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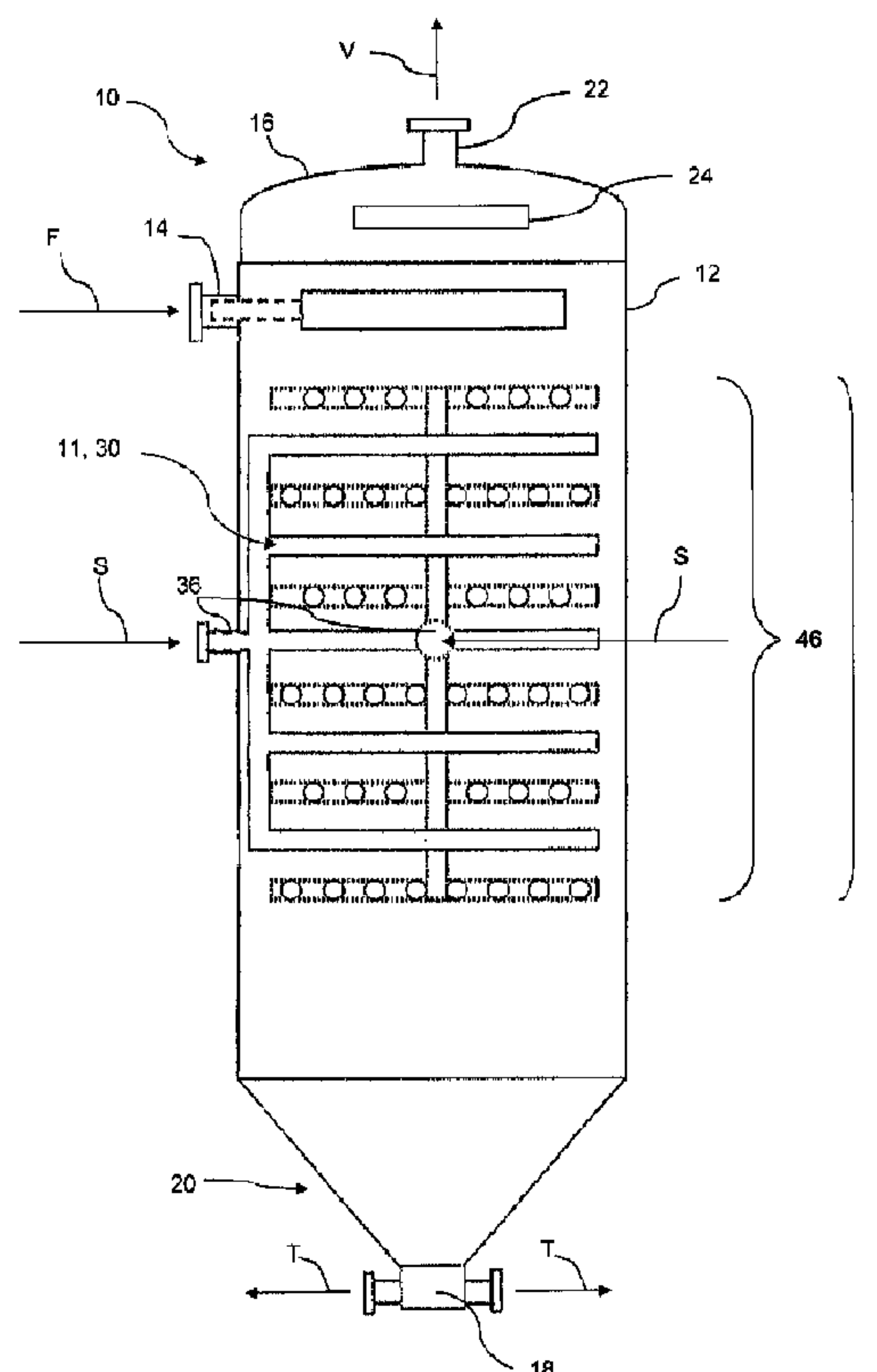
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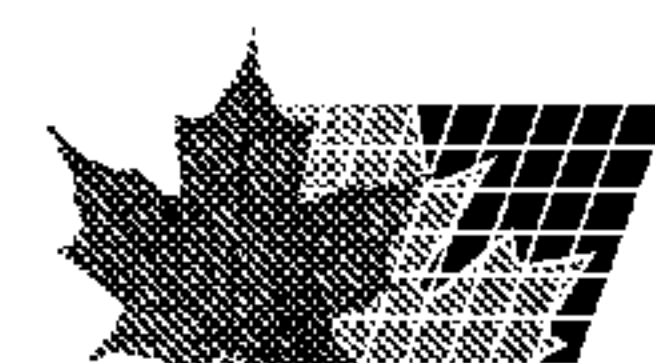
(54) Titre : GRILLE A VAPEUR MULTICOUCHE POUR TRANSFERT DE CHALEUR ET DE MASSE DANS UNE UNITE  
DE RECUPERATION DE SOLVANT DE RESIDUS

