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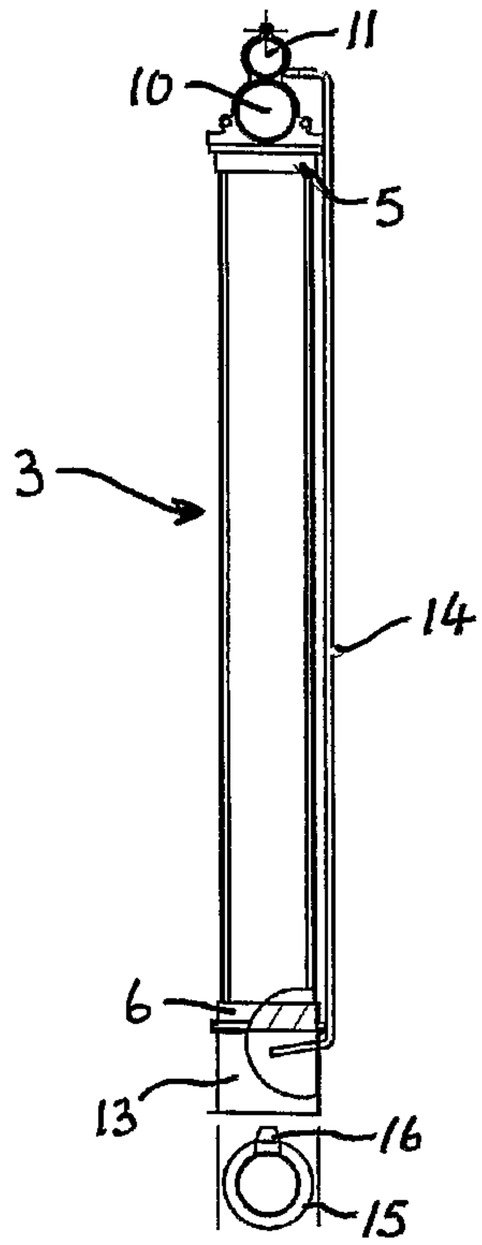
(54) Title: SQUARE MBR MANIFOLDING SYSTEM



(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 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).

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(54) Title: SQUARE MBR MANIFOLDING SYSTEM

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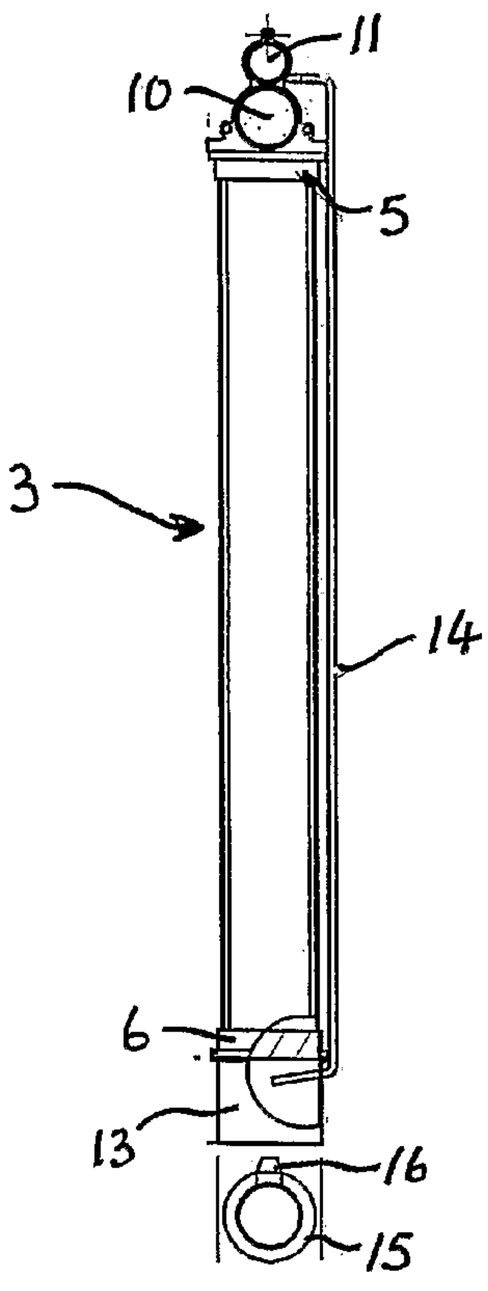

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SQUARE MBR MANIFOLDING SYSTEM

TECHNICAL FIELD

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 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 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 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.

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.

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.

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 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 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 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 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 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 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.

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 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 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 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) 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 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 proved by interlocking formations provided on adjacent lower headers of the modules. For further preference, the formations 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

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 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 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.

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.

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;

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 Figures 1 and 2;

Figure 4 shows a plan view of the cell of Figure 3 with some of the 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;

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 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 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

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 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. 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.

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

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 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.

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 partitioned bundles 4 within the potting heads 5 and 6 and the slots 12 open into the region 13 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 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 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.

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

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 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 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 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 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 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 connection of the dropper tube 14.

Figures 8c, 9 and 10 show in more detail the lower potting head 5. The lower potting head 5, in this embodiment, comprises a potting element 29

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.

Referring to Figure 9 the lower potting head 5 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 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 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.

A pair of vertically extending module interlock clips 33 and 34 are provided on a 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 is this embodiment formed along the lower edge of opposed sides 39 and 40 of the element 39 for attachment of the skirt 13. It will be appreciated that any suitable formation may be used to attach the skirt 13 to element 39 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 5. The regions between the channels 30 are open to form fluid distribution openings 41 beneath the slots 12.

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.

Referring to Figures 11 and 12, the upper potting head 6 is formed of potting insert 42 which surrounds an 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 upwardy open groove 43 extending around its upper side for receipt of o-ring 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.

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 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 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 membranes by applying suction to the filtrate header 19.

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.

It will be appreciated that further embodiments and exemplifications of the invention are possible without departing from the spirit or scope of the invention described.

CLAIMS:

1. 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 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.

2. A membrane module according to claim 1 wherein the headpiece includes a filtrate conduit in fluid communication with open ends of said membranes for the withdrawal of filtrate therefrom.

3. A membrane module according to claim 2 wherein the headpiece includes a further gas/air conduit for communicating gas/air to the module.

4. A membrane module according to claim 1 wherein the module is square or rectangular shaped in cross-section.

5. A membrane module according to claim 1 wherein a skirt is provided below said one header.

6. A membrane module according to claim 1 wherein said membranes are mounted vertically and the source of liquid includes an opening in a conduit positioned below said skirt.

7. A membrane module according to claim 1 wherein the source of gas includes a pipe or tube passing through a sidewall of said skirt, the distal end of said pipe being positioned below said openings for feeding gas thereto.

8. A membrane module according to claim 7 wherein the pipe or tube is connected to the gas/air conduit of the headpiece.

9. A membrane module according to claim 5 wherein said skirt is arranged to mix said gas and liquid before passing through said openings.

10. A membrane module according to claim 1 wherein the headers are spaced and supported by one or more support members longitudinally extending between the headers.

11. A membrane module according to claim 10 wherein the support members

are rods.

12. A membrane module according to claim 10 or 11 wherein one of more of the support members are hollow tubes and used to supply gas to the skirt from the gas/air conduit.

13. A membrane module according to claim 1 wherein the membranes are enclosed along part of their length by a screen for retaining gas/air bubbles and liquid flow within the module.

14. A membrane module according to claim 13 wherein the screen is substantially impervious to gas/air bubbles and/or liquid or both.

15. A membrane module according to claim 1 wherein the membranes comprise porous hollow fibres, the fibres being fixed at each end in a header, the lower header having a plurality of openings formed therein.

16. A membrane module according to claim 15 wherein the fibres are sealed at the lower end and open at their upper end to allow removal of filtrate.

17. A membrane module according to claim 15 wherein the fibres are arranged in partitioned bundles.

18. A membrane module according to claim 17 wherein the openings are positioned to coincide with the spaces formed between said partitioned bundles.

19. A membrane module according to claim 17 wherein said openings comprise a slot, slots or one or more rows of holes.

20. A membrane module according to claim 19 wherein the fibre bundles are located in the potting head between the slots or rows of holes.

21. A membrane module rack including a plurality of membrane modules according to claim 1 connected together by said headpieces.

