17 can be attached to the wheel 40, and as the wind-up wheel 40 is rotated, fibers that are on a rotatable drum supply reel indicated at 50 will be wound onto the wheel periphery and across the corners and formed into straight fiber lengths 45.

As can be seen in Figure 5, at each of the corners, the cross members 44 support separate insert molds 52 and 54. The molds 52 and 54 either include heaters or are near a heat source 45 so they can be heated. The molds 52 and 54 are channel shaped so the hollow fibers 17 lay in the molds 52 and 54 when the winding process is taking place. The individual hollow

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fibers 17 coming from the reel 50 are then rest into the channels of the molds 52 and 54 as the wind-up wheel 40 rotates, and the desired number of fibers 17 are built up into position around the wheel 40 so that the opposite ends of the fibers 17 on each end of the wheel 40 are positioned in one of the molds 52 or 54. For example, 400 to 600 fibers 17 can be placed in the molds 52 and 54 that have a width traverse to the fiber length of about 1 1/2 inches and a thickness of in the range of 1/8 inch. The length of the molded block 20 also may be about 2 inches.

As shown in Figure 6, the channel shaped molds 52 and 54 will hold a plurality of hollow fibers 17 schematically shown, and once the desired number of fibers 17 have been placed into the molds 52 and 54, the molds 52 and 54 are covered with suitable, removable covers indicated generally at 60. The end of the molds 52 and 54 also can have closing members as needed, but the fibers 17 cannot be crushed, as they must remain tubular. Fibers up to 2 mm diameters are used in some application particularly when made from tetrafluoroethylene (Teflon), as is desired for transferring ozone. At least 5 fibers are then molded in a packet. The small fibers described may be formed into packets of one to two hundred or more.

The covers 60 have an injector fitting 62 leading from an injector shown schematically at 64, which in turn supplies molding material from a source 66 and injects this material into the cavity 68 of the mold 52 that is shown in Figure 6. The material can be injected into the sides of the mold 52 also, if desired. The same process is used for the molds 54. Each of the molds 52 and 54 at the corners of the winding wheel 40 are then provided with the potting material that is

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used. The potting material sold under the trademark ALUMILITE has been found to be acceptable, and this is a liquid polyurethane based material that sets up quickly and can be easily injected. Other potting materials that will flow into the molds 52 and 54 under moderate pressure and can be cured are usable. Some resilience is desirable.

All eight molds are used and the fiber lengths in the molds are molded together as a bundle. Care is taken to avoid damaging the hollow fibers 17 that are near the edges of the molds, and to insure that each of the fibers is adequately potted in place. The hollow fibers 17 are held under a suitable tension on the wheel 40 during winding to insure the hollow fibers 17 remain straight. The width (thickness) of the mold is selected to be narrow so the molding material will enter the spaces between the hollow fibers 17 before setting up. This makes the packets 16 easy to form and easy to use as modules in manifold 26 of a wide variety of sizes.

When the molding material has set, the mold caps can be removed and the hollow fibers 17 are cut between molds at each of the corners of the wheel. Of course, the fiber 17 coming from the supply reel 50 will have been trimmed and held into place before the fibers 17 are molded in the molds 52 and 54.

Fibers 17 are removed from the winding wheel 40 and both ends of the fibers 17 will be held in a separate block of molded on material. As shown in Figure 7, the blocks 20A and 20B will be trimmed at the outer ends to remove flashing, and to insure that the exposed ends of the hollow fibers 17 are open to the interior of the hollow fibers 17 at inlet end 19 of block 20A and 20B. The block 20A is the block that is placed in the hollow fibers 17 of the manifold 26. The

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ends of the fibers in block 20B may thus be plugged, for example, by applying a liquid cement that flows into the interior of the hollow fibers 17 sufficiently far so that the block 20B can be reversed and the exposed ends remain plugged. The block 20B is then severed and the fiber packet insert 16 shown in Figure 8 is formed.

The block 20B also can be used in a double manifold arrangement shown in Figure 9, in which case the lumens of the fibers are opened as they are at block 20A.

The thickness of the molds 52 and 54, and thus of the molded block 20 is substantially less than the width of the block when a hundred or more hollow fibers 17 are molded in place. The narrow thickness is to insure that the liquid material will fill the spaces between each fiber so the hollow fibers 17 are properly potted in place without centrifuging. A suitable adhesive or glue is applied onto the molded block 20A of polyurethane, and the blocks are slid into the hollow fins 28 so that they will be securely held in place. Any suitable type of cement or glue can be utilized.

The free remote ends, or the entire lengths of the hollow fibers 17 can be coated if desired.

After the fiber packet inserts 16 have been inserted into the pocket formed by each of the manifold fins 28, the manifold 26 is ready to be placed into the tube 12. Thus, the manifold 26 construction gives rise to relatively rapid potting of small, easily molded packets of fibers that can be inserted into receptacles or holders in a manifold 26, which as shown are spaced apart so that water can flow between the manifold fins 28 and across the hollow fibers 17 for satisfactory, rapid gas transfer. The modular packet inserts 16 can be used in many different configurations.

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It should be noted that during the molding steps, the fibers 17 should remain under tension so that they remain straight and uniform in length.

Several of the fiber packet inserts 16 may be placed in each of the pockets of fins 28 so it is easy to assemble the manifold 26. The individual packet inserts 16 of fibers may also be glued together side by side for wider fins.

In Figure 9, a flow tube 75 is made to provide for a fluid inlet, as indicated by the arrow 76, and in this form of the invention, two of the manifolds such as that shown at 26 are included. There is a first manifold 26A that is constructed exactly as shown by the previous disclosure of manifold 26, and which has a plurality of packet fibers indicated at 16A extending therefrom. The difference in this particular construction is that a second manifold 26B is mounted on an opposite end of the flow tube 75 from the manifold 26A, and is made to receive the molded in blocks such as that shown at 20B holding remote ends of hollow fibers 17 after the blocks have been trimmed to insure that the lumens of the hollow fibers 17 are exposed. The blocks 20B, that are shown, are placed into pockets in the manifold 26B in exactly as that shown in connection with manifold 26A. In this form of the invention, the fluid flowing in as indicated by the arrow 76 will flow over the hollow fibers, and a gas (or other fluid) from a source can be introduced into a fitting 77 to the manifold 26B and flow through the hollow fiber, and then discharged from a gas outlet 78 from the manifold 26A.

The exchange of fluid, would include the gas flowing through the interior of the flow-through hollow fibers 17, which can be transferred into a separate fluid such as a liquid passing through the flow tube 75.

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There can be an increase the amount of fluid transfer between the gaseous fluid and the liquid, by controlling the gas pressure to a greater degree.

5 The fiber lengths of the hollow fibers 17, however are captured and the remote ends do not intertwine or intermesh as shown in connection with the structure of Figure 1, of course the removal of gas from the fluid flowing through the flow tube can be accomplished by applying a vacuum to either the gas
10 inlet or the gas outlet, and plugging the other one of the connections.

In Figure 10, a further modified arrangement is illustrated, where an elongated manifold 81 extends along the longitudinal axis shown at 79, and has a
15 plurality of individual pockets 80 formed therein. Pockets are of size to receive the molded blocks 20 of the fiber inserts packet 16. The blocks 20 are cemented in place in the pocket 80 as previously described in connection with the manifold 26. In this instance, a
20 connection 83 connected to a suitable fluid source is open to a plenum conduit 84, which in turn extends along the length of the manifold 81 and is open to each of the pockets 80 through suitable apertures, so that fluid, such as a gas, can either flow into or out of the hollow
25 fibers 17 forming the fiber packet inserts 16 shown in this form of the invention. In this instance, there could be flow along or across the manifold transverse to the hollow fiber length or past the manifold in direction longitudinally along the fibers 17, coming
30 from a suitable fluid source.

The linear arrangement or elongated arrangement of the manifold has advantages in certain installations where the circular type manifold is inappropriate for use.

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The operation of winding wheel 40 can be programmed for automatic operation to rotate the wheel 40 the desired number of times and then stop. The molding process also can be done by indexing the wheel 40 to position the molds on the wheel 40 during molding.

The procedure of using packets is applicable for holding a selected number of hollow fibers in an insertable assembly is useful for microbubble, bubbling and bubbleless applications.

The number of fibers included in each packet depends on the size of the fibers and the total number of fibers to be used in the manifold. Preferably, with the molded block dimensions listed before the packets will not contain more than about 400 hollow fiber membranes with an outside diameter of 300 microns, or about 170 hollow fiber membranes with an outside diameter of 415 microns, by way of example.

Generally, each packet will have in the range of 10% or less of the total fibers needed in an application. Each packet is thus smaller than a molding holding the total number of fibers needed in the manifold. This simplifies the bonding or potting of the fibers. The concept of the packets is to make the retaining of the fibers simpler by having small modular packets of fibers that can be easily retained in a block of molded material, and then as many packets as needed can be placed into a manifold.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

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WHAT IS CLAIMED IS:

1. A manifold assembly for transferring fluids through lumens of elongated fibers that have walls forming the lumens of the fibers, comprising at least one packet of individual fibers having at least one end molded into a block of material with the lumens of the fibers exposed at one end of the block of material, a manifold having a pocket for receiving the packet, said pockets being enclosed to form a passageway for transferring fluid to the exposed ends of the fibers, and said at least one packet being sealed to surfaces of said pocket with the fibers extending outwardly from the pocket.
2. The manifold of claim 1, wherein said manifold is elongated and has a plenum formed therein extending the length of the manifold with the pocket passageway being connected to the plenum.
3. The manifold of claim 1, wherein said manifold is circular in cross section and has a continuous plenum, the pocket passageway being connected to the plenum.
4. The manifold of claim 1, wherein said manifold includes an annular housing wall formed around a central axis, and wherein there are a plurality of pockets and a plurality of packets, said pockets being formed by wall members extending inwardly from outer edges of said annular wall.
5. The manifold of claim 4, wherein said pockets comprise hollow fins extending substantially radially relative to a center axis of the manifold.
6. The manifold of claim 5, and an opening for liquid flow through the manifold at an end of said

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manifold opposite from the end from which the fibers extend outwardly.

7. The manifold of claim 6, wherein said manifold is mounted in an open end of a tube, and said fibers have closed ends remote from the manifold and extend along the length of the tube, said liquid flowing inwardly from the opening of the manifold along an exterior of said fibers as the liquid flows through said tube.

8. The manifold of claim 7, wherein the closed-end hollow fibers have pores through walls thereof that permit gas to pass through, and the plenum of said manifold and the lumen of said sealed-end hollow fibers are pressurized with a gas to permit the dissolution of the gas into the liquid flowing past the fibers, as the gas passes through the fibers.

9. The manifold of claim 7, wherein the plenum of said manifold and the lumens of said closed-end hollow fibers are connected to a vacuum to permit the removal of dissolved gases from the liquid flowing past the fibers.

10. The manifold of claim 6, wherein two of said manifolds are mounted in an open tube with one at an inlet and the second at an outlet, the hollow fibers being flow-through hollow fibers which extend the length between the manifolds, and said liquid flows inwardly from the opening of an upstream manifold, along the outside of the flow-through hollow fibers as the liquid flows through the said tube, and exits at the outlet end of the downstream manifold.

11. A method of forming a packet of hollow fibers used for liquid-gas exchange comprising the steps of

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supporting a plurality of hollow fibers with the fibers extending into a mold cavity, closing the mold cavity and injecting a settable liquid material into the mold to mold a block of material to support the fibers, and removing the block of molded material and molded in fibers from the mold.

12. The method of claim 11, including the step of molding a second end of the fibers into a separate second block of material.

13. The method of claim 12 and including the step of filling the ends of fibers held by one block of material to plug the ends of the hollow fibers, installing the first mentioned block into a fluid transfer manifold, and removing the second block to permit the plugged ends of the fibers to move relative to each other.

14. The method of claim 12, wherein the supporting step includes supporting the plurality of fibers on a rotating wheel having support surfaces thereon, said wheel having at least four sides to permit supporting four straight lengths of fibers with two mold cavities on each side, and rotating the wheel while removing fiber from a source such that the fiber is wrapped around the wheel until the desired number of fiber lengths are positioned in the mold cavities.

15. The method of claim 14, wherein said wheel includes molds for supporting opposite ends of the lengths of fibers on each side of the wheel, the molds on adjacent sides of the wheel being spaced apart at corners of the wheel, and including the step of setting the fibers between adjacent molds on adjacent sides of the wheel at each corner.

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16. The method of claim 11, including the step of inserting a plurality of hollow fiber packets into a manifold by cementing the molded blocks of material into pockets formed in the manifold with the hollow fibers extending outwardly from the manifold.

17. The method of claim 11, including the step of curing the liquid material by applying heat after the material has been injected into the mold.

18. A modular packet of hollow fibers each having membrane walls and a lumen for transferring a fluid between lumens of the fibers and a different fluid in contact with outer surfaces of the membrane walls, the packets each comprising a plurality of individual elongated hollow fibers and a molded block of material supporting end portions of the hollow fibers in an assembly for insertion into a retaining pocket carrying a fluid, the lumens of the hollow fibers being open through an end of the molded block for transfer of the fluid between a plenum and the lumens of hollow fibers in the packet.

19. The packet of claim 18, wherein the packet comprises at least five individual fibers molded in a block having a thickness substantially less than its width to insure that the material used for molding surrounds each fiber across the thickness.

20. The packet of fibers of claim 19, wherein the fibers have second ends opposite the molded block, said second ends being plugged to close the passageways of the tubular fibers.

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21. The packet of fibers of claim 18, the fibers having second ends supported in a separate molded block.

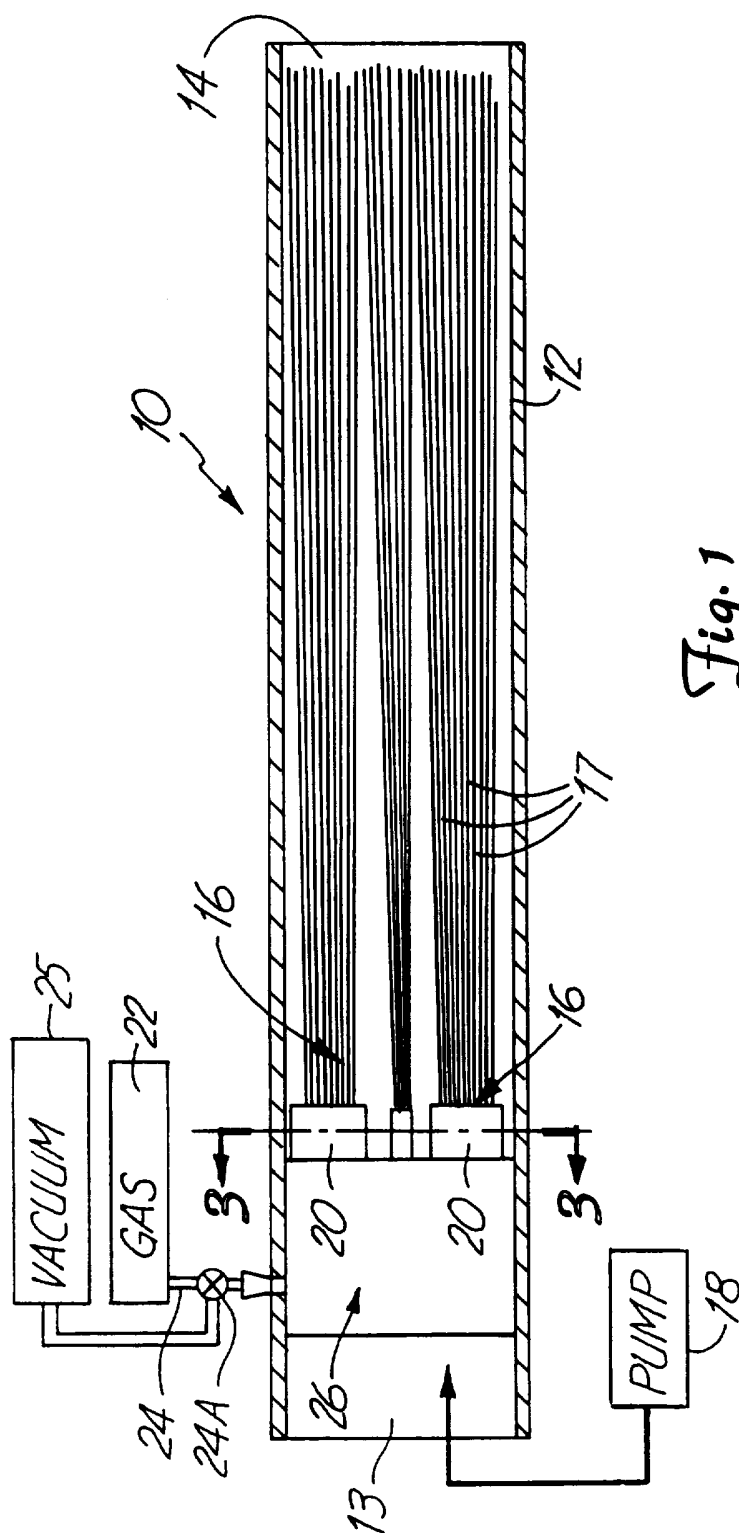
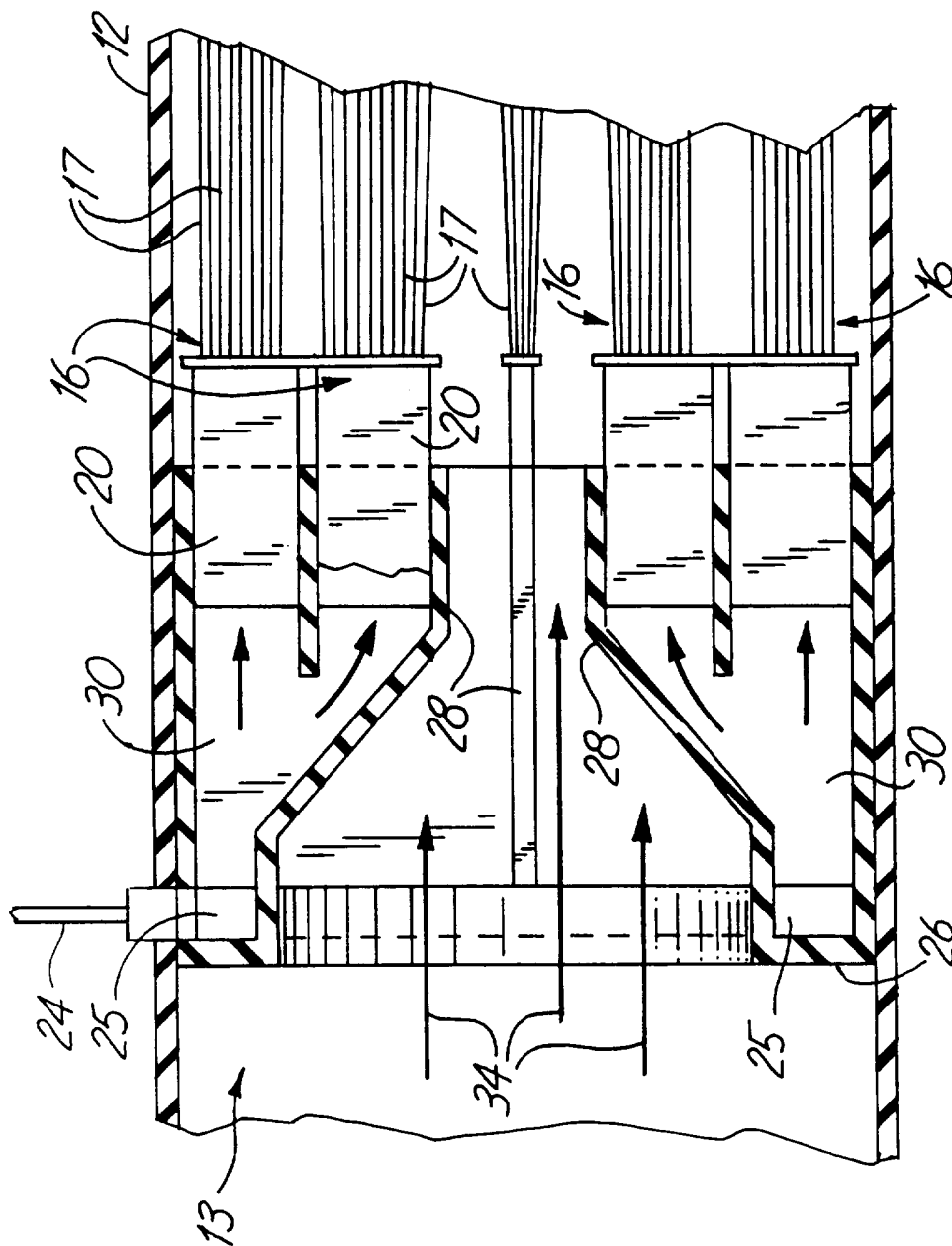


Fig. 2



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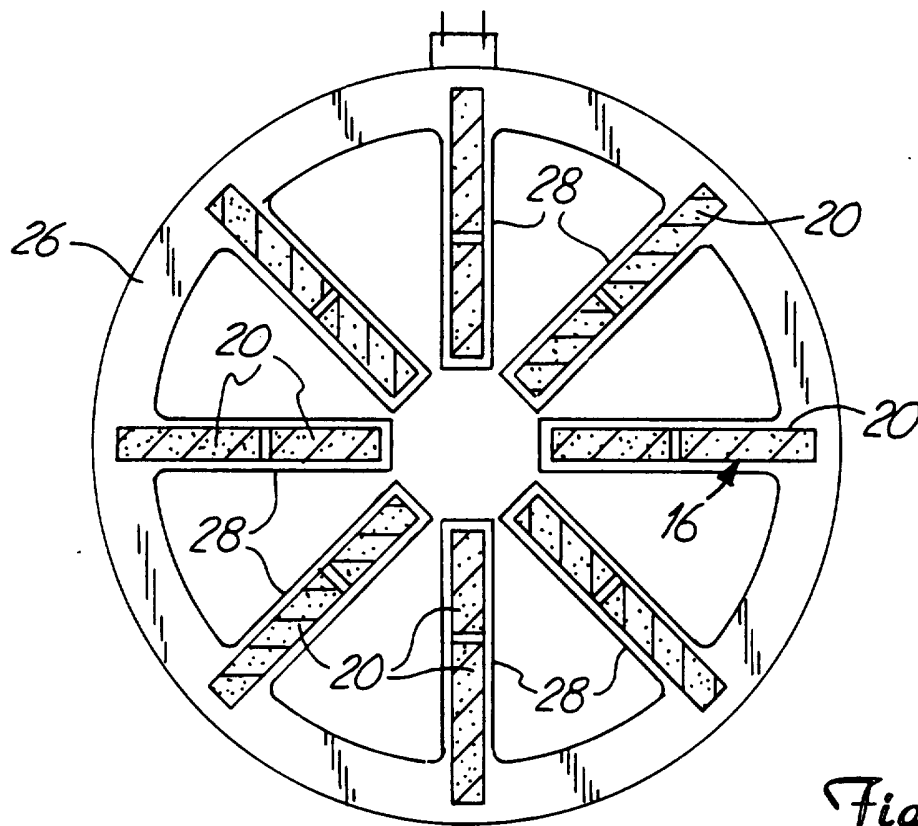


Fig. 3

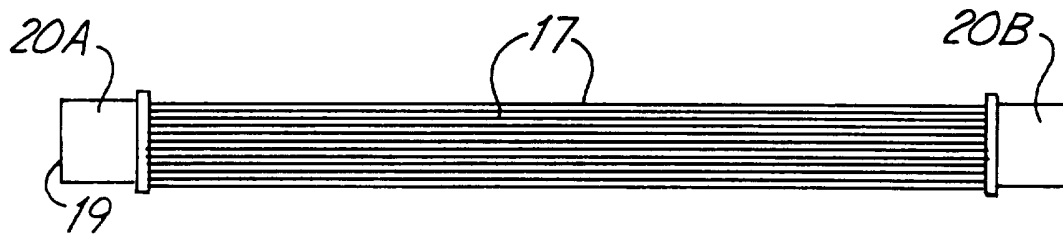


Fig. 7

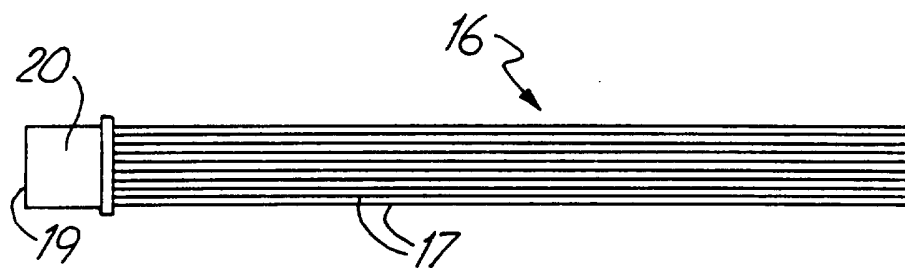
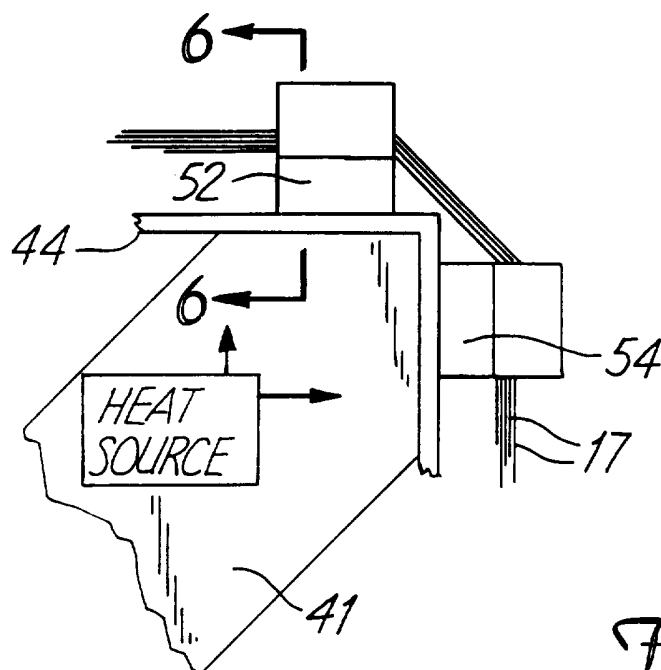
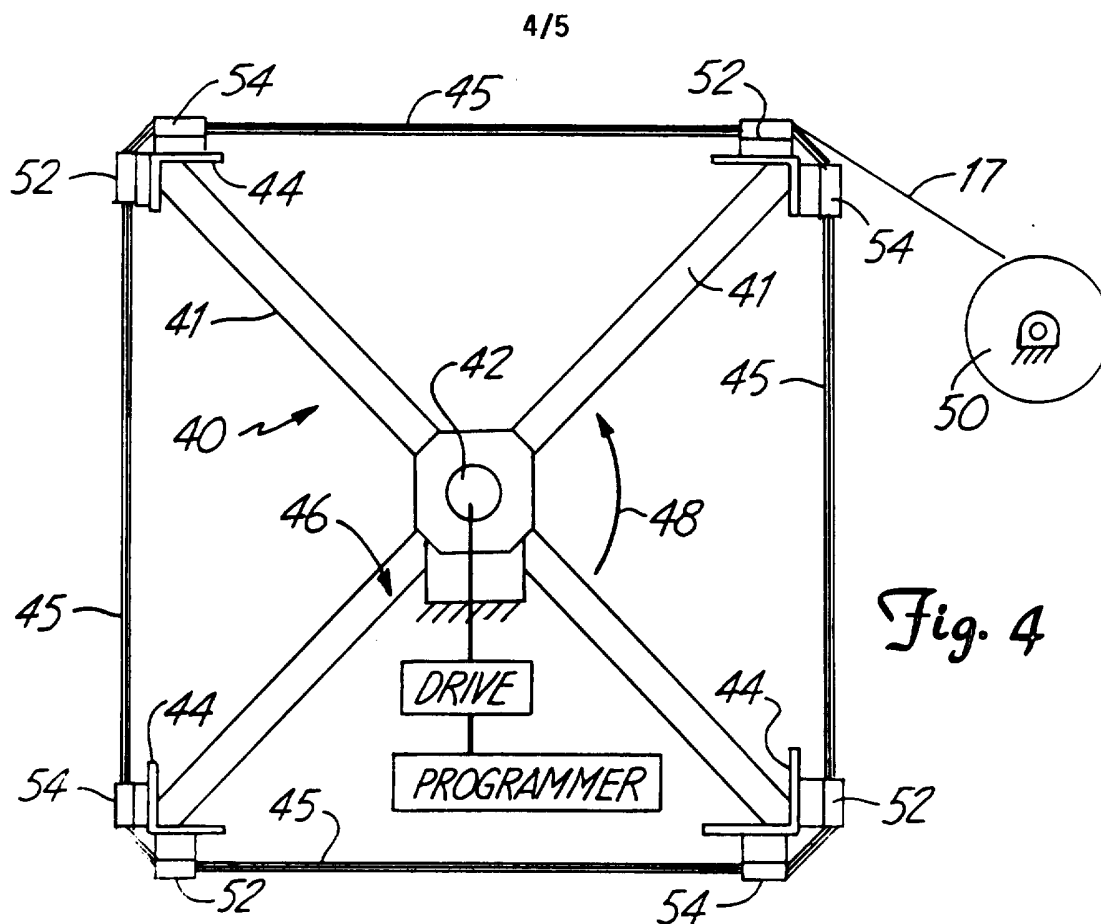
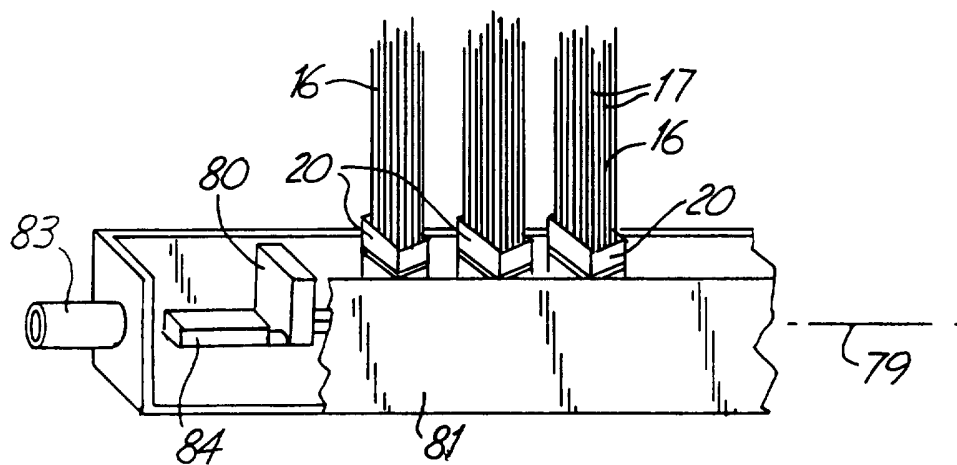
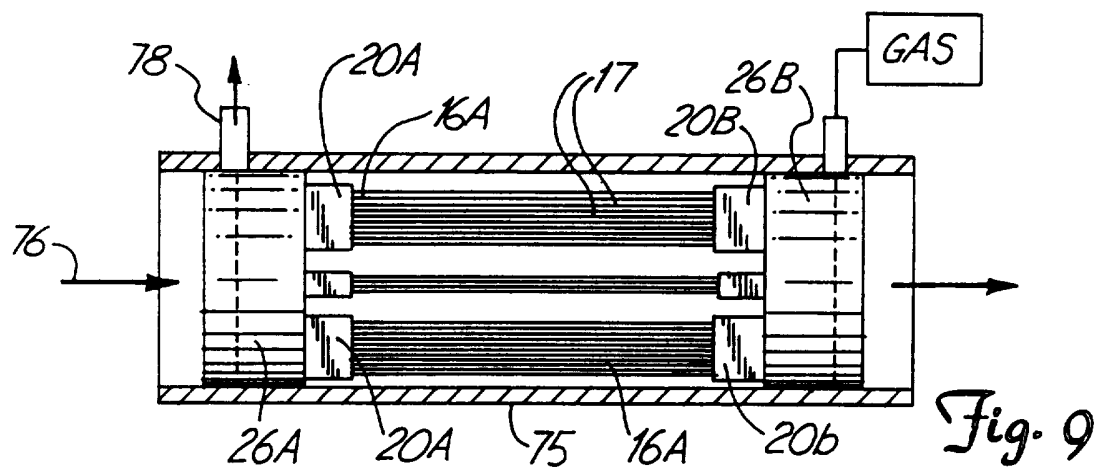
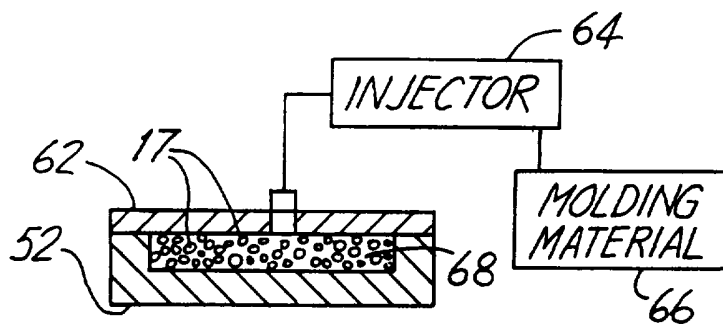


Fig. 8





INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/11212

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : B01F 3/04

US CL : 261/104

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 261/104; 210/321.89, 321.8; 264/261

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,228,991 (STROHM ET AL) 20 JULY 1993. See Figure 6; column 5, lines 17-20 and 50-54; column 7, lines 1-5.	1, 3, 18-21
X	US, A, 3,228,876 (MAHON) 11 JANUARY 1966. See Figure 4 and column 6, lines 43-52.	1, 3, 18, 19, 21
X	US, A, 3,702,658 (McNAMARA ET AL) 14 NOVEMBER 1972. See Figure 3 and column 8, lines 50-58.	1, 3, 18-21
X	US, A, 5,059,374 (KRUEGER ET AL) 22 OCTOBER 1991. See Figure 2; column 15, lines 11-16, 26-30 and 45-51.	1, 3, 18-21
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Y		16

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Z" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

30 OCTOBER 1995

Date of mailing of the international search report

20 DEC 1995

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/11212

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,143,612 (HAMANAKA ET AL) 01 SEPTEMBER 1992. See Figure 1 and column 10, lines 32-37.	1, 3, 18, 19, 21
X	US, A, 4,781,889 (FUKASAWA ET AL) 01 NOVEMBER 1988. See Figure 1 and column 4, lines 44-48.	1, 3, 18, 19, 21
X	US, A, 4,689,191 (BECK ET AL) 25 AUGUST 1987. See Figures 3a-3c; column 2, lines 42-46; column 3, lines 57-63; column 4, lines 54-58; column 5, lines 29-32.	11, 12, 17
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Y	US, A, 5,192,478 (CASKEY) 09 MARCH 1993. See column 7, lines 13, 14.	17
A	US, A, 4,097,324 (EMMEL) 27 JUNE 1978. See Figure 5.	14, 15
A	US, A, 3,419,449 (VALERIO ET AL) 31 DECEMBER 1968. See Figure 6.	14, 15
A	US, A, 3,471,178 (ROE) 07 OCTOBER 1969. See column 1, lines 20-24.	16
A	US, A, 4,105,731 (YAMAZAKI) 08 AUGUST 1978. See Figure 1.	1-21
A	US, A, 5,332,498 (ROGUT) 26 JULY 1994. See Figure 3.	2