



(86) Date de dépôt PCT/PCT Filing Date: 2005/08/19

(87) Date publication PCT/PCT Publication Date: 2006/02/23

(45) Date de délivrance/Issue Date: 2014/04/22

(85) Entrée phase nationale/National Entry: 2007/02/14

(86) N° demande PCT/PCT Application No.: AU 2005/001253

(87) N° publication PCT/PCT Publication No.: 2006/017911

(30) Priorité/Priority: 2004/08/20 (AU2004904769)

(51) Cl.Int./Int.Cl. *B01D 63/04* (2006.01)

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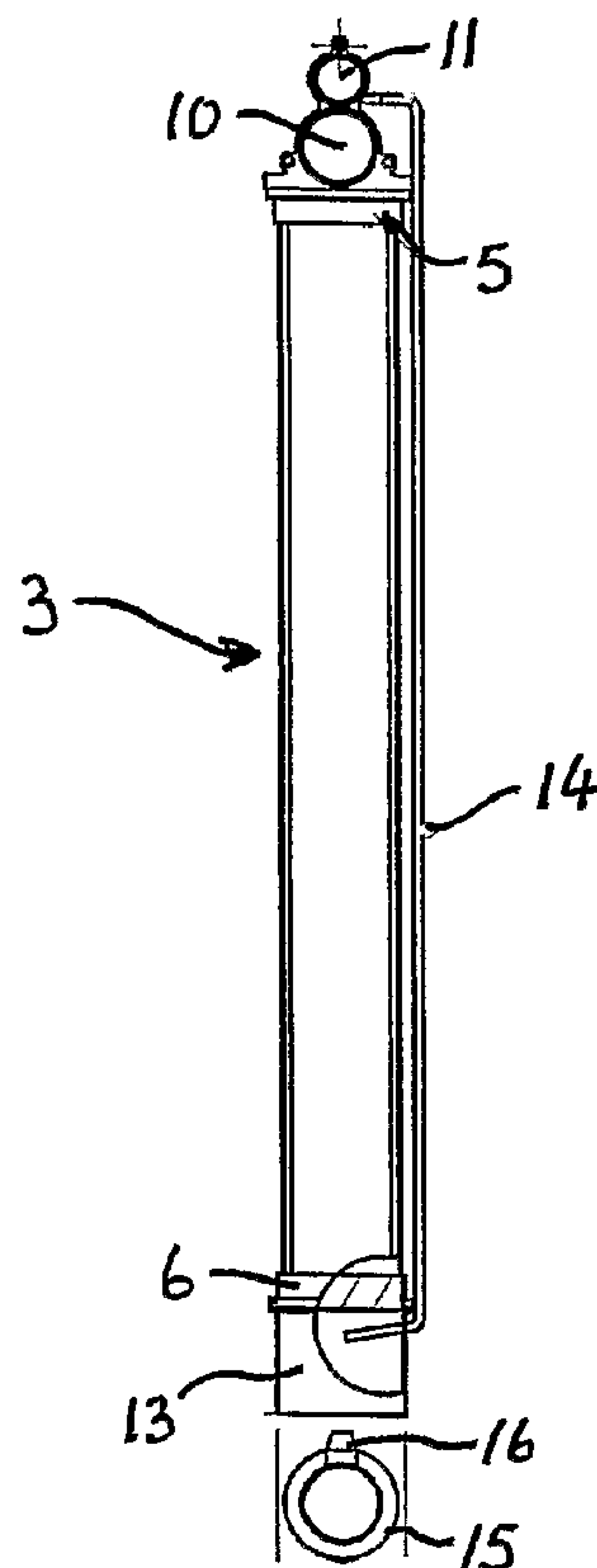
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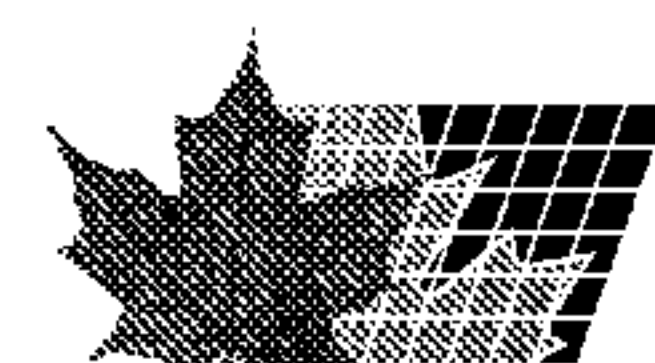
(54) Titre : MODULES A MEMBRANES COMPRENANT DES CONDUITS DE GAZ ET DE FILTRAT ET SUPPORTS
AINSI FORMES

(54) Title: MEMBRANE MODULES WITH GAS AND FILTRATE CONDUITS AND RACKS FORMED THEREFROM



(57) Abrégé/Abstract:

A membrane module (3) comprising a plurality of porous hollow membranes (8). The membranes (8) extend between and are fixed at each end in a header (5, 6). One header (6) has one or more of openings (12) formed therein. The openings (12) are in fluid



(57) **Abrégé(suite)/Abstract(continued):**

communication with a source of gas and/or liquid (13, 14, 15). The other of the headers (5) is sealingly connected to and in fluid communication with a head-piece (9). The head-piece (9) is adapted to couple to an associated head-piece of a further module to form a rack of modules (17). A potting head (6) for use in mounting porous hollow membranes (8) is also disclosed comprising a preformed potting element (29). The potting element (29) includes one or more cavities (30) for receiving curate potting material which, in use, supports said membranes (8).

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

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
23 February 2006 (23.02.2006)

PCT

(10) International Publication Number
WO 2006/017911 A1(51) International Patent Classification⁷: **B01D 63/04**(21) International Application Number:
PCT/AU2005/001253

(22) International Filing Date: 19 August 2005 (19.08.2005)

(25) Filing Language: English

(26) Publication Language: English

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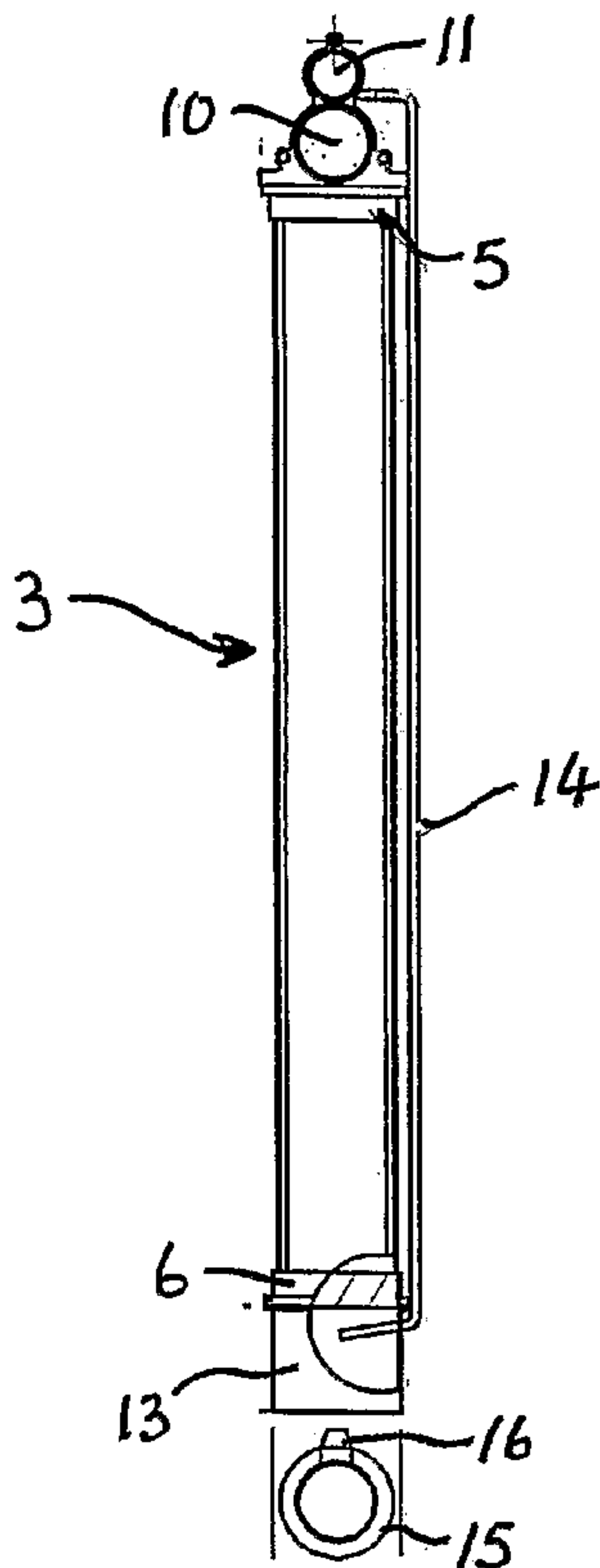
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU,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

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(54) Title: SQUARE MBR MANIFOLDING SYSTEM



(57) Abstract: A membrane module (3) comprising a plurality of porous hollow membranes (8). The membranes (8) extend between and are fixed at each end in a header (5, 6). One header (6) has one or more of openings (12) formed therein. The openings (12) are in fluid communication with a source of gas and/or liquid (13, 14, 15). The other of the headers (5) is sealingly connected to and in fluid communication with a head-piece (9). The head-piece (9) is adapted to couple to an associated head-piece of a further module to form a rack of modules (17). A potting head (6) for use in mounting porous hollow membranes (8) is also disclosed comprising a preformed potting element (29). The potting element (29) includes one or more cavities (30) for receiving curate potting material which, in use, supports said membranes (8).

WO 2006/017911 A1

WO 2006/017911 A1



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)) for US only*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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MEMBRANE MODULES WITH GAS AND FILTRATE CONDUITS AND RACKS FORMED THEREFROM

TECHNICAL FIELD

5 The present invention relates to submerged membrane filtration systems and more particularly to those types used in bioreactor processes.

BACKGROUND ART

 A variety of membrane filtration systems are known and many of these use pressurised systems operating at high transmembrane pressures (TMP) to
10 produce effective filtering and high filtrate flux. These systems are highly effective but are also expensive to produce, operate and maintain. Simpler systems using membrane arrays freely mounted vertically in a tank and using suction applied to the fibre lumens to produce TMP have also been developed, however, these systems have been found in the past to be less effective than
15 the pressurised systems.

 Examples of such known systems are illustrated in U.S. Patent 5,192,456 to Ishida et al, U.S. Patent No. 5,248,424 to Cote et al and WO 97/06880 to Zenon Environmental Inc.

 Recent developments have used combinations of gas scouring and
20 backwashing in non-pressurised submerged membrane systems to improve operating efficiency. Many of these systems require complex and expensive manifolding to provide the required delivery/removal of liquids and gas at various stages of the process. The configuration and footprint of modules has also become important to many users of such systems.

25 DISCLOSURE OF THE INVENTION

 The present invention relates particularly to a plurality of porous membranes arranged to form a membrane module. These porous membranes may be in the form of fibres or plate type membranes as described in the above prior art.

30 The present invention seeks to overcome or at least ameliorate the problems of the prior art by providing a simple, effective manifolding and mounting system for submerged membranes modules.

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According to a first aspect, the present invention provides a membrane module comprising a plurality of porous hollow membranes, said membranes extending between and being fixed at each end in a header, one header having one or more of openings formed therein; said openings being in fluid
5 communication with a source of gas and/or liquid; the other of said headers being sealingly connected to and in fluid communication with a head-piece; said head-piece being adapted to couple to an associated head-piece of a further module to form a rack of modules.

Preferably, the headpiece includes a filtrate conduit in fluid communication
10 with open ends of said membranes for the withdrawal of filtrate therefrom. For further preference the headpiece includes a further gas/air conduit for communicating gas/air to the module.

Preferably, the module is square or rectangular shaped in cross-section. For preference a skirt is provided around a perimeter of a bottom face of said
15 one header for directing said gas and or liquid into said openings. For preference, said membranes are mounted vertically and the source of liquid may include an opening in a conduit carrying gas and/or liquid positioned below said skirt. For further preference, said opening comprises a nozzle, jet or the like. For preference the source of gas includes a pipe or tube passing through a
20 sidewall of said skirt, the distal end of said pipe being positioned below said openings for feeding gas thereto. In one embodiment the pipe or tube is connected to the gas/air conduit of the headpiece. Preferably, said skirt is arranged to mix said gas and liquid before passing through said openings.

For preference, the headers are spaced and supported by one or more
25 support members longitudinally extending between the headers. Preferably the support members are rods. In one arrangement one of more of the support members are hollow tubes and used to supply gas to the skirt from the gas/air conduit.

Preferably, the membranes are enclosed along part of their length by a
30 screen for retaining gas/air bubbles and liquid flow within the module. The screen may be impervious or substantially impervious to gas/air bubbles or liquid or both.

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Preferably, the membranes comprise porous hollow fibres, the fibres being fixed at each end in a header, the lower header having one or more openings formed therein. The fibres are normally sealed at the lower end and open at their upper end to allow removal of filtrate. The fibres are preferably arranged in
5 partitioned bundles.

Preferably, the openings are positioned to coincide with the spaces formed between said partitioned bundles. For preference, said openings comprise a slot, slots or one or more rows of holes. Preferably, the partitioned fibre bundles are located in the potting head between the slots or the one or more rows of
10 holes.

For further preference, gas bubbles are entrained or mixed with a liquid flow before being fed through the openings, though it will be appreciated that gas only may be used in some configurations. The liquid used may be the feed to the membrane module. The fibres and/or fibre bundles may cross over one
15 another between the potting heads though it is desirable that they do not.

In one form of the invention, the upper and lower potting heads are molded from a plastic material, typically injection-molded nylon, though it will be appreciated that other suitable molding materials could be used. The use of molded heads reduces the amount of potting material (e.g. polyurethane)
20 required while also enabling intricate shapes to be formed in the potting heads for use with high strength mounting and connection arrangements. This results in cost reductions and more flexibility in mounting and connection arrangements.

According to a second aspect, the present invention provides a membrane
25 module rack including a plurality of membrane modules according to the first aspect connected together by said headpieces. Preferably, the lower headers are also connected together by connection means. For preference, this connection means may be provided by interlocking formations provided on adjacent lower headers of the modules. For further preference, the formations
30 are guides that slide into each other to interlock the adjacent headers and remove the need for extra loose parts.

Filtrate is normally withdrawn from the fibres by application of suction

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applied thereto, however, it will be appreciated that any suitable means of providing TMP may be used.

According to a preferred further aspect, the present invention provides a filtration system including a rack of membrane modules according to said
5 second aspect wherein said modules are positioned vertically in a tank containing feed liquid to be filtered, means to apply a transmembrane pressure to said membranes in said modules to cause filtrate to pass through pores in said membranes and means to supply continually or intermittently a supply of gas to said openings so as to produce gas bubbles which move upwardly
10 between said fibres to scour the outer surfaces thereof.

Preferably the supply of gas to said openings includes a mixture of gas and liquid.

It should be understood that the term "gas" used herein includes any gas, including air and mixtures of gases as well as ozone and the like.

15 The embodiments of the invention will be described in relation to micro porous fibre membranes employed in a bioreactor type application, however, it will be appreciated that the invention is equally applicable to any form of membrane module and may be employed in a wide variety of filtration systems used to remove unwanted solids from a liquid feed.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

Figure 1 shows a simplified end elevation view of one embodiment of a membrane module in accordance with the present invention;

25 Figure 2 shows a simplified end elevation view of the module of Figure 1;

Figure 3 shows a sectional side elevation view of one cell of the filtration system according to one embodiment of the invention showing a rack of membranes modules of the type shown in the Figures;

Figure 4 shows a plan view of the cell of Figure 3 with some of the
30 membrane module racks installed;

Figure 5 shows a pictorial front perspective view of the cell of Figure 3;

Figure 6 shows a pictorial rear perspective view of the cell of Figure 3;

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Figures 7a to 7c show an end elevation view, underside view and perspective view respectively of a head piece used in conjunction with module of Figure 1;

Figures 8a to 8c show a plan view, side elevation view and underside view
5 respectively of a membrane bundle and upper and lower potting heads used in the module of Figure 1;

Figure 9 shows a perspective view of the upper side of the lower potting head of Figure 8c;

Figure 10 shows a perspective view of the under side of the lower potting
10 head of Figure 9;

Figure 11 shows an isometric view of the underside of a potting insert of the upper potting head of Figure 8a;

Figure 12 shows an isometric view of the upper side of a potting insert of Figure 11; and

15 Figure 13 shows a simplified sectional view of the base of the module of Figure 1.

MODES FOR CARRYING OUT THE INVENTION

Referring to Figure 1 and 2, the membrane module 3, according to this
20 embodiment, comprises a square-shaped in section array or bundle of hollow fibre membranes 4 extending longitudinally between upper and lower generally square shaped in section potting heads 5 and 6, respectively. While a square shaped module is shown and described it will be appreciated that other regular straight-sided shapes such as rectangular or triangular could also be employed.
25 Such cross-sectional shapes enable closer packing of the modules.

A number of longitudinally extending spacer support rods 7 are positioned between the upper and lower potting heads 5 and 6. These rods are preferably potted into the upper and lower potting heads 5 and 6 during the potting process.

30 A screen or sleeve (not shown) at least partially surrounds the fibre bundles 4 along part of their length and serves to hold the fibres 8 in close

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proximity to each other, prevent excessive movement therebetween and prevent damage during handling. The screen also serves to entrain the gas and mixed liquor within the module 3.

The fibres 8 are open at the upper potting head 5 to allow for filtrate
5 removal from their lumens and sealed at the lower potting head 6. A modular headpiece 9 is sealingly attached to the upper potting head 5 and is in fluid communication with the open ends of the fibres 8. The headpiece 9 includes a pair of conduits 10 and 11 extending above the potting head 5. Conduit 10 is a filtrate conduit and conduit 11 is a gas/air conduit.

10 The lower potting head 6 has a number of openings 12, in this case slots, distributed therein to enable the two phase mixture of gas/air and mixed liquor formed in the skirt region to be supplied therethrough. Although slots 12 are shown it will be appreciated that any form and shape of opening may be used including a linear array of closely spaced holes. The fibres 8 are fixed in
15 partitioned bundles 4 within the potting heads 5 and 6 and the slots 12 open into the region between each partitioned bundle 4 so as to provide, in use, a distribution of gas bubbles and mixed liquor between the fibres 8.

The lower potting head 6 is provided with a downwardly extending skirt 13 for conveying gas/air and mixed liquor to the slots 12 in the lower potting head
20 6. A dropper tube 14 extends from the gas/air conduit 11 in the headpiece 9 into the side of the skirt 13 for, in use, feeding gas/air thereto. In one embodiment one or more of the spacer support rods 7 are hollow and are used to feed gas from the conduit 11 to the skirt 13 in place of the dropper tube 14.

A mixed liquor pipe 15 is positioned below the skirt 13 and provided with
25 jets 16 for feeding mixed liquor into the skirt 13. The skirt 13 functions to provide a confined space to allow gas/air to be mixed with the mixed liquor flow from the jet 16 before entering the slots 12 in the lower potting head 6. Optionally, the mixed liquor pipe may be omitted and delivery of feed to the skirt is achieved by complete mixing within the feed tank 18.

30 As best shown in Figures 3 to 6, the modules 3 of the type described above are formed into a module rack 17 by connecting the head-pieces 9 to form a manifold rack support from which the modules 3 are suspended. The

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modules 3 may also be connected at the lower potting heads 6 if desired. Typically, the lower potting heads 6 are provided with interlocking formation which enable the modules to be slid together vertically. It will be appreciated that other forms of interlocking and clipping may also be used. In this type of configuration the screen described above for each module 3 may be replaced
5 by a rack screen which at least partially surrounds a rack of modules in a similar manner to the individual module screens.

The module racks 17 are positioned in a cell or feed tank 18 with the conduits 10 and 11 of the headpiece 9 of one end module being coupled to the
10 main filtrate and gas headers 19 and 20, respectively. A hose 21 is used to connect the main gas header 20 to the conduit 11 of each rack 17.

The racks 17 are suspended above a mixed liquor pipe 15, which extends along the bottom 22 of the cell 18 and has spaced jets 16 positioned along the pipe at locations below the skirt 13 of each module 3. In this embodiment, a
15 mixed liquor header 23 is positioned at one end of the cell 18 and connects each of the mixed liquor pipes 15 to a source of mixed liquor (not shown). In other embodiments mix liquor headers may be provided at both ends of the cell.

Referring to Figures 7a to 7c, the headpiece 9 is shown in detail. The headpiece 9 includes a pair of cylindrical conduits 10 and 11 extending parallel
20 to each other and the gas/air conduit 11 being positioned above the filtrate conduit 10. The lower filtrate conduit 10 has an open wall 24 in fluid communication with a coupling flange 25 which, in use, is sealingly connected to the upper potting head 5 of each module 3. The ends 26 of the headpiece 9 are provided with formations 27 which enable the headpieces 9 of a number of
25 modules 3 to be sealingly connected to each other to form a rack of modules 17 and provide fluid communication between associated conduits 10 and 11 along the length of the rack formed. The headpieces 9 are constructed to be of sufficient strength to support the modules 3 when formed into a rack 17.

A hollow spigot tube 28 extends from the upper gas conduit 11 to allow
30 connection of the dropper tube 14.

Figures 8c, 9 and 10 show in more detail the lower potting head 6. The lower potting head 6, in this embodiment, comprises a potting element 29

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preformed from injection molded plastic material, typically nylon. It has been found that by minimising the amount of curable potting material (usually polyurethane) required to mount the hollow fibre membranes in the potting heads significant cost saving can be achieved.

5 Referring to Figure 9 the lower potting head 6 comprises a preformed potting element 29 having a number of spaced, parallel extending membrane insertion channels 30 formed therein. The island areas 31 between each insertion channel 30 have the slots 12 formed therein. A moulded cavity 32 is provided in each corner of the element 29 for receiving the ends of the spacer
10 support rods 7. For preference, the cavities 32 for the rods 7 may be isolated with a wall from the potting channels 30 for the fibres 8. This allows the fibres 8 to be potted separately from the rods 7. This gives a precise and easy method of creating fibre slack. The fibres 8 can be potted first with no slack, then the rods 7 can be lowered down into their cavities and potted separately after the
15 potting material around the fibres 8 has partially or fully cured. The distance the rods 7 are lowered at this second stage creates the same amount of fibre slack, without the need to grip and manipulate fibres 8. This is particularly advantageous when the fibres 8 are in the form of mats which are difficult to grip and manipulate without causing fibre damage.

20 A pair of vertically extending module interlock clips 33 and 34 are provided on each pair of opposed sides 35 and 36 of the potting element 29. In this embodiment a tube clip 37 is molded into one side of the element 29 for retaining the dropper tube 14, though it will be appreciated a separate non-integral clip may also be used. A skirt clip ledge 38 in this embodiment formed
25 along the lower edge of opposed sides 29 and 40 of the element 29 for attachment of the skirt 13. It will be appreciated that any suitable formation may be used to attach the skirt 13 to element 29 and the formation/s may be provided at any suitable location on the opposed sides 39 and 40.

Figure 10 shows the underside of the lower potting head 6. The regions
30 between the channels 30 are open to form fluid distribution openings 41 beneath the slots 12.

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In use, the membrane insertion channels 30 are at least partially filled with curable potting material into which the fibre membranes 8 are potted. This serves to reduce the amount of material required while also providing a strong, durable potting head.

5 Referring to Figures 11 and 12, the upper potting head 6 is formed of potting insert 42 which surrounds and reinforces a pot (not shown) formed from typical potting material, such as polyurethane, into which the upper ends of the fibre membranes 8 are potted. The potting insert 42 is provided with an upwardly open groove 43 extending around its upper side for receipt of o-ring
10 seal. Each corner of the potting insert 42 is provided with a rod location formation 44 for receipt of the spacer support rods 7. Threaded stainless steel inserts 45 are provided in each rod location formation 44 to enable threaded engagement with the rods 7. Openings 46 are formed in the lower side of the insert 42 to allow keying with the potting material.

15 The operation of the bioreactor arrangement will now be described with reference to Figure 13. In use, mixed liquor is fed into the membrane modules 3 through main header 23, pipes 15 and jets 16. The mixed liquor is injected into the base of the skirt 13 and is then mixed with gas, typically air, within the skirt 13 to form a two phase stream of the gas/air and mixed liquor. The air is
20 fed into the skirt 13 through dropper tube 14 which is connected to the gas/air conduit 11 of the headpiece 9. The gas/air conduit 11 is in turn connected to the main gas/air header 20 by a hose 21.

The mixed liquor and gas mixture formed in the skirt then passes upward through the openings 12 in the lower potting head 6 and into the fibre
25 membrane bundles 4. Filtrate is withdrawn from the fibre lumens and passes out of the open ends of the fibres in the upper potting head 5 and into the headpiece 9. In the headpiece 9 the filtrate passes through the wall opening 24 into the filtrate conduit 10 and along the joined headpieces of the module rack 17 to the main filtrate header 19. Filtrate is typically withdrawn from the fibre
30 membranes by applying suction to the filtrate header 19.

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The system while described in respect of a bioreactor may be used for treatment surface or drinking water, sewage/biological waste treatment or combined with an activated sludge or similar system.

WHAT IS CLAIMED IS:

1. A membrane module configured to be mounted vertically comprising:
 - a plurality of porous hollow membranes, said porous hollow
5 membranes extending between and being fixed at a first end in a
first header and at a second end in a second header, the first
header including a lower potting head having one or more of
openings formed therein;
 - said openings being in fluid communication with at least one of a
10 source of gas and a source of liquid;
 - the second header including an upper potting head sealingly
connected to and in fluid communication with a headpiece;
 - said head-piece being adapted to couple to an associated head-
piece of a further membrane module to form a rack of membrane
15 modules wherein:
 - said head-piece includes a filtrate conduit and a gas
conduit;
 - said head-piece is configured to be coupled to said
associated head-piece to provide fluid communication
20 between associated filtrate conduits and associated gas
conduits along the length of the rack formed;
 - said first header is provided with a skirt;
 - the source of gas includes a pipe or tube, the distal end of
said pipe or tube being positioned below said openings for
25 feeding gas thereto; and
 - the pipe or tube is connected to the gas conduit of the
head-piece.

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2. A membrane module according to claim 1 wherein at least one of the first end or second end of each of the porous hollow membranes is open and the head-piece includes the filtrate conduit in fluid communication with open ends of said porous hollow membranes for the withdrawal of filtrate therefrom.
5
3. A membrane module according to claim 1 or claim 2 wherein the membrane module is square or rectangular shaped in cross-section.
4. A membrane module according to any one of claims 1 to 3 wherein the source of liquid includes an opening in a conduit positioned below said skirt.
10
5. A membrane module according to any one of claims 1 to 4 wherein in use, said gas and liquid are mixed in said skirt before passing through said openings in the lower potting head.
6. A membrane module according to any one of claims 1 to 5 further comprising one or more support members longitudinally extending between the headers to support and space said headers.
15
7. A membrane module according to claim 6 wherein the support members are rods.
8. A membrane module according to claim 6 or claim 7 wherein one or more of the support members are hollow tubes and used to supply gas to the skirt from the gas/air conduit.
20
9. A membrane module according to any one of claims 1 to 8 wherein the porous hollow membranes are enclosed along part of their length by a screen for retaining gas/air bubbles and liquid flow within the membrane module.
25
10. A membrane module according to claim 9 wherein the screen is substantially impervious to gas/air bubbles or liquid or gas/air bubbles and liquid.

11. A membrane module according to any one of claims 1 to 10 wherein the porous hollow membranes comprise porous hollow fibres.
12. A membrane module according to claim 11 wherein each of the porous hollow fibres are sealed at the first end and open at the second end to allow removal of filtrate.
13. A membrane module according to claim 11 or claim 12 wherein the porous hollow fibres are arranged in partitioned bundles.
14. A membrane module according to claim 13 wherein the openings in the lower potting head are positioned to coincide with spaces formed between said partitioned bundles.
15. A membrane module according to claim 13 wherein said openings comprise one or more slots or one or more rows of holes.
16. A membrane module according to claim 15 wherein the partitioned bundles extend from the lower potting head at a location in the lower potting head between the slots or rows of holes.
17. A membrane module rack including a plurality of membrane modules according to any one of claims 1 to 16 connected together by said head-pieces.
18. A membrane module rack according to claim 17 wherein the first header of each membrane module are connected together.
19. A membrane module rack according to claim 18 wherein the first header of each membrane module are connected together by connection means which includes interlocking formations provided on the first header of each membrane module.
20. A filtration system including the membrane module rack according to any one of claims 17 to 19 wherein said membrane modules are positioned vertically in a tank containing feed liquid to be filtered, means to apply a transmembrane pressure to said porous hollow membranes in said

membrane modules to cause filtrate to pass through pores in said porous hollow membranes and means to supply continually or intermittently a supply of gas to said openings in the lower potting head so as to produce gas bubbles which move upwardly between said porous hollow membranes to scour the outer surfaces thereof.

21. A membrane module according to claim 4 wherein said opening in the conduit comprises a jet.

22. A membrane module configured to be mounted vertically comprising:

a first header having one or more openings formed therein, said first header being provided with a skirt;

a plurality of porous hollow membranes arranged in partitioned bundles, each of the porous hollow membranes extending between and being fixed at a first end in the first header and at a second end in a second header, at least one of the first end or second end of each of the porous hollow membranes being open, the one or more openings formed in the first header positioned to coincide with spaces formed between the partitioned bundles; and

a head-piece sealingly connected to and in fluid communication with the second header, the head-piece comprising:

a filtrate conduit in fluid communication with open ends of said porous hollow membranes for the withdrawal of filtrate therefrom;

a gas conduit to communicate gas to the membrane module through the one or more openings formed in the first header, the gas conduit in communication with a source of gas; and

a pipe or tube connected to the gas conduit of the head-piece and having a portion thereof positioned below the one or more openings formed in the first header.

23. The membrane module according to claim 22, wherein the membrane module is square or rectangular shaped in cross-section.
24. The membrane module according to claim 22 or claim 23, wherein a source of liquid including an opening in a conduit is positioned below the skirt.
5
25. The membrane module according to claim 24, wherein said opening in the conduit comprises a jet.
26. The membrane module according to any one of claims 22 to 25, wherein the pipe or tube passes through a sidewall of the skirt, the distal end of the pipe or tube being positioned below the one or more openings
10 formed in the first header, the pipe or tube for feeding gas to the one or more openings.
27. The membrane module according to claim 24, wherein in use, gas and liquid is mixed in the skirt before passing the mix of gas and liquid
15 through the one or more openings formed in the first header.
28. The membrane module according to any one of claims 22 to 27, further comprising one or more support members longitudinally extending between the headers to support and space said headers.
29. The membrane module according to claim 28, wherein the support
20 members comprise rods.
30. The membrane module according to claim 28 or claim 29 wherein one or more of the support members comprise hollow tubes to supply gas to the skirt from the gas conduit.
31. The membrane module according to any one of claims 22 to 30, wherein
25 the porous hollow membranes are enclosed along part of their length by a screen to retain gas bubbles and liquid flow within the membrane module.

32. The membrane module according to claim 31, wherein the screen is substantially impervious to at least one of the gas bubbles and liquid.
33. The membrane module according to any one of claims 22 to 32, wherein the porous hollow membranes comprise porous hollow fibres.
- 5 34. The membrane module according to claim 33, wherein each of the porous hollow fibres are sealed at the first end and open at the second end.
35. The membrane module according to any one of claims 22 to 34, wherein the one or more openings formed in the first header comprise at least
10 one of one or more slots, and one or more rows of holes.
36. The membrane module according to claim 35, wherein the partitioned bundles of porous hollow membranes are fixed at an end thereof in a potting head between the slots or the rows of holes.
37. The membrane module according to any one of claims 22 to 36, wherein
15 the head-piece is adapted to couple to an associated head-piece of a further membrane module to form a rack of membrane modules and to provide fluid communication between the filtrate conduit and a filtrate conduit of the further membrane module and to provide fluid communication between the gas conduit and a gas conduit of the further
20 membrane module.
38. A membrane module rack comprising:
a plurality of membrane modules, each of the plurality of membrane modules being mounted vertically and including:
a plurality of porous hollow membranes, the porous hollow
25 membranes arranged in partitioned bundles, the porous hollow membranes extending between and fixed at a first end in a first header and at a second end in a second header;

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the first header having one or more of openings formed therein, the openings positioned to coincide with spaces formed between the partitioned bundles, the openings in fluid communication with at least one of a source of gas and a source of liquid;

the first header being provided with a skirt;

the second header sealingly connected to and in fluid communication with a head-piece including a gas conduit to communicate gas to the membrane module;

a source of gas in communication with the gas conduit;

the head-piece being coupled to an associated head-piece of a further membrane module to form the membrane module rack and to provide fluid communication between the gas conduit and a gas conduit of the further membrane module;

a pipe or tube connected to the gas conduit of the head-piece and having a portion thereof positioned below the one or more openings formed in the first header;

the plurality of membrane modules connected together by the head-pieces.

39. The membrane module rack according to claim 38, wherein the first headers are connected together by interlocking formations provided on the first headers of the membrane modules.

40. The membrane module rack of claim 38 or claim 39, wherein the pipe or tube passes through a sidewall of the skirt, a distal end of the pipe or tube being positioned below the one or more openings formed in the first header.

41. A filtration system comprising:

a rack of membrane modules, each of the membrane modules being mounted vertically and including:

5 a plurality of porous hollow membranes arranged in partitioned bundles, the porous hollow membranes extending between and being fixed at a first end in a first header and at a second end in a second header;

10 the first header having one or more openings formed therein, the one or more openings positioned to coincide with spaces formed between the partitioned bundles, the one or more openings being in fluid communication with at least one of a source of gas and a source of liquid;

a skirt provided below the first header;

15 the second header sealingly connected to and in fluid communication with a head-piece, the head-piece including a filtrate conduit in fluid communication with open ends of the porous hollow membranes and being coupled to an associated head-piece of a further membrane module to form the membrane module rack and to provide
20 fluid communication between the filtrate conduit and a filtrate conduit of the further membrane module;

a gas conduit formed in the head-piece and in communication with a source of gas;

25 a pipe or tube connected to the gas conduit of the head-piece and having a portion thereof positioned below the one or more openings formed in the first header;

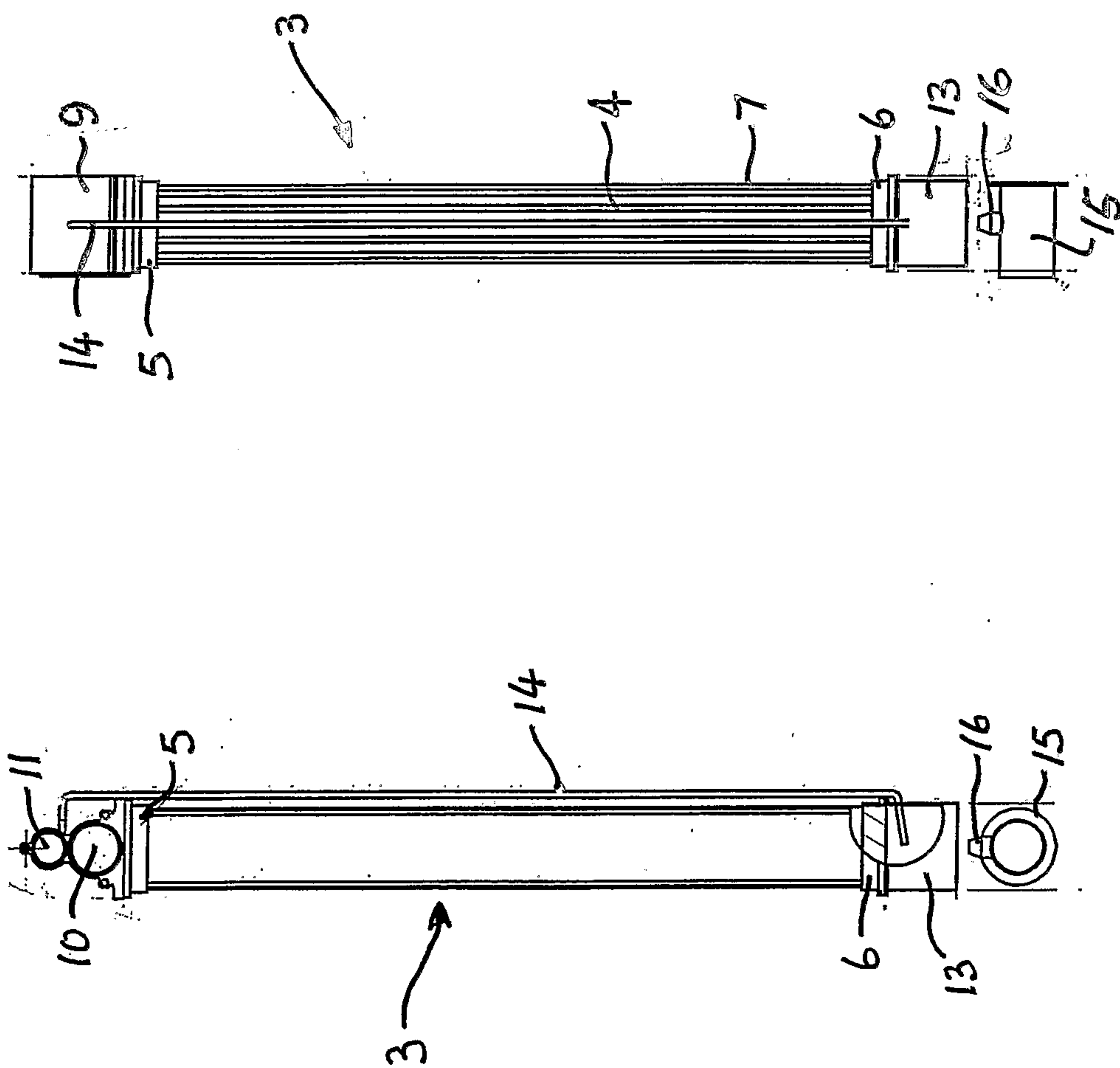
wherein the membrane modules are positioned vertically in a tank containing feed liquid to be filtered; and

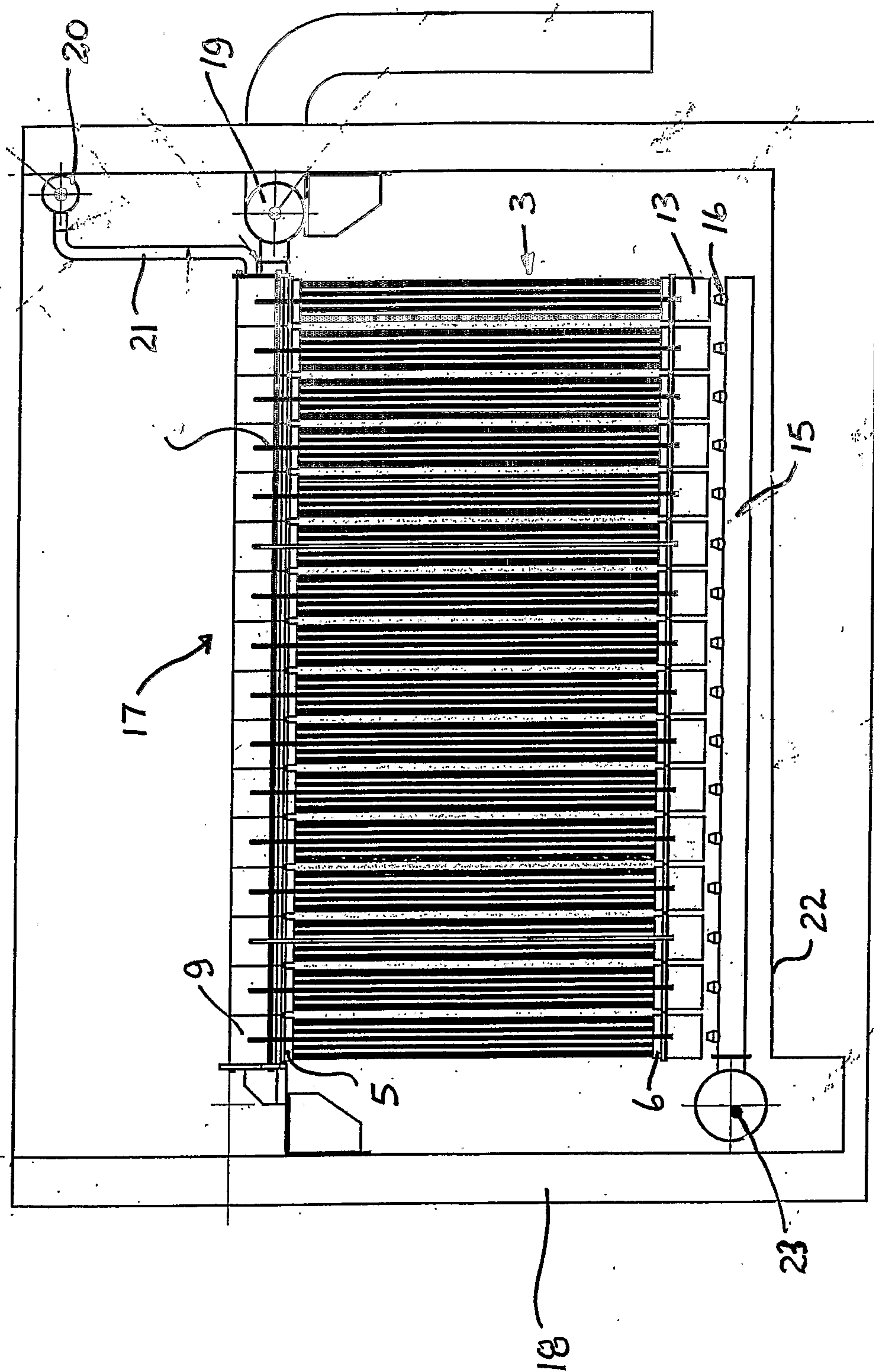
30 a source of suction configured to provide a transmembrane pressure to the porous hollow membranes in the

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membrane modules to cause filtrate to pass through pores
in the porous hollow membranes, the source of gas
configured to at least one of continually or intermittently
supply gas to the one or more openings so as to produce
5 gas bubbles which move upwardly between the porous
hollow membranes to scour the outer surfaces thereof.

42. The filtration system according to claim 41, wherein the one or more
openings formed in the first header of each module receives a mixture of
gas and liquid produced from said source of gas and said source of
10 liquid.

Fig. 2Fig. 1

Fig. 3

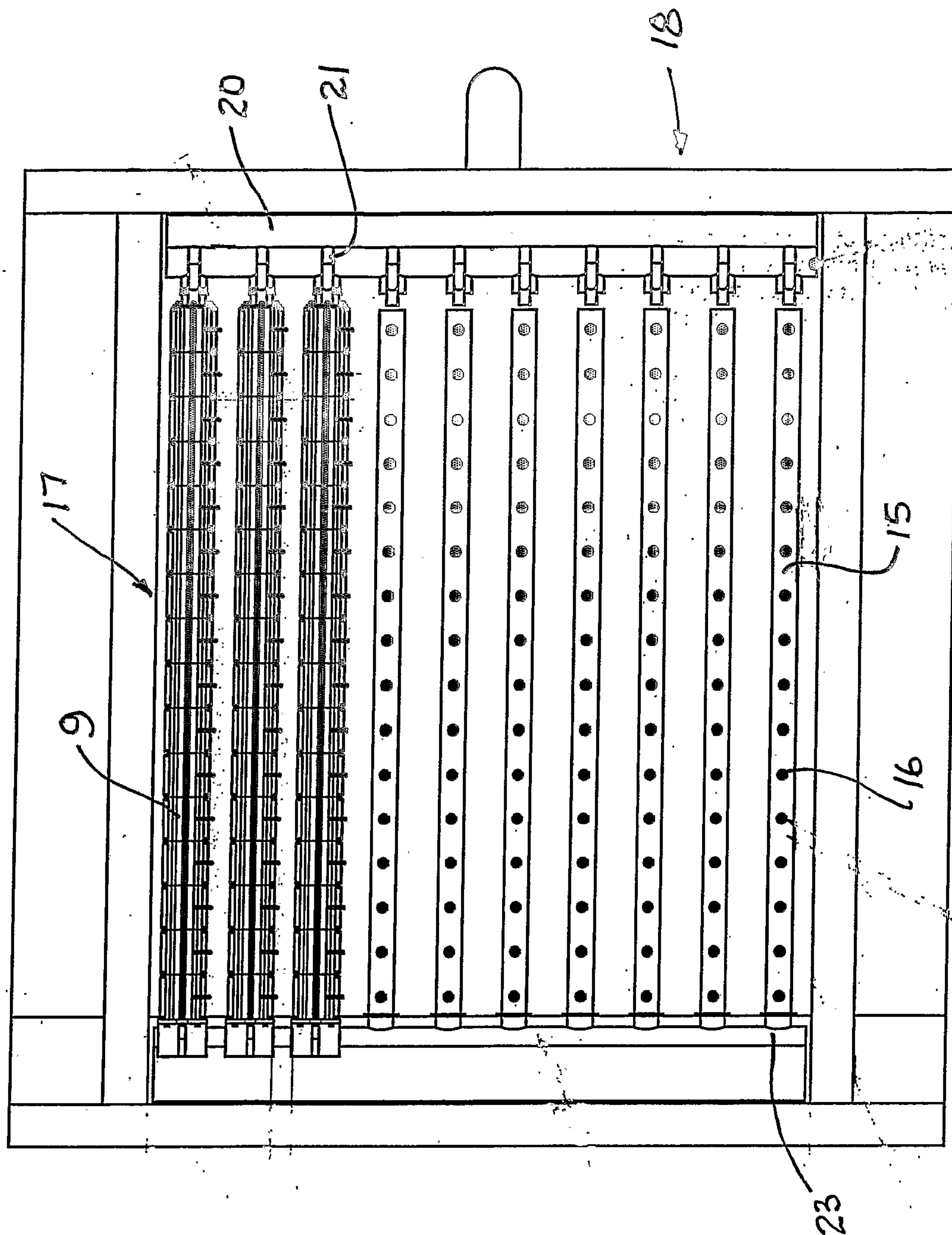
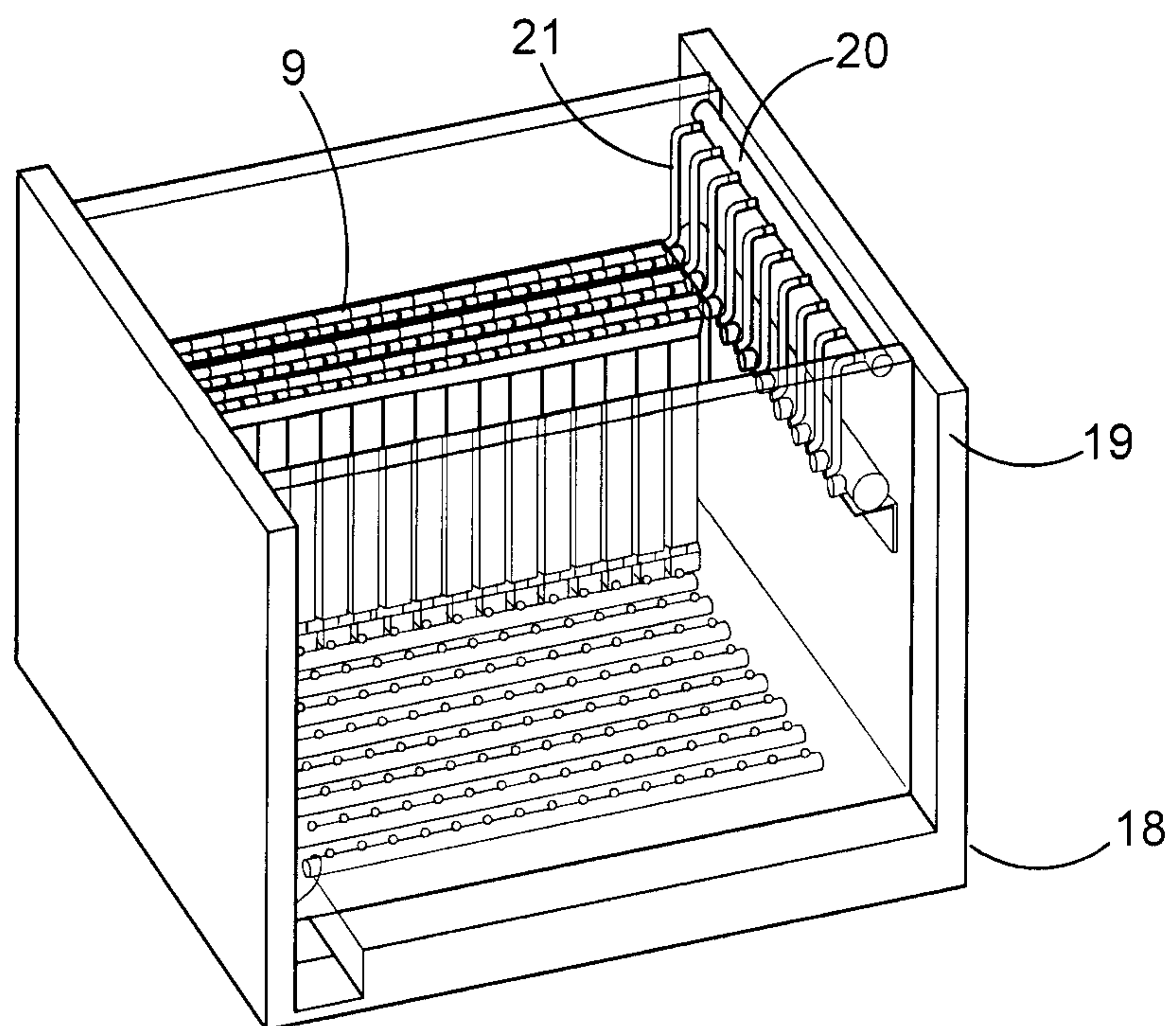
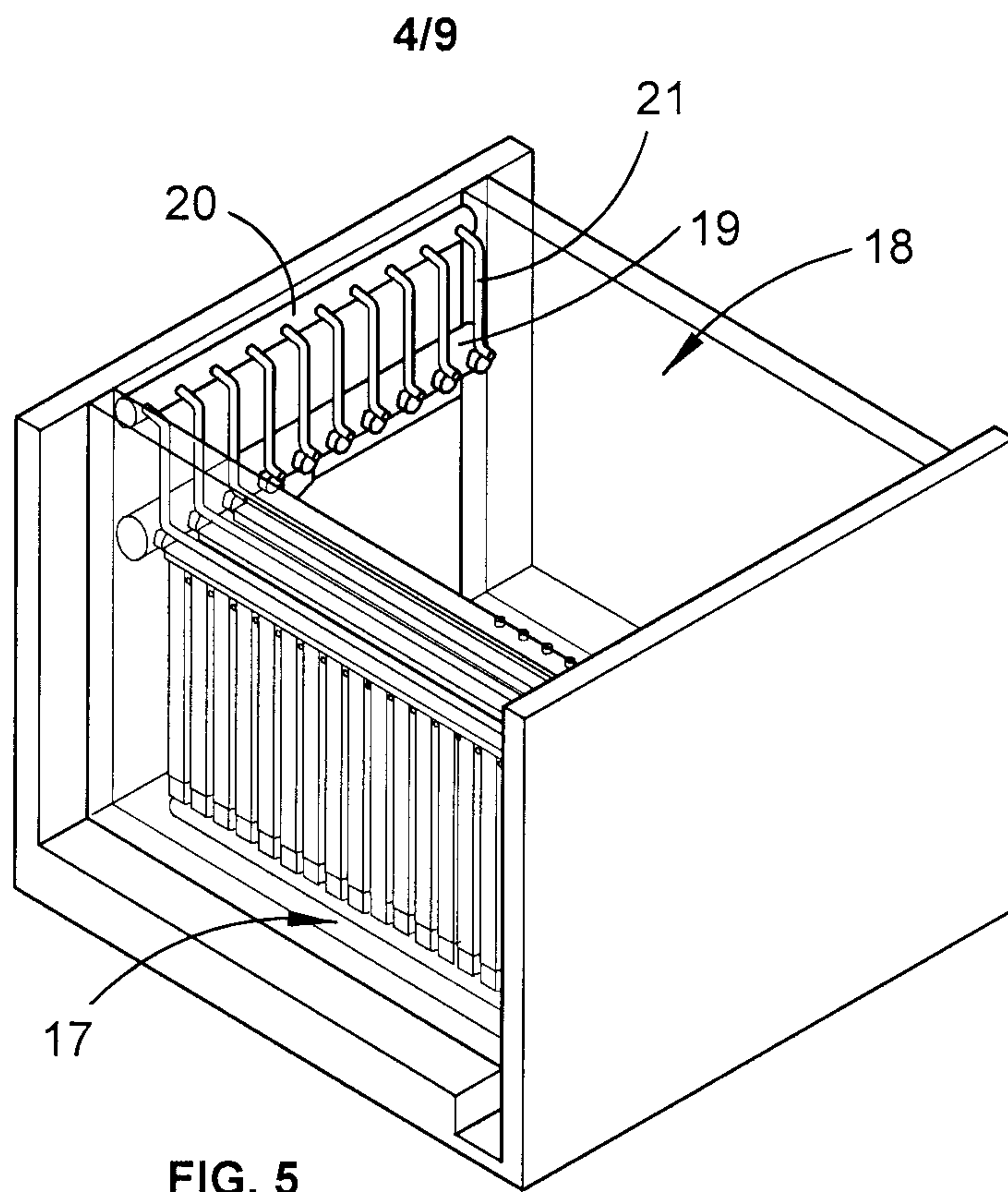


Fig. 4



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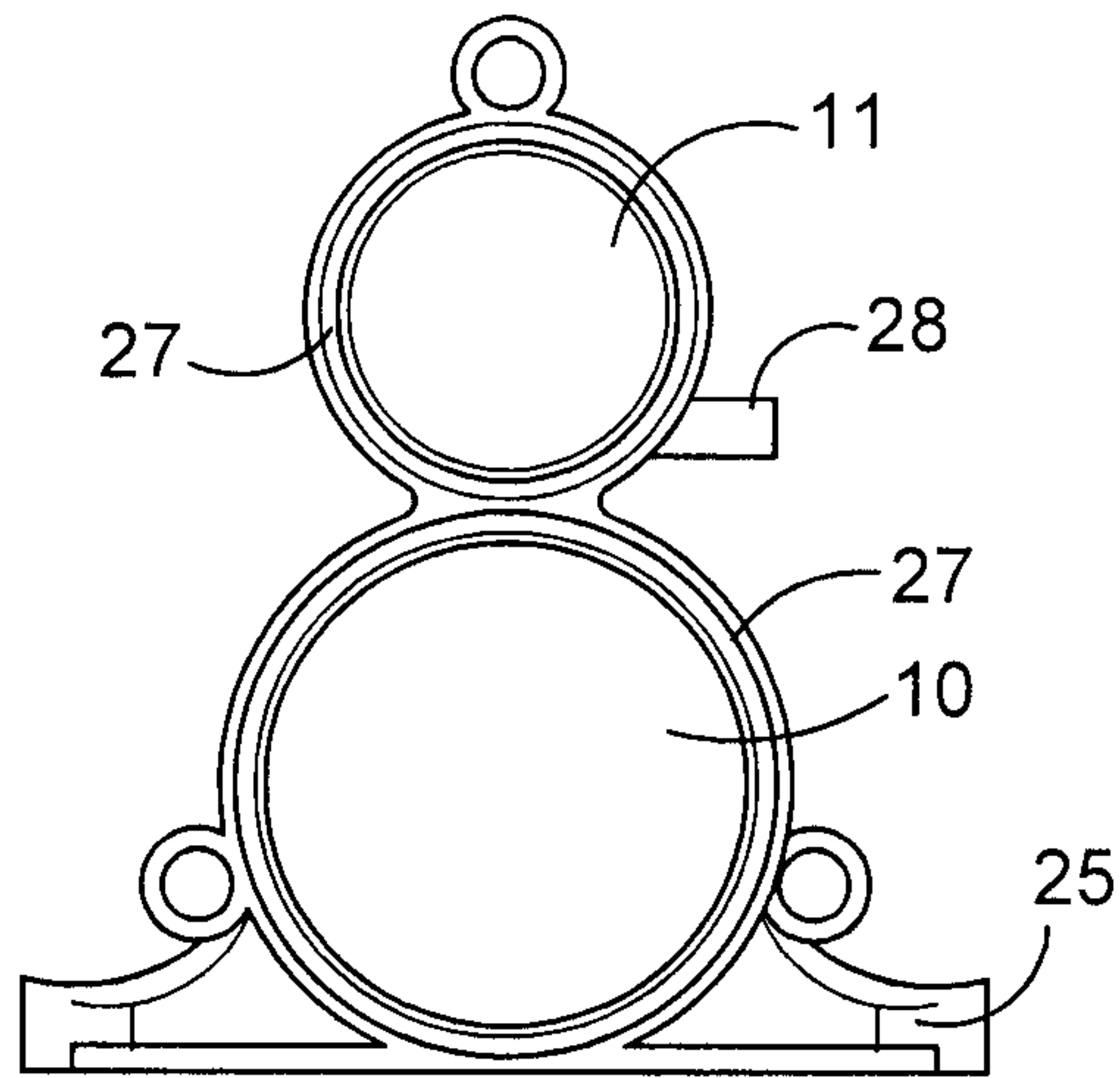


FIG. 7a

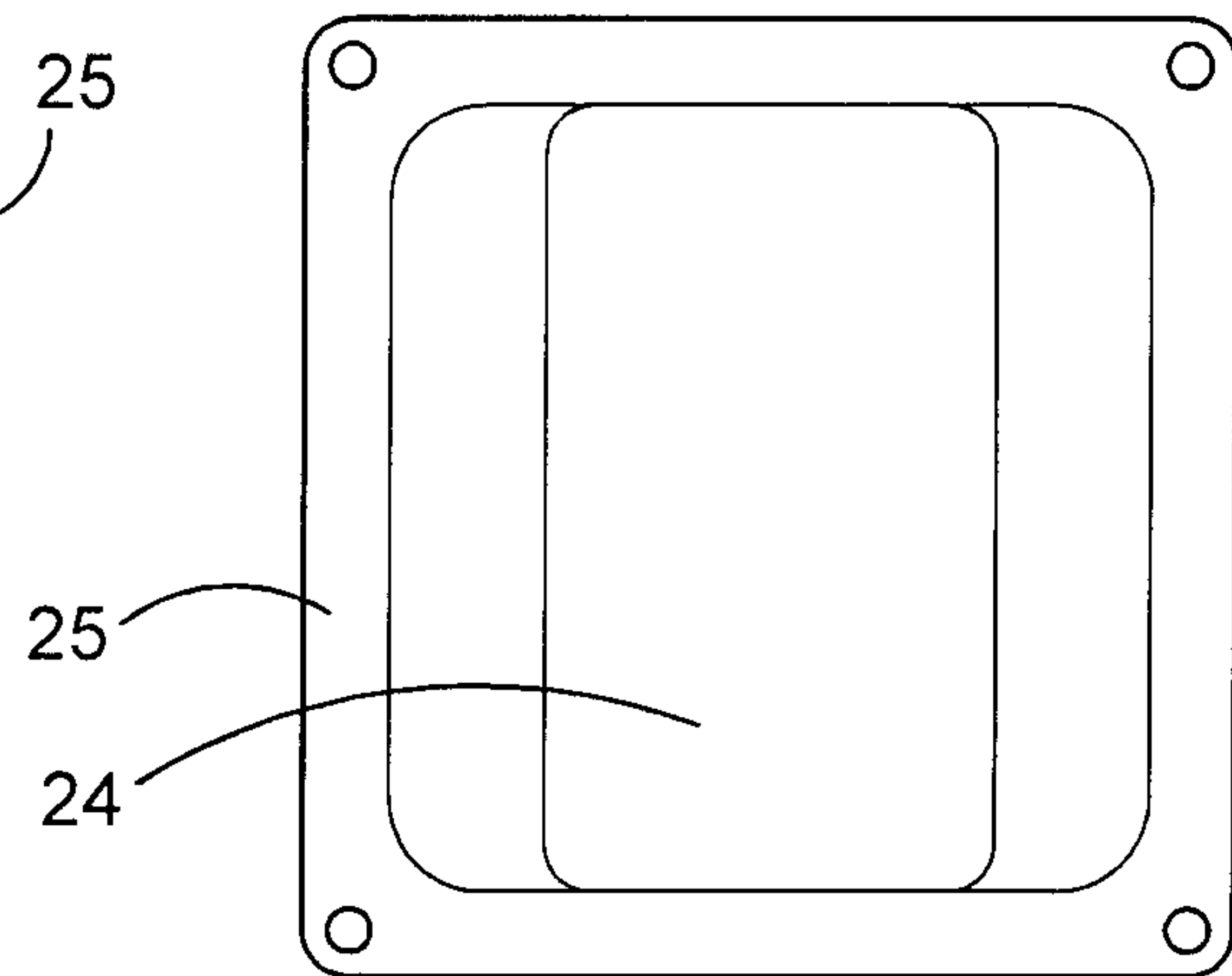


FIG. 7b

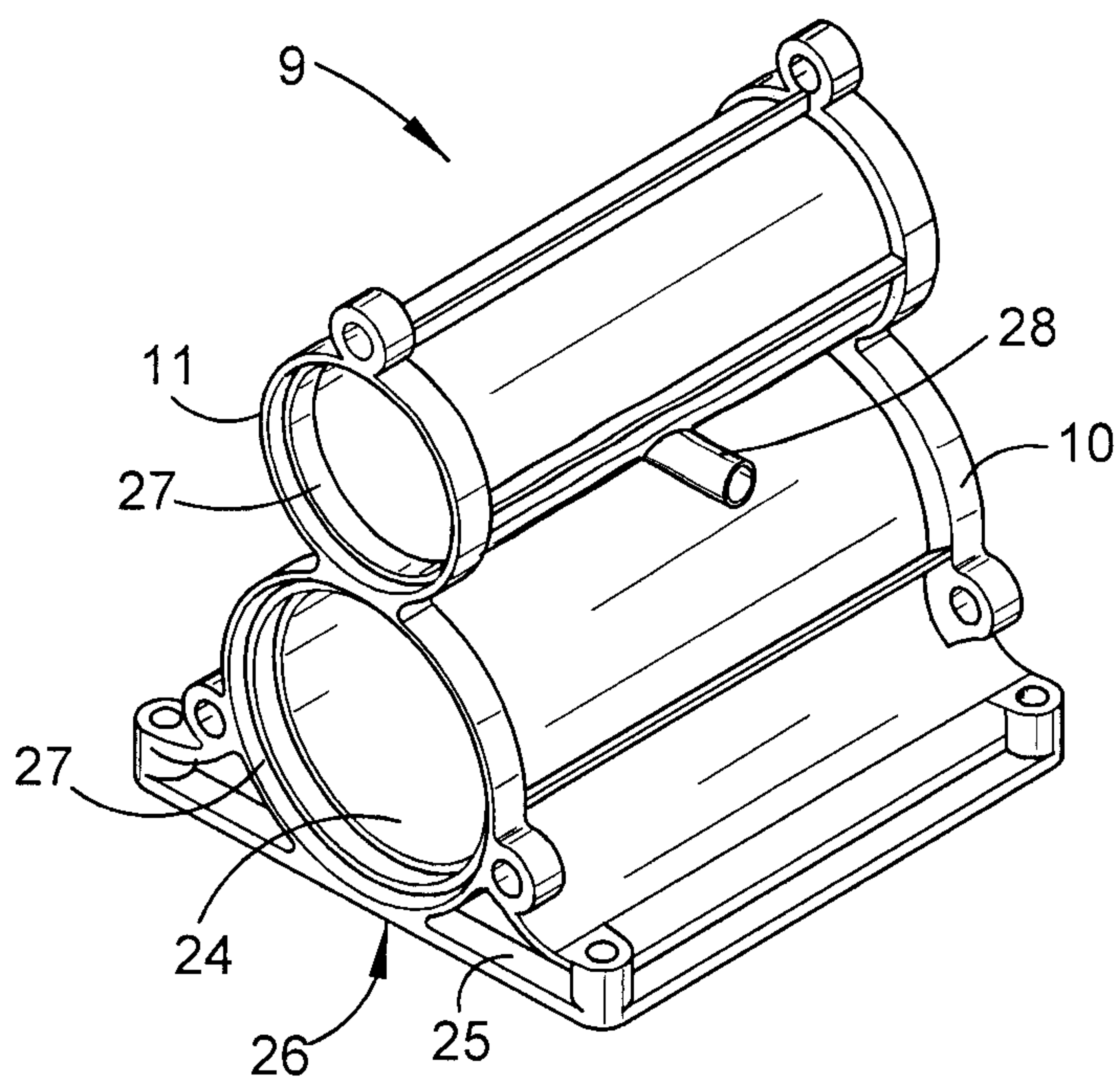
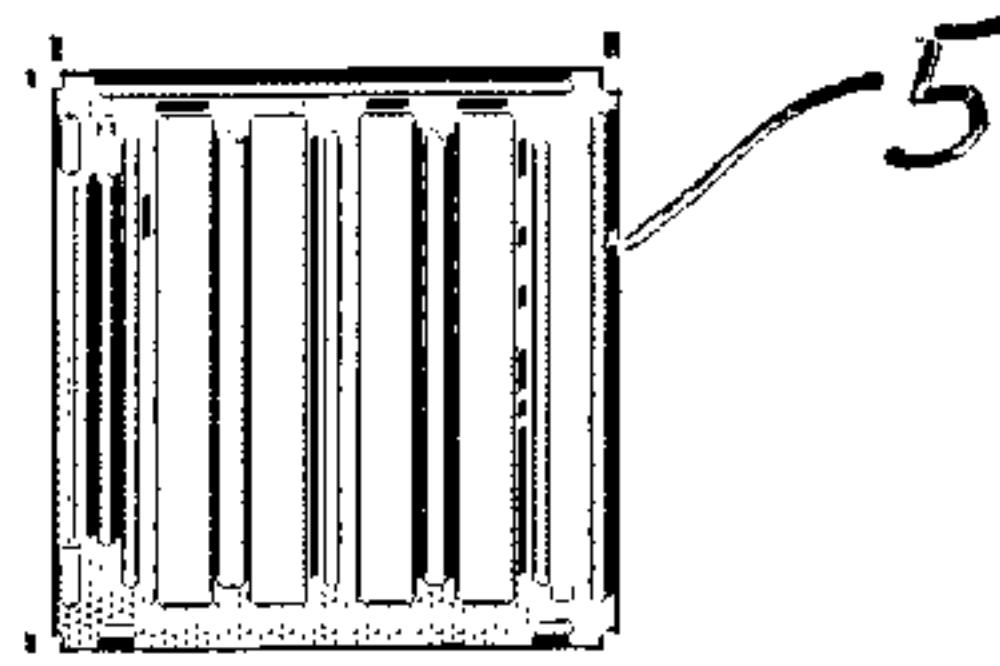
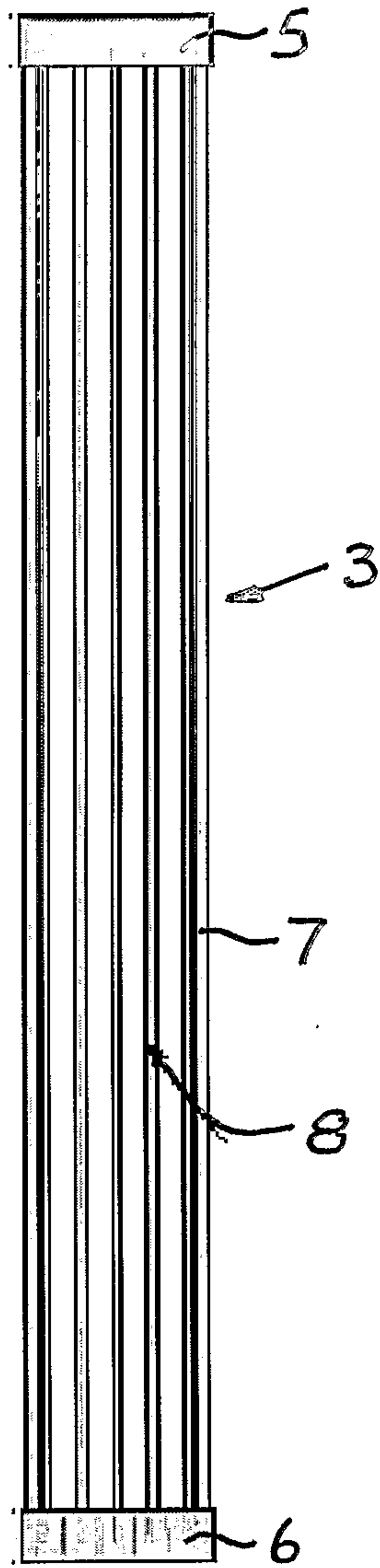
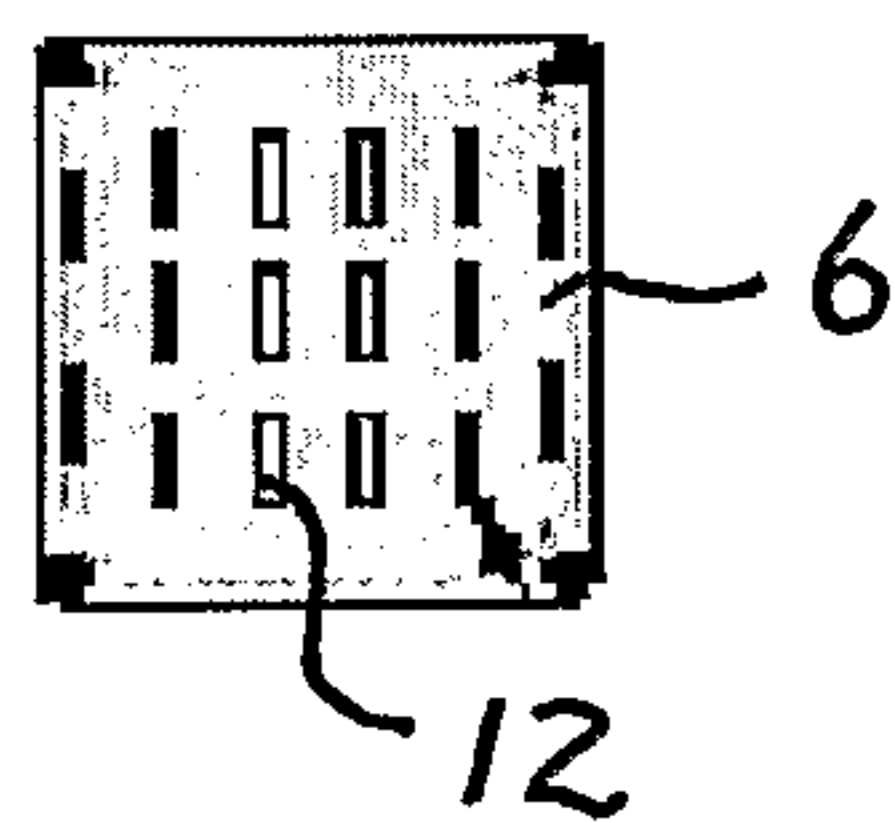
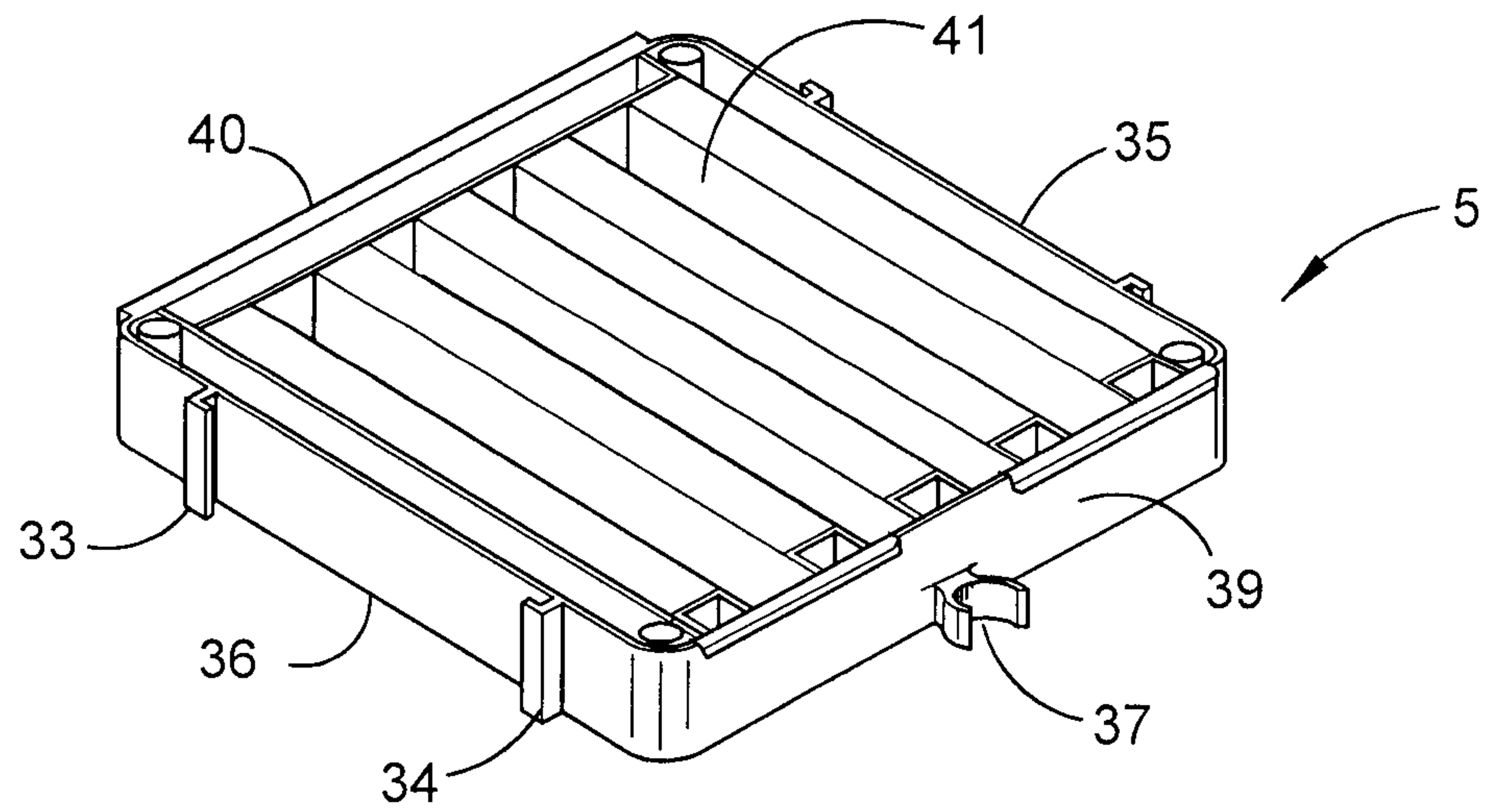
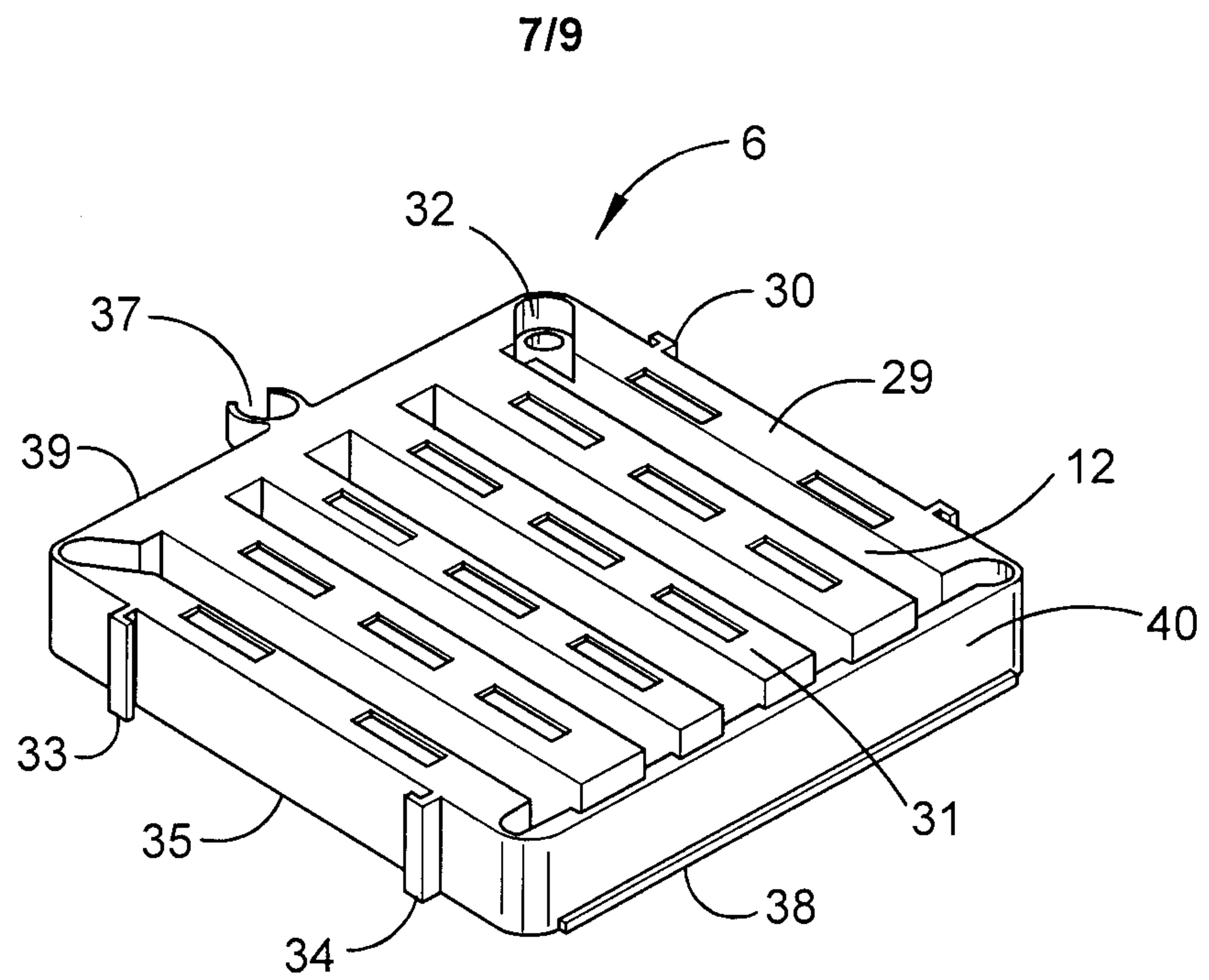
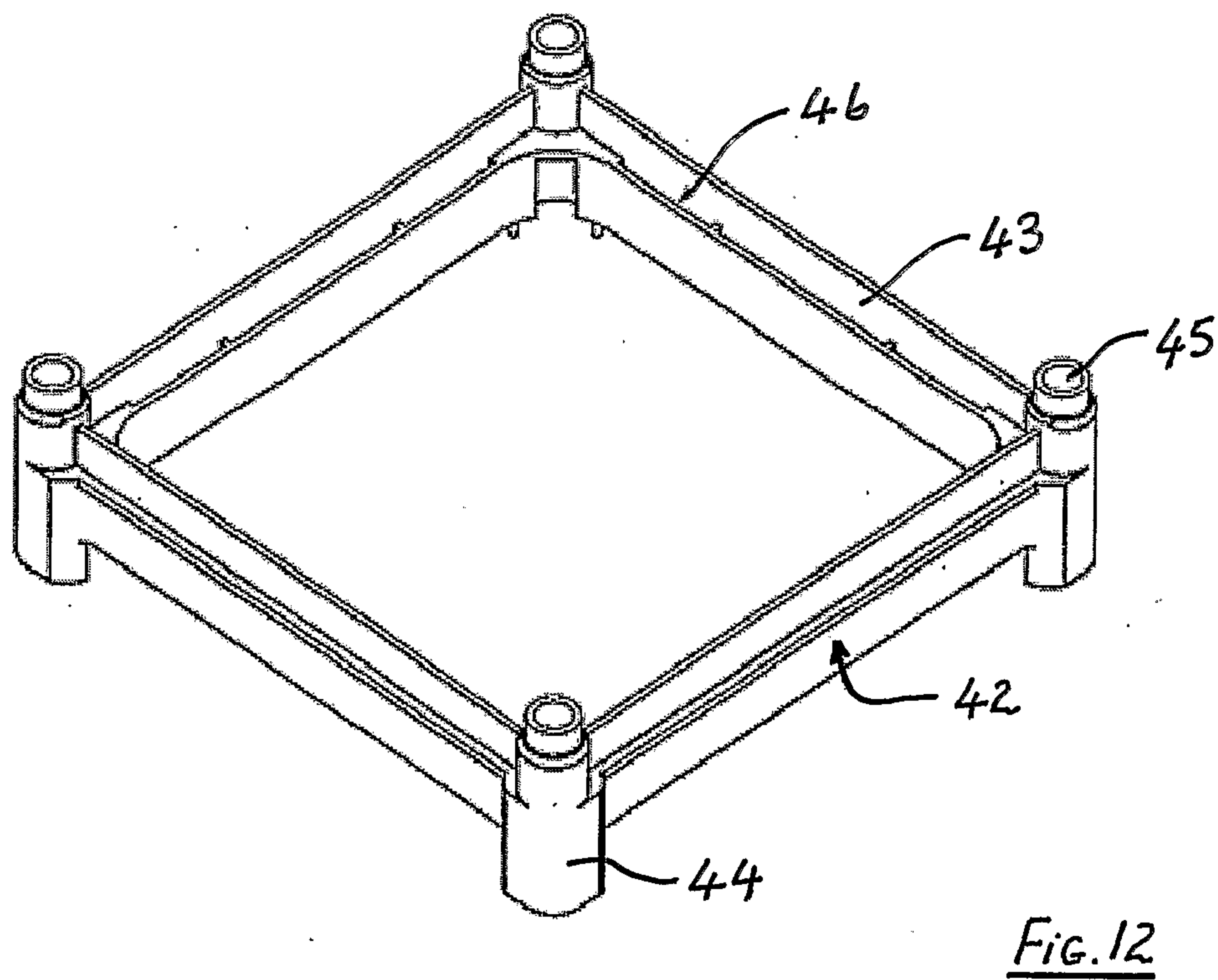
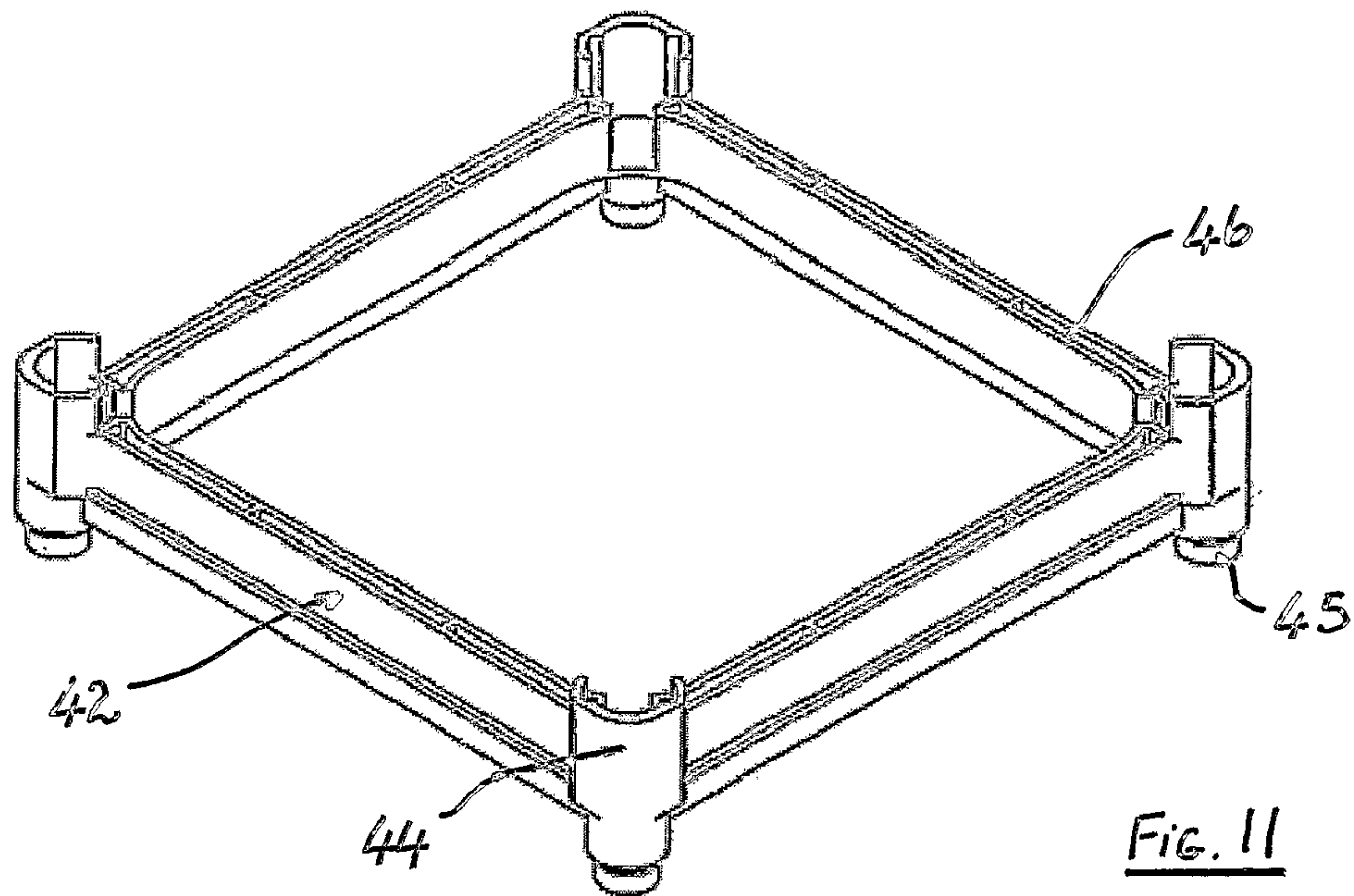
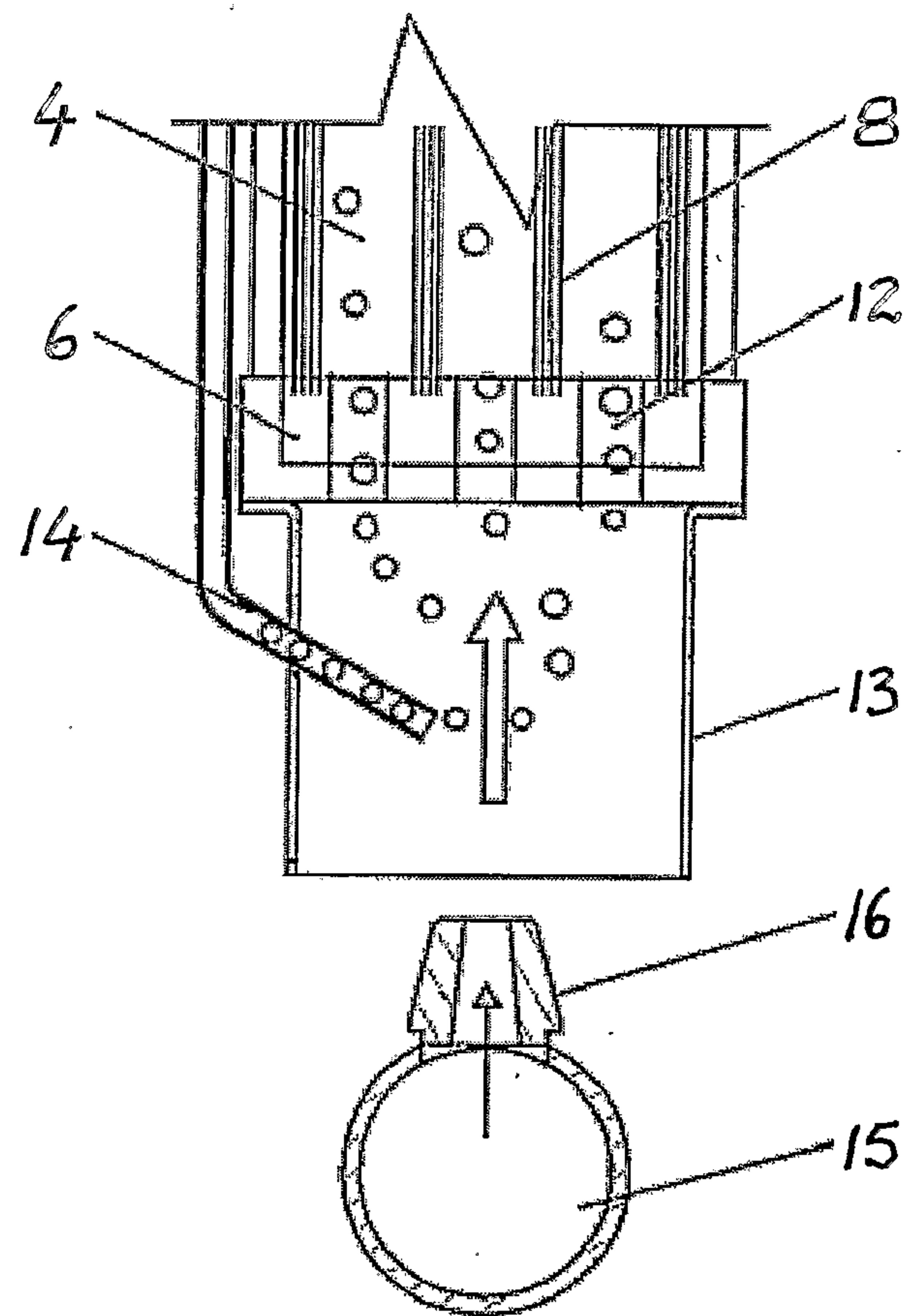


FIG. 7c

Fig. 8aFig. 8bFig. 8c





Fig. 13