22. A membrane module according to claim 21 wherein the said one headers are connected together by connection means.

23. A membrane module according to claim 22 wherein the connection means includes interlocking formations provided on said one headers of the modules.

24. A filtration system including a rack of membrane modules according to claim 1 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 between said fibres to scour the outer surfaces thereof.

25. A filtration system according to claim 24 wherein the supply of gas to said openings includes a mixture of gas and liquid.

26. A potting head for use in mounting porous hollow membranes comprising a preformed potting element, said potting element including one or more cavities for receiving curable potting material which, in use, supports said membranes.

27. A potting head according to claim 26 wherein the potting element is formed from injection-molded plastic material.

28. A potting head according to claim 26 wherein the potting element has one or more through openings formed therein for communication of fluid therethrough.

29. A potting head according to claim 28 wherein said through openings are located between said cavities.

30. A potting head according to claim 26 wherein said cavities comprise channels formed in said potting element.

31. A membrane module comprising a plurality of porous hollow membranes, said membranes extending between and being fixed at each end in a header, at least one of said headers comprising a preformed potting element, said potting element including one or more cavities containing a curable potting material which fixes and supports said membranes, said potting element having one or more of through openings formed therein; said through openings being in fluid communication with a source of gas and/or liquid.

32. A membrane module according to claim 31 wherein said through openings are located between said cavities for flowing said gas and/or liquid between said membranes.

33. A membrane module according to claim 32 wherein said membranes comprise bundles of membranes and said flow of gas and/or liquid is between said bundles and membranes.

34. A membrane module according to claim 33 wherein the bundle is in the form of a mat.

35. A membrane module according to claim 6 wherein said opening comprises a jet.

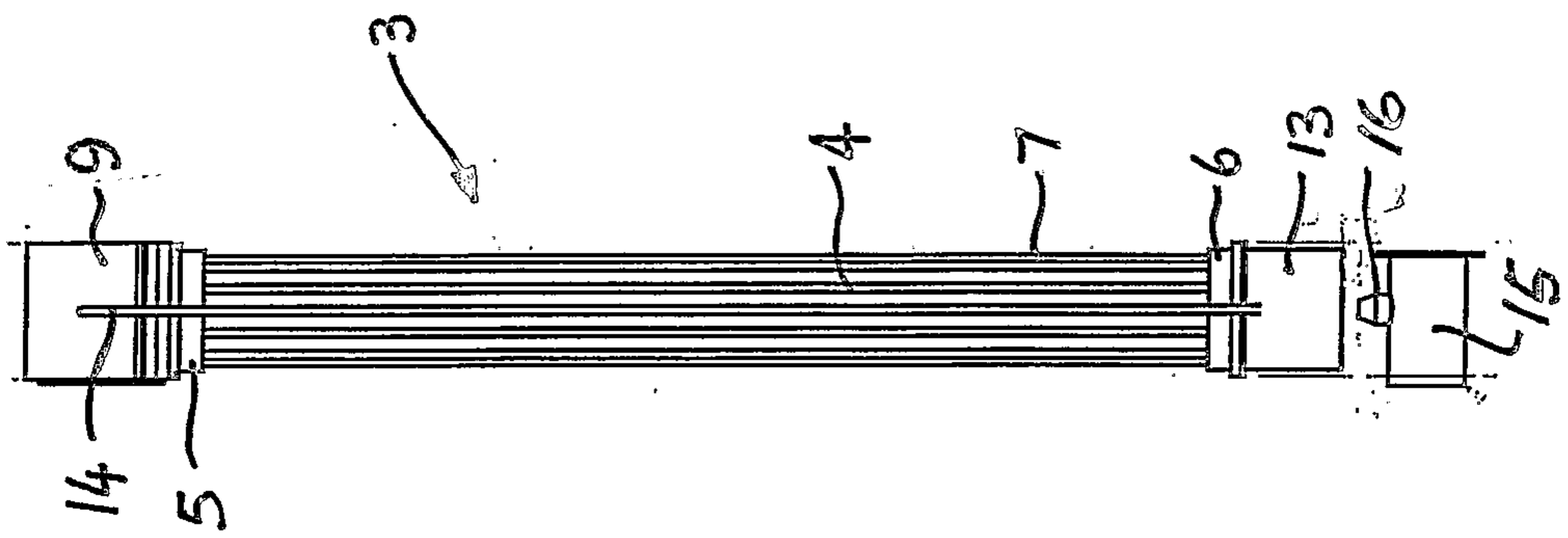


Fig. 2

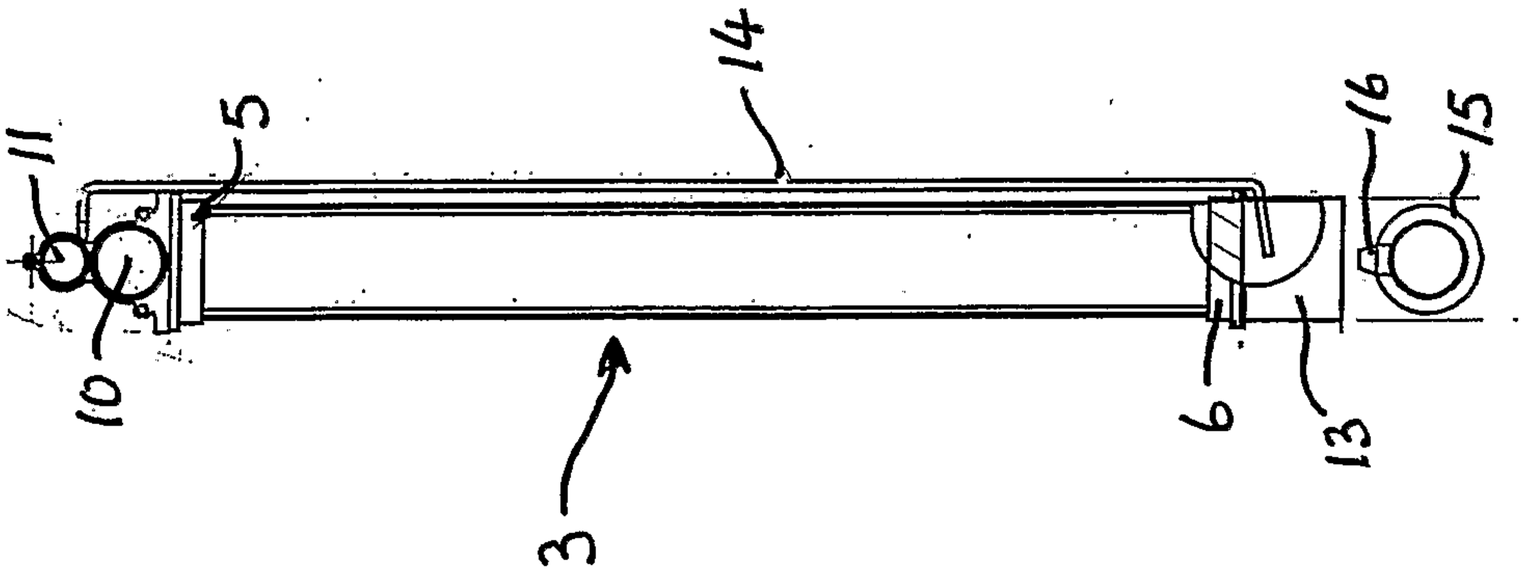


Fig. 1

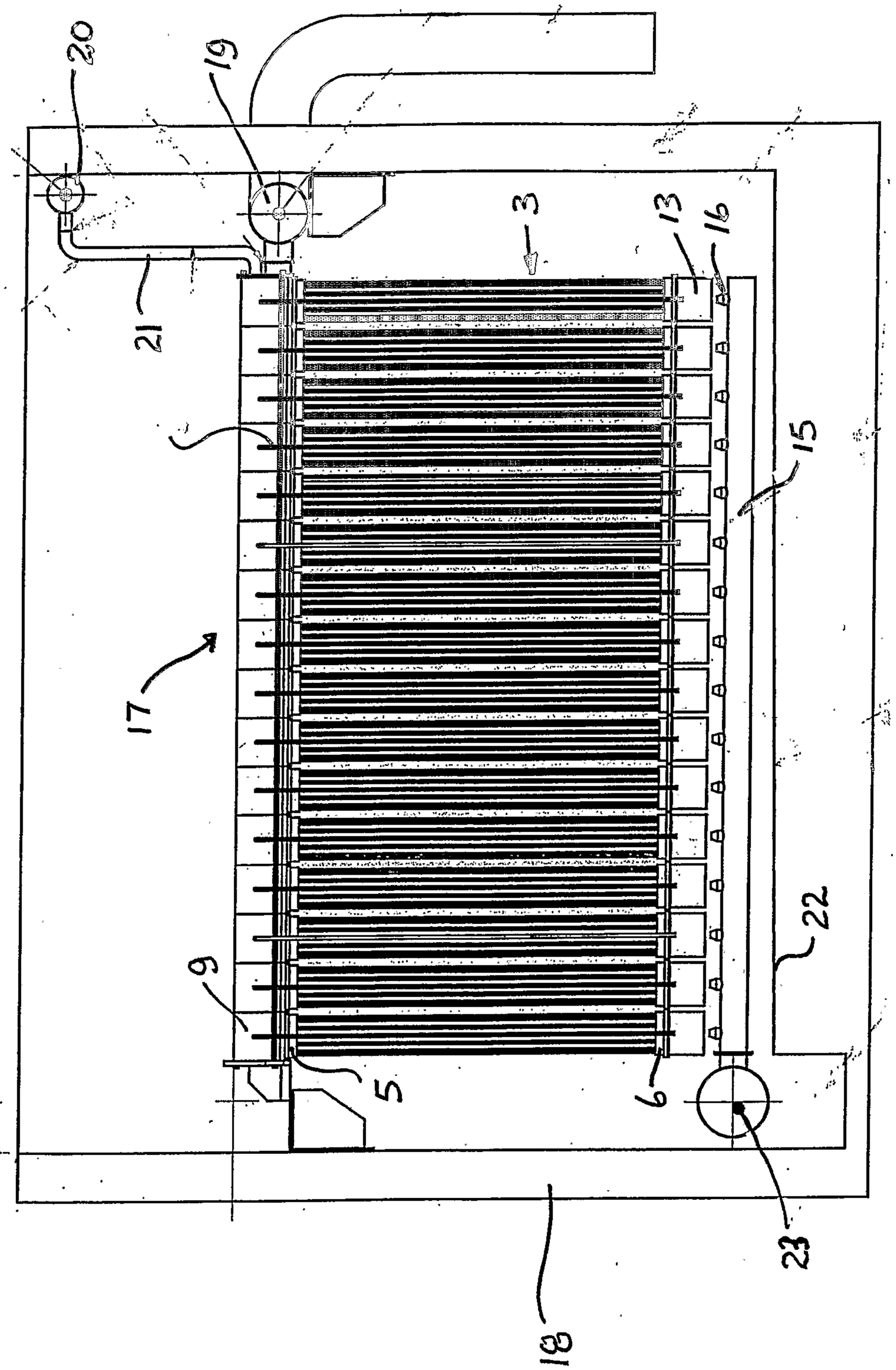


Fig. 3

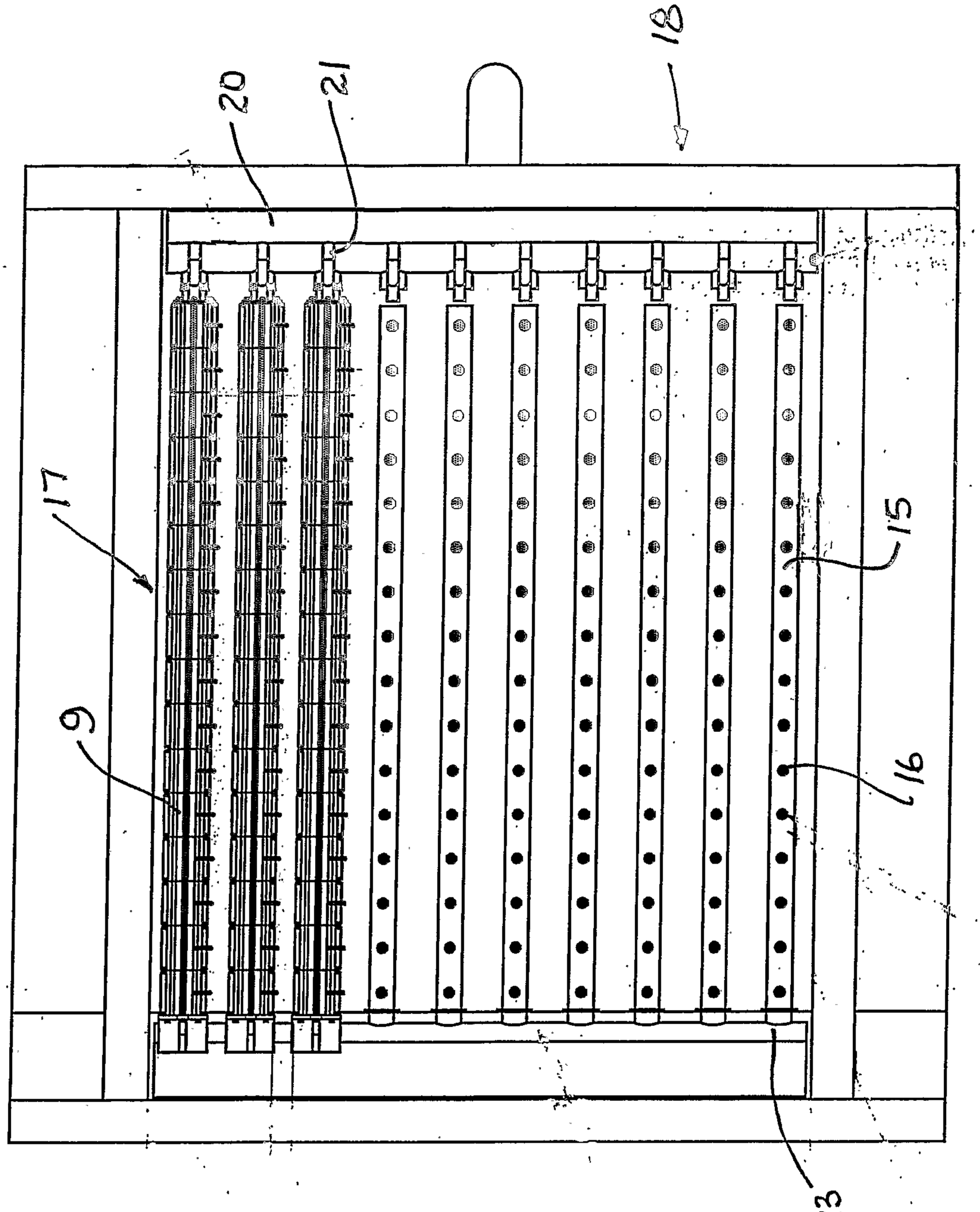


Fig. 4

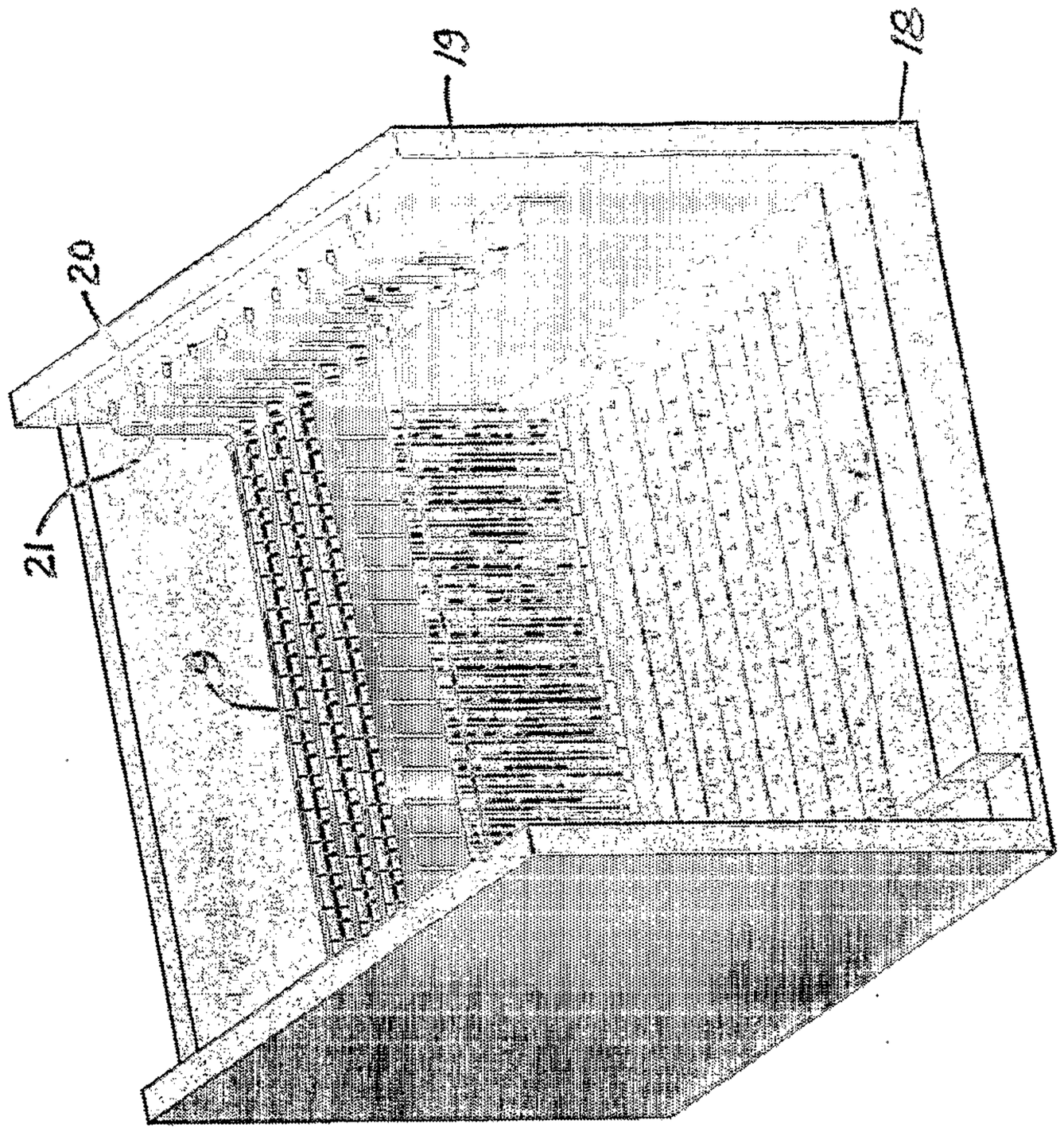


Fig. 6

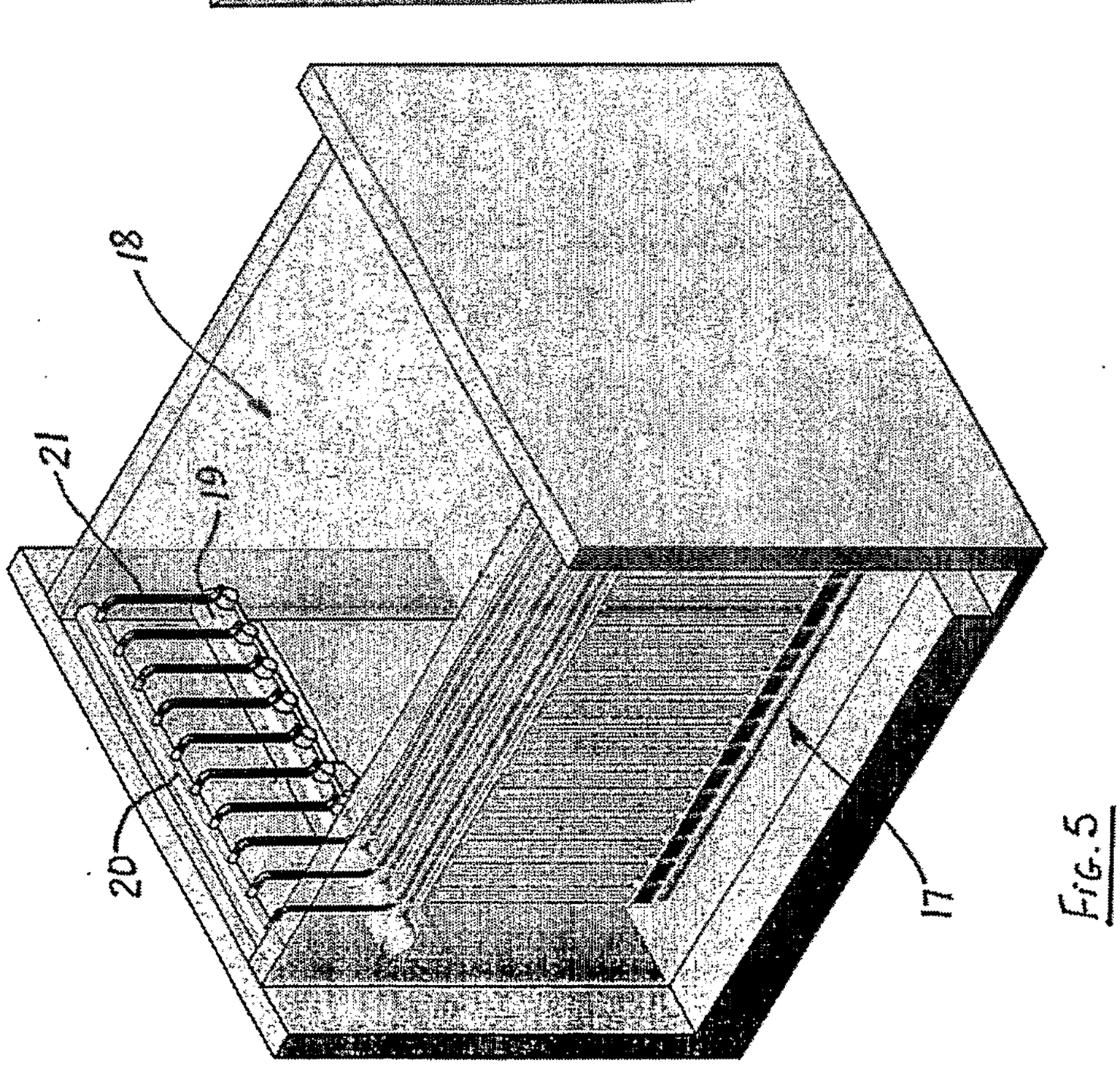


Fig. 5

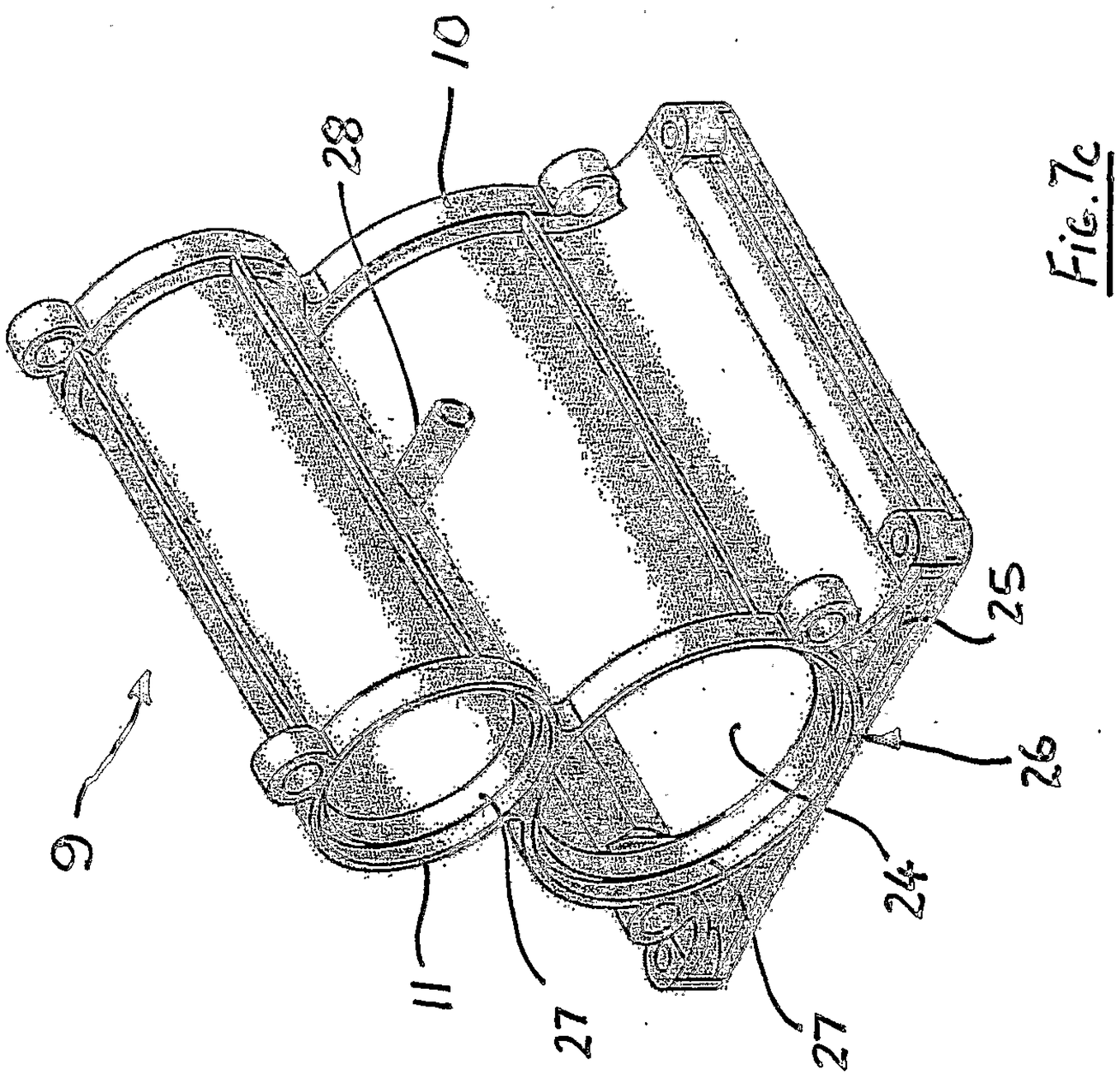


Fig. 7c

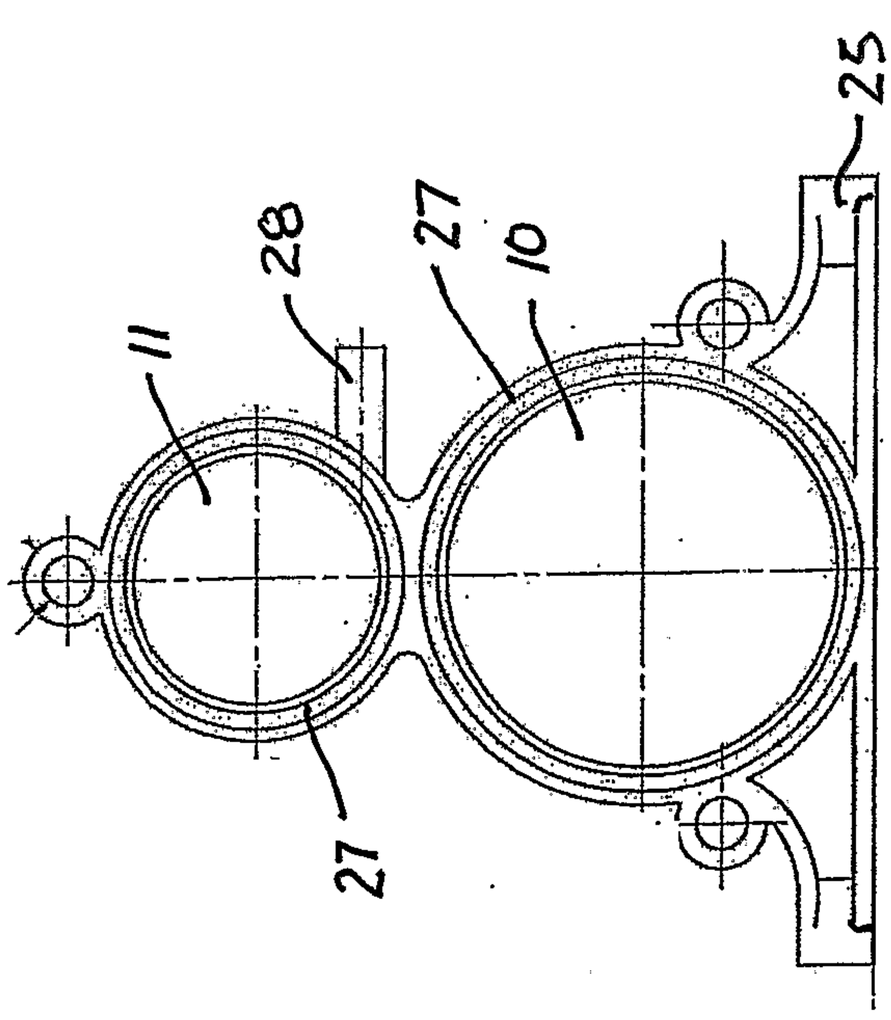


Fig. 7a

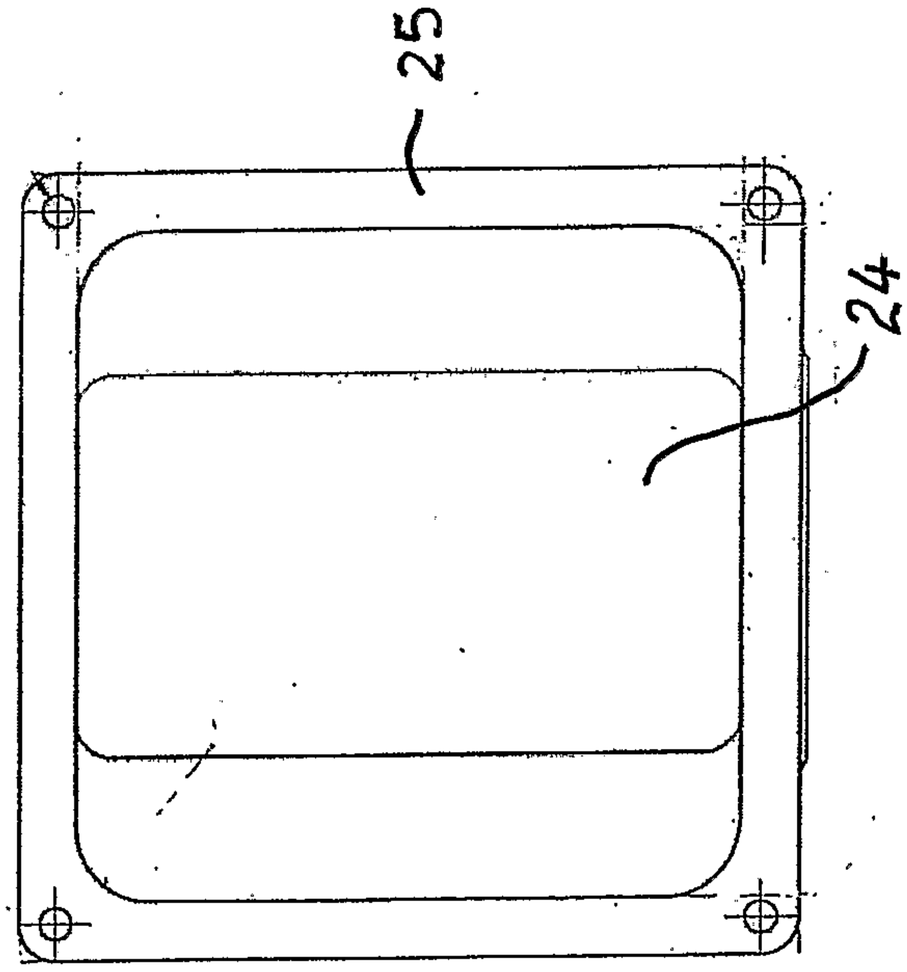


Fig. 7b

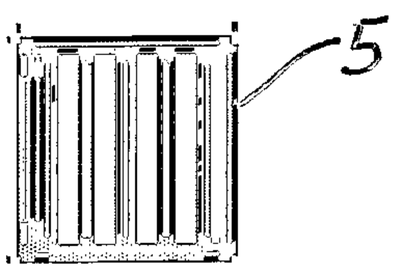


Fig. 8a

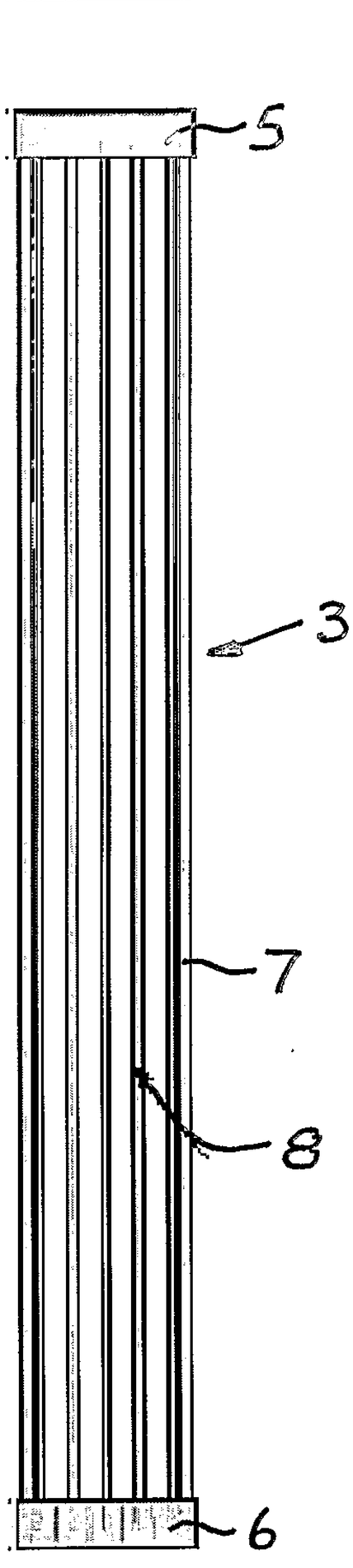


Fig. 8b

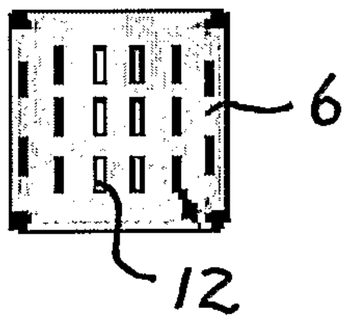


Fig. 8c

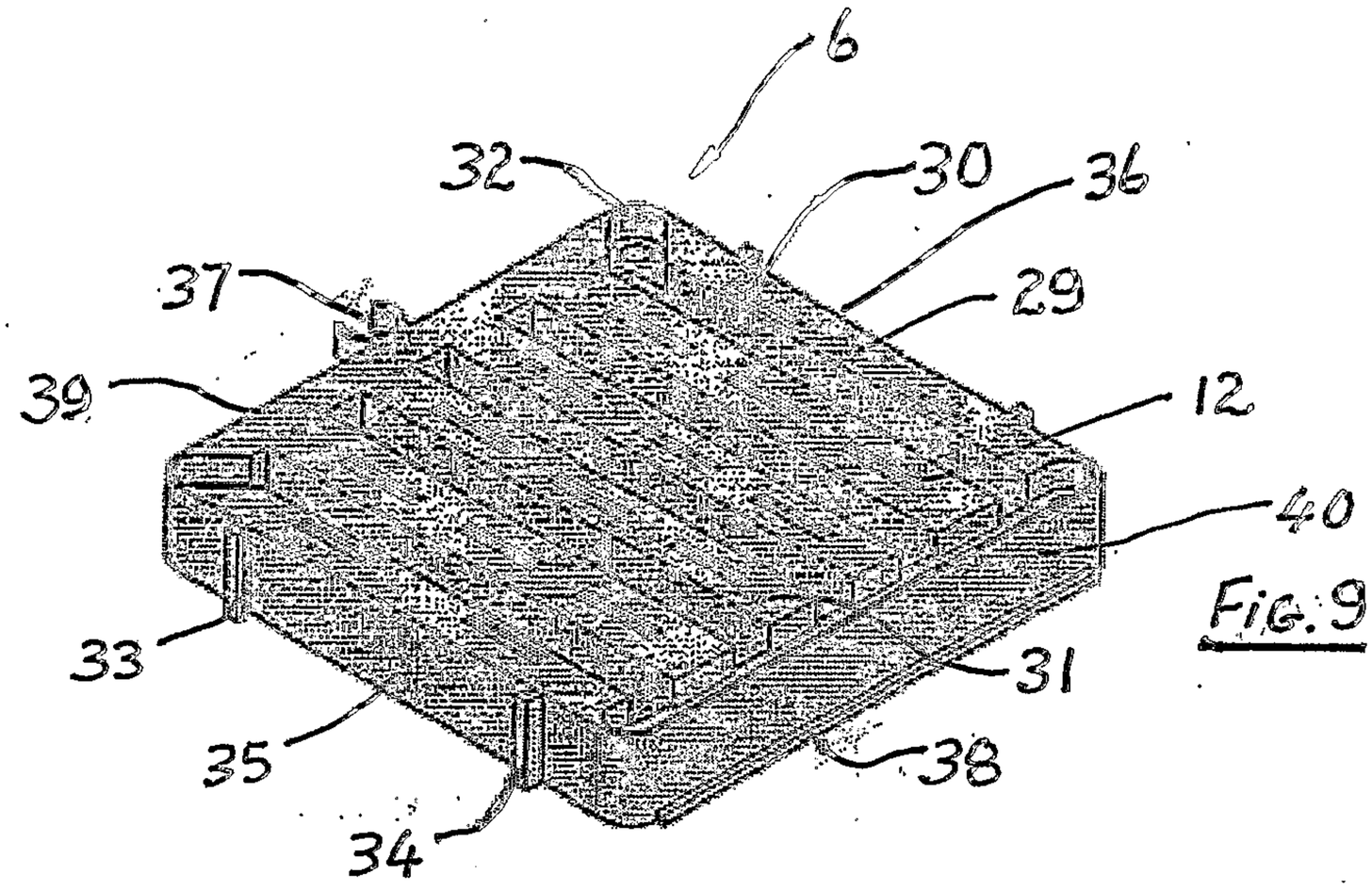


Fig. 9

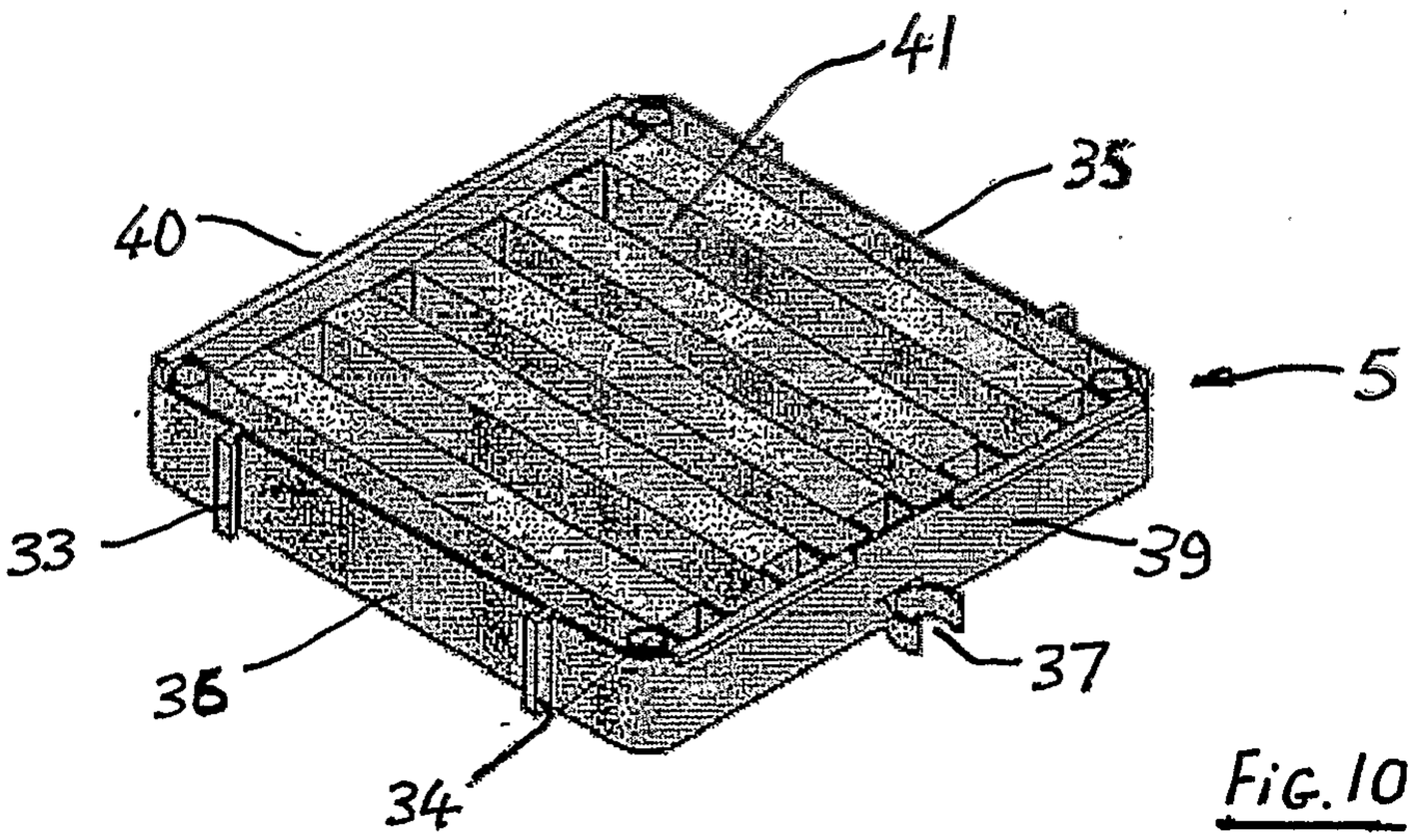


Fig. 10

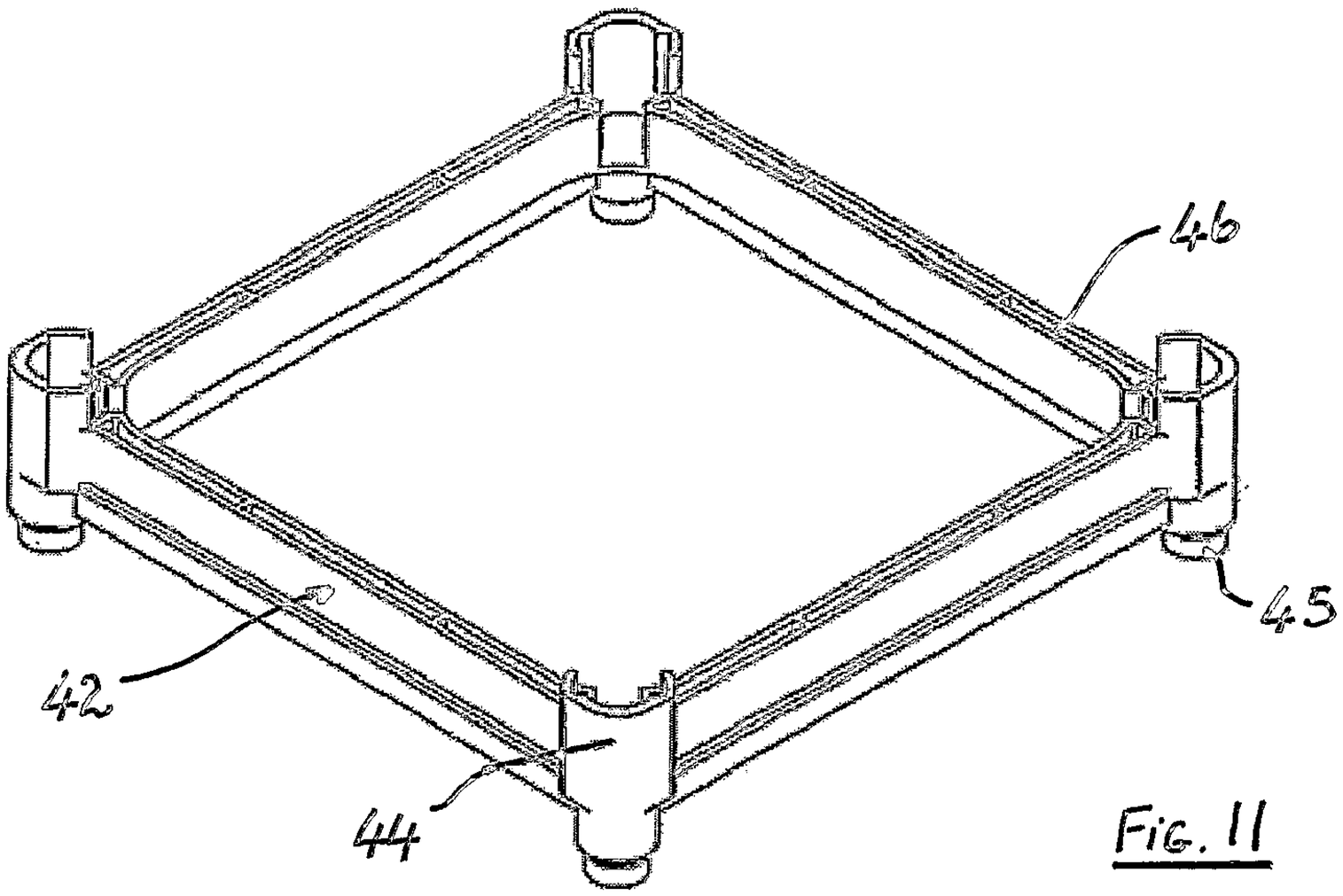


Fig. 11

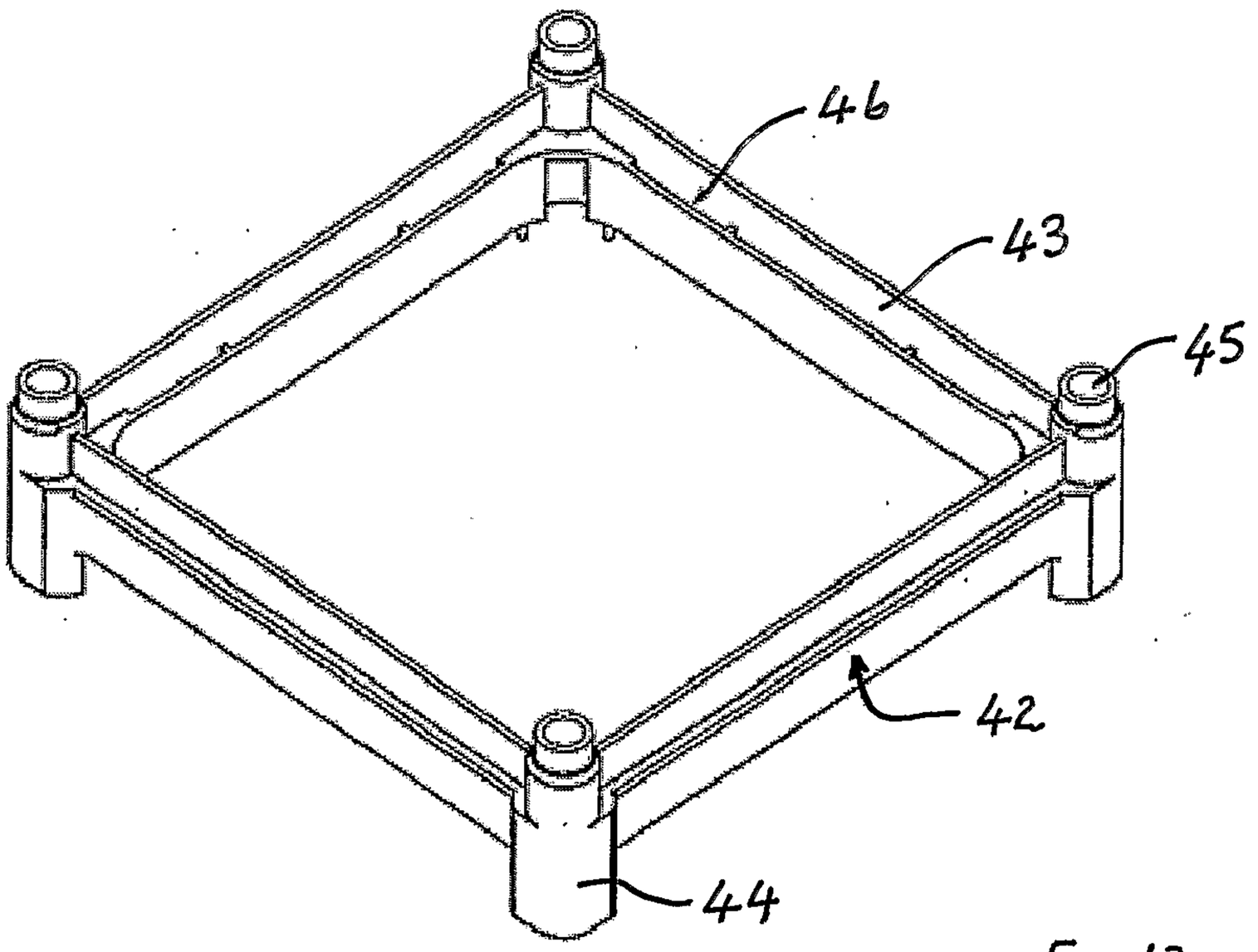


Fig. 12

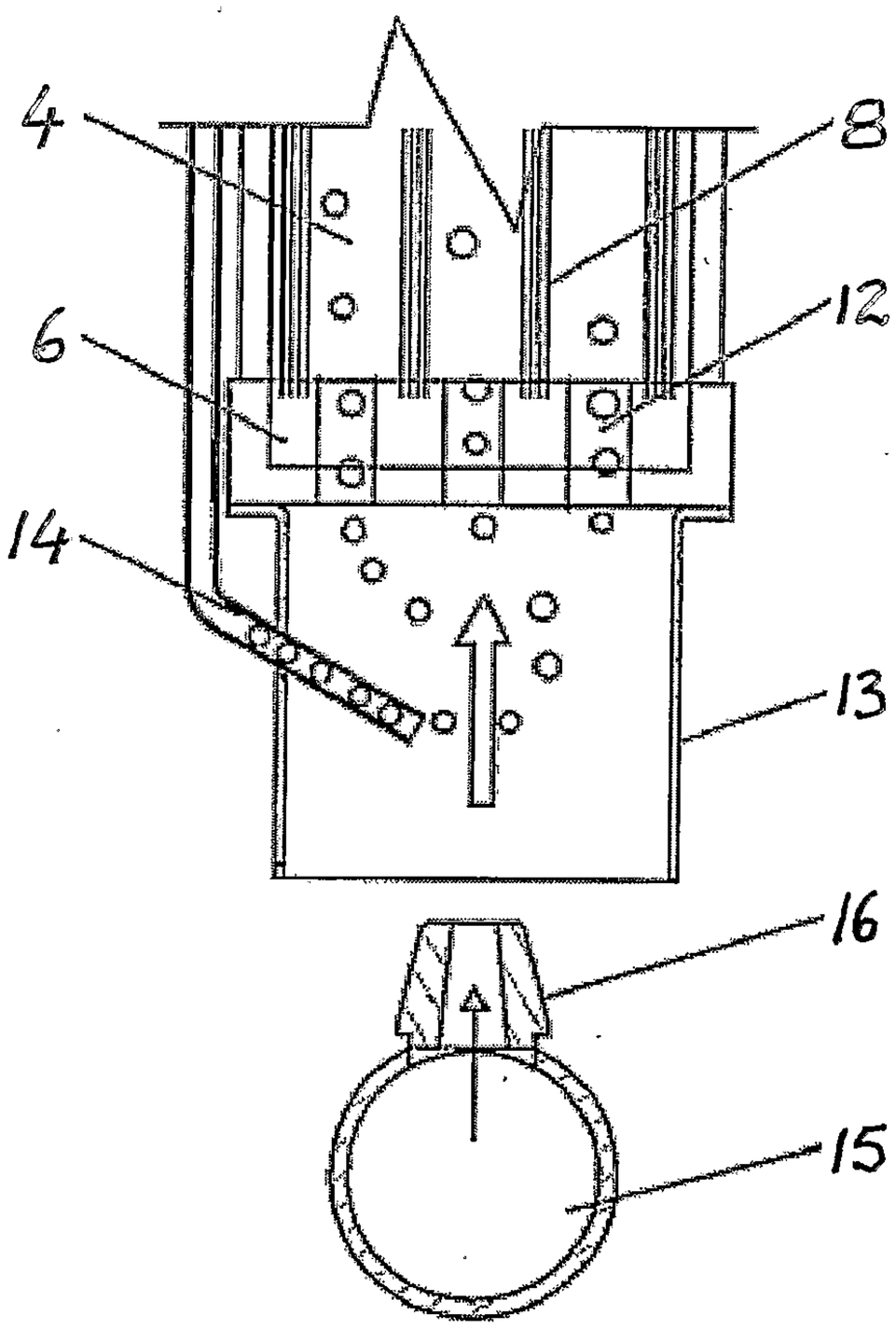
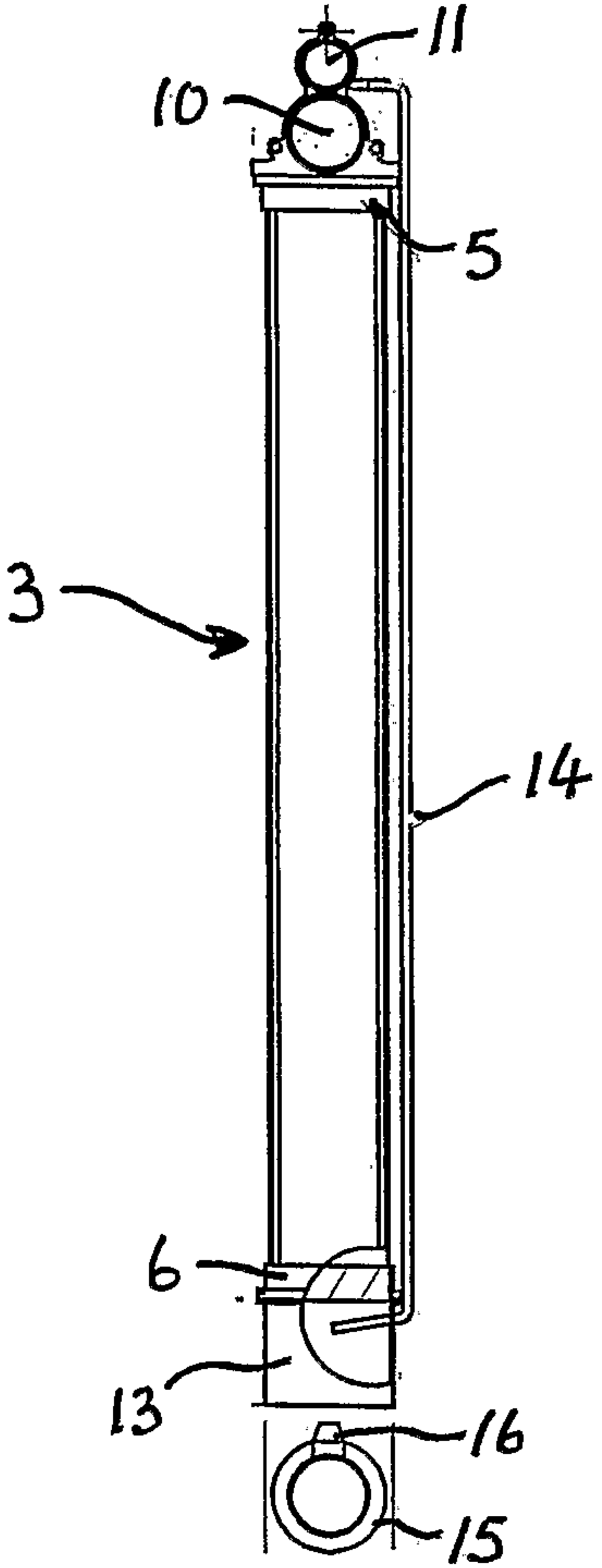


Fig. 13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