(54) Title: MULTI-LAYER STEAM GRID FOR HEAT AND MASS TRANSFER IN A TAILINGS SOLVENT RECOVERY  
UNIT



(57) **Abrégé/Abstract:**

A grid of pipes for conducting steam at a pressure greater than a vessels' operating pressure and delivering the steam throughout the grid forms the internals for a tailings solvent recovery unit. The delivery of steam throughout the grid aids in maintaining a relatively low partial pressure throughout the vessel to act as a driver for mass transfer. Conducting the steam at the higher pressure through the pipes in the grid permits a surface of the pipes to be heated to a temperature higher than possible in a conventional vessel, increasing the heat transfer to the feed stream which flows through the grid.



ABSTRACT

A grid of pipes for conducting steam at a pressure greater than a vessels' operating pressure and delivering the steam throughout the grid forms the internals for a tailings solvent recovery unit. The delivery of steam throughout the grid aids in maintaining a relatively low partial pressure throughout the vessel to act as a driver for mass transfer. Conducting the steam at the higher pressure through the pipes in the grid permits a surface of the pipes to be heated to a temperature higher than possible in a conventional vessel, increasing the heat transfer to the feed stream which flows through the grid.

1           **"MULTI-LAYER STEAM GRID FOR HEAT AND MASS TRANSFER IN A**  
2           **TAILINGS SOLVENT RECOVERY UNIT"**

3  
4                           FIELD OF THE DISCLOSURE

5           Embodiments relate to the recovery of hydrocarbon diluent from  
6 tailings resulting from the treatment of bitumen froth formed during bitumen  
7 recovery from oil sands and, more particularly, relate to apparatus for distributing  
8 steam within a vessel for the recovery of the hydrocarbon diluent from said  
9 hydrocarbon diluent-containing tailings.

10  
11                           BACKGROUND

12           Bitumen is produced from oil sand such as is found in the Fort  
13 McMurray region of Alberta, Canada. The oil sand is mined and has been  
14 commercially recovered using hot water processes which generally require slurring  
15 the oil sand with at least heated water or steam. The slurry is conditioned and the  
16 resulting froth separated from the solids portion for recovery of the bitumen  
17 therefrom.

18           The bitumen-containing froth is typically diluted with a hydrocarbon  
19 diluent, such as a naphthenic or paraffinic solvent, to reduce the viscosity and to aid  
20 in separating the bitumen from water and solids contained in the froth. Separation of  
21 the bitumen from the solids and water typically results in a bitumen-rich stream and  
22 a solvent-containing tailings feed stream.

23           In order to improve the economics of the bitumen recovery processes  
24 and the environmental impact of tailings disposal, solvent recovery apparatus and

1 processes, generally known as tailings solvent recovery units (TSRU) are employed  
2 to recover the solvent from the solvent-containing tailings stream prior to disposal.  
3 The recovered solvent is typically recycled for use in the froth treatment processes.  
4 Conventional solvent recovery is typically effected by increasing the surface area of  
5 the solvent-containing tailings feed stream by creating a thin film of feed using  
6 internals such as shed decks or by retaining a pool of solvent containing tailings  
7 within the vessel for sufficient time, typically at least 5 to 15 minutes, to permit  
8 solvent release from the pool.

9 US Patent 6,712,215 to Scheybeler describes a solvent recovery  
10 vessel having pairs of nozzles located within the vessel. Each pair of nozzles is  
11 arranged horizontally in a 180-degree, opposed relationship. The nozzles have a  
12 first inlet for receiving solvent-containing tailings and a second inlet for receiving  
13 steam. A single outlet discharges a mixed steam/tailings stream. Adiabatic  
14 expansion of the steam, when contacted with the tailings, carries the discharge  
15 stream at high speed toward a centre of the vessel. The opposing orientation of the  
16 nozzles causes the discharge streams to collide at high speed forming small  
17 droplets in the vessel. The relatively larger surface area of the droplets facilitates  
18 release of the solvent from the liquid phase to the vapour phase. Shed decks  
19 located below the collision zone are heated using a steam sparger located beneath  
20 the shed decks and act to spread the droplets into thin layers thereon to facilitate  
21 heat transfer resulting in further solvent release. Another steam sparger is located  
22 in a lower portion of the column and further aids in stripping residual solvent from

1 the liquid within the vessel. Pressure in the vessel is maintained at sub-atmospheric  
2 conditions through use of a steam eductor.

3 Canadian Patent 2,272,045 to Mocal Energy Limited et al (Syncrude)  
4 teaches introduction of froth treatment tailings into a near-atmospheric steam  
5 stripping TSRU vessel having a plurality of interior, vertically-spaced shed decks.  
6 The liquid tailings stream is evenly distributed over the shed decks creating a thin  
7 film of the liquid feed on an upper surface of the shed decks. Steam is introduced  
8 below the vertically-spaced shed decks and flows countercurrent to the tailings  
9 stream in order to vapourize the hydrocarbon diluents from the thin film of feed  
10 material. The vessel is preferably maintained at near atmospheric conditions (about  
11 95 kPa).

12 Canadian Patents 2,587,166, 2,613,873 and 2,614,669 to Imperial Oil  
13 Resources Limited teach steam stripping TSRU vessels having internals, typically  
14 shed decks, with feed streams that contain asphaltenes. Both one-stage and two-  
15 stage processes are claimed. Steam is introduced below the internals or directly  
16 into a pool of liquids in the vessel and, in all cases, no agitation is utilized to mix the  
17 contents of the pool. At least a first TSRU vessel is operated at an absolute  
18 pressure between 100 kPa - 200 kPa and at a temperature of between 75°C and  
19 100°C. A second TSRU is contemplated and is operated at a pressure lower than  
20 the first TSRU, being about 20-200 kPa and preferably 25-100 kPa and at a  
21 temperature of between 75°C and 100°C. Additional TSRU vessels are  
22 contemplated to be added in series.

1                   In the prior art vessels, steam is generally injected below the internals,  
2   such as shed decks and the like. The temperature of the internals therefore can  
3   only become as hot as the temperature of the steam being condensed at vessel  
4   operating pressures. The internals in the vessel therefore provide a relatively poor  
5   heat transfer surface, particularly where the feed contains asphaltenes which  
6   require significant heat to soften and release solvents trapped therein.

7                   Further, in conventional TSRU's, the majority of the steam is  
8   condensed in contact with the tailings feed stream at the bottom of the vessel to  
9   transfer heat to the tailings stream. As a result, the partial pressure of the solvent is  
10   higher at the top of the vessel compared to the bottom of the vessel. The  
11   concentration of solvent vapour is also highest at the top of the vessel and therefore  
12   there is less impetus for mass transfer within the vessel.

13                  There remains significant interest in the industry for apparatus and  
14   processes which result in more efficient and effective solvent recovery, particularly  
15   for feed streams which contain paraffinic solvents and asphaltenes resulting  
16   therefrom and to meet ever more stringent regulations regarding minimizing solvent  
17   loss and tailings disposal generally.

18



1 pressure for heating the internals to a temperature greater than a vessel  
2 temperature.

3           In another broad aspect, a tailings solvent recovery unit comprises a  
4 substantially vertical vessel having an operating pressure and temperature. A feed  
5 inlet is adjacent a top of the vessel for receiving a non-homogeneous solvent-  
6 containing tailings feed stream therethrough. Internals extend vertically throughout  
7 the vessel, steam being conducted through the internals at a pressure greater than  
8 the vessel operating pressure, the steam being discharged therefrom at a plurality  
9 of locations therethrough and flowing countercurrent to the feed stream. A vapour  
10 outlet at a top of the vessel permits removal of solvent vapour released from the  
11 solvent-containing tailings feed stream. A solvent-depleted tailings outlet at the  
12 bottom of the vessel permits removal of the solvent-depleted tailings stream. A  
13 surface of the internals is heated by the steam to a temperature greater than the  
14 vessel operating temperature, the feed stream contacting the surface of the  
15 internals for heat transfer thereto as the feed stream flows about the internals.

16           In yet another broad aspect, the internals comprise a steam grid  
17 adapted for delivering steam to a tailings solvent recovery vessel having an  
18 operating pressure and temperature. The steam grid comprises a vertically-  
19 extending grid of fluidly-connected steam delivery pipes for conducting steam at a  
20 pressure greater than vessel pressure. The steam grid has a vertical height and a  
21 diametral extent and a plurality of steam outlets distributed therein, along the  
22 vertical height and across the diametral extent of the steam grid for discharging  
23 steam therefrom along substantially an entirety of the vertical height and

1 substantially an entirety of a cross-section of the vessel. The outlets are sized for  
2 conducting steam within the steam delivery pipes at a pressure greater than the  
3 vessel's operating pressure, heating an outer surface of the steam delivery pipes to  
4 a temperature greater than the vessel's operating temperature.

5 In embodiments, the plurality of fluidly-connected steam delivery pipes  
6 are arranged in transverse layers forming a vertically extending grid of layers. The  
7 transverse layers substantially fill a cross-section of the vessel. The steam delivery  
8 pipes in each of the layers are spaced apart and parallel. The steam grid provides a  
9 tortuous path for the feed stream flowing therethrough. The pipes in each layer can  
10 be oriented in the same direction as pipes in an adjacent layer or can be angled  
11 relative to the pipes in the adjacent layer, such being oriented 90 degrees relative to  
12 the pipes in an adjacent layer. Further, where the pipes are oriented in the same  
13 direction, either adjacent or every other layer, the pipes can be spaced to be  
14 laterally offset.

15 In embodiments, the steam delivery pipes are substantially circular in  
16 cross-section which causes the feed stream to flow thereabout toward steam outlets  
17 or orifices which are positioned in a downward-facing surface of the pipes. The feed  
18 stream contacts the steam exiting the orifices. Any remaining steam flows upward  
19 therefrom through the grid for contacting the feed stream flowing therethrough.

20 Advantageously, steam which condenses in the pipes is delivered  
21 from the orifices as a spray which aids in preventing cake build-up on the pipes  
22 below. Further, any foam which may form falls through openings in the grid between

1 the pipes onto the pipes below, breaking the foam. Thus, foam production in the  
2 vessel is reduced.

3

4 **BRIEF DESCRIPTION OF THE DRAWINGS**

5 Figure 1 is a diagrammatic representation of a cross-sectional view of  
6 a tailings solvent recovery unit (TSRU) vessel having a multi-layer steam grid  
7 according to an embodiment of the disclosure;

8 Figure 2 is a fanciful, perspective view of the steam grid of Fig. 1;

9 Figure 3A is a cross-sectional view of a layer of fluidly-connected  
10 steam delivery pipes of the multi-layer steam grid of Fig. 2;

11 Figure 3B is a cross-sectional view of a single steam delivery pipe  
12 according to Fig. 3A;

13 Figures 4A and 4B are diagrammatic representations of an  
14 embodiment of an orientation of steam delivery pipes within adjacent layers in the  
15 multi-layer steam grid, the pipes in adjacent layers being oriented 90 degrees to one  
16 another, more particularly

17 Fig. 4A is an end view of three adjacent layers; and

18 Fig. 4B is a plan view according to Fig. 4A;

19 Figures 5A and 5B are diagrammatic representations of an  
20 embodiment of an orientation of steam delivery pipes within adjacent layers in the  
21 multi-layer steam grid, the pipes being oriented 90 degrees to one another and the  
22 pipes in every other layer being oriented in the same direction but offset relative to  
23 each other, more particularly,

1                    Fig. 5A is an end view of three adjacent layers; and

2                    Fig. 5B is a plan view according to Fig. 5A;

3                    Figures 6A and 6B are diagrammatic representations of an  
4                    embodiment of an orientation of steam delivery pipes within adjacent layers in the  
5                    multi-layer steam grid, each layer having pipes oriented in the same direction, every  
6                    other layer having the pipes being offset relative to the pipes in the adjacent layers,  
7                    more particularly,

8                    Fig. 6A is an end view of three adjacent layers; and

9                    Fig. 6B is a plan view according to Fig. 6A;

10                   Figures A7A and 7B are diagrammatic representations of the heights  
11                   for an equivalent surface area of vessel internals comparing conventional shed  
12                   decks (Fig. 7A) to a multi-layer steam grid (Fig. 7B) according to an embodiment of  
13                   the disclosure;

14                   Figure 8 is a diagrammatic representation of a two-stage system  
15                   utilizing two TSRU vessels according to embodiments of the disclosure;

16                   Figure 9 is a sectional view of a TSRU vessel according to an  
17                   embodiment of the disclosure;

18                   Figure 10 is a plan view of odd numbered and even numbered layers  
19                   in a multi-layer steam grid according to Fig. 8, the layers being viewed side-by-side  
20                   for comparison;

21                   Figure 11 is a longitudinal sectional view of the multi-layer steam grid  
22                   arranged according to Fig. 9;

1                   Figures 12A and 12B illustrate a comparison between a TSRU vessel  
2   having a multi-layer steam grid according to Fig. 11 (Fig. 12A) and a TSRU vessel  
3   having a plurality of prior art shed decks (Fig. 12B), for an equivalent, effective  
4   surface area, a height of the shed decks being greater than a height of the steam  
5   grid and the overall height of the vessel being greater where shed decks are used;

6                   Figures 13A to 13C illustrate multi-layer internals used for testing and  
7   comparison of solvent recovery efficiency between a prior art configuration and two  
8   different embodiments of the disclosure; more particularly;

9                   Fig. 13A illustrates a prior art arrangement of flat metal plates,  
10   steam being delivered therebelow;

11                  Fig. 13B illustrates a steam grid according to Fig. 11;

12                  Fig. 13C illustrates a steam grid according to Figs. 4A and 4B;

13                  and

14                  Figure 14 is a graph of linear regression analysis of methanol recovery  
15   data generated from the internals configurations of Figs. 13A-13C.

16

1                    **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

2                    Embodiments disclose apparatus and a method for recovering solvent  
3                    from a solvent-containing tailings feed stream F produced as an underflow stream  
4                    from a froth treatment facility. A typical feed stream F is generally non-  
5                    homogeneous and comprises about 61% water, 7% solvent, 12% bitumen and 20%  
6                    solids. Thus, unlike the feed streams used with conventional steam stripper  
7                    technology, the solvent-containing tailings feedstream F is unlikely to form an ideal  
8                    falling film as it flows through internals in a tailings solvent recovery (TSRU) vessel.

9                    In embodiments, as shown in Fig. 1, internals 11 in a tailings solvent  
10                    recovery unit (TSRU) stage 10 conduct steam S therethrough and discharge steam  
11                    S at a plurality of locations along a height H of the internals 11 and across a cross-  
12                    section of the TSRU vessel 12. The steam S is conducted therethrough at a  
13                    pressure higher than a vessel pressure for steam-heating the internals 11 to a  
14                    temperature greater than would normally be possible at a vessel operating  
15                    pressure, resulting in an increased heat transfer to the feedstream flowing  
16                    therethrough. Further, delivery of steam S at the plurality of locations results in a  
17                    relatively low partial pressure substantially throughout the vessel 12 when  
18                    compared to a TSRU with conventional internals, the relatively low partial pressure  
19                    being a driver for promoting mass transfer therein.

20                    In an embodiment the discharge of steam at the plurality of locations  
21                    is throughout substantially the entirety of the height H of the internals 11 and across  
22                    substantially the entirety of the cross-section of the TSRU vessel 12.

1           The TSRU 10 comprises a vertical vessel 12 having a feed inlet 14  
2   adjacent a top 16 of the vessel 12 for introducing the solvent-containing tailings  
3   feed stream F to the vessel 12. A tailings outlet 18 at the bottom 20 of the vessel 12  
4   discharges substantially solvent-depleted tailings T from the vessel 12. A vapour  
5   outlet 22 at the vessel's top 16 discharges solvent vapour V, released from the feed  
6   stream F within the vessel 12. The feed stream F is discharged through the feed  
7   inlet 14 into the vessel 12 under a pressure drop. The vessel 12 is operated at a  
8   vessel pressure and temperature.

9           A demister pad 24 can be positioned in the top 16 of the vessel 12  
10   between the feed inlet 14 and the vapour outlet 22 through which recovered vapour  
11   V passes for removing entrained liquids therefrom. The recovered vapour V,  
12   discharged from the vapour outlet 22, is subsequently cooled to condense the  
13   recovered vapour and liquid solvent is recovered therefrom, as is known in the art.  
14   The recovered liquid solvent is thereafter recycled for use, typically within the froth  
15   treatment process.

16           In embodiments of the disclosure, internals 11 in the vessel 12  
17   comprise a multi-layer steam grid 30 which extends vertically within the vessel 12  
18   and is located intermediate the feed inlet 14 and the tailings outlet 18. The multi-  
19   layer steam grid 30 has the vertical height H and extends to substantially fill a cross-  
20   section of the vessel 12. The multi-layer steam grid 30 further comprises a plurality  
21   of steam outlets 34 for discharging steam S at the plurality of locations along the  
22   vertical height H of the multi-layer steam grid 30 and throughout the cross-section of  
23   the vessel 12.

1           The multi-layer steam grid 30 receives steam S at one or more inlets  
2 36, the steam S conducted within the multi-layer steam grid 30 being at a pressure  
3 and temperature greater than the operating pressure and temperature within the  
4 vessel 12. The outlets 34 and the steam supply conditions dictate the elevated  
5 pressure and temperature in the multi-layer steam grid 30. The elevated pressure  
6 within the multi-layer steam grid 30 permits a heat transfer surface 38 of the multi-  
7 layer steam grid 30 to be heated to a higher temperature than would be possible if  
8 the steam S were at lower pressure, such as at the vessel's operating pressure.  
9 Thus, it is possible to heat the feed stream F, which contacts the heat transfer  
10 surface 38, to higher temperatures.

11           TSRU vessel pressure is typically maintained below the vapour  
12 pressure of the solvent at the temperature of the feed stream F, which is generally  
13 defined by an upstream froth settling unit (FSU). In a conventional TSRU, a majority  
14 of steam S provided thereto is condensed to heat agglomerates and liquids in the  
15 bottom of the conventional TSRU vessel. As a result, in the conventional TSRU, the  
16 concentration of steam S in the vapour phase is lower at a top of the vessel  
17 compared to a bottom of the vessel and therefore the solvent partial pressure is  
18 higher in the top than in the bottom, which results in reduced diffusivity and  
19 inefficient removal of solvent throughout the vessel.

20           In embodiments, steam discharge at the plurality of locations  
21 throughout the internals 11, as a result of the plurality of steam outlets 34 in the  
22 multi-layer steam grid 30, results in a relatively low partial pressure substantially

1 throughout the vessel 12. The relatively low partial pressure throughout the vessel  
2 is a driver for promoting mass transfer therethrough.

3 Applicant believes that embodiments of the disclosure maximize the  
4 synergistic effects of the enhanced heat transfer and mass transfer within the TSRU  
5 vessel 12 to increase the efficiency of solvent recovery therein.

6 Generally, in a conventional TSRU, as solvent vapourizes from the  
7 agglomerates, the agglomerates cool and harden which hinders solvent removal as  
8 solvent is trapped therein.

9 Applicant believes that the increased temperature at the heat transfer  
10 surface 38, provided in embodiments of the disclosure, is particularly advantageous  
11 where the feed stream F comprises asphaltene agglomerates. Imparting higher  
12 temperatures to the agglomerates softens the agglomerates, permitting vapourizing  
13 and release of solvent trapped therein. Thus, the prior art problem of removal of  
14 solvent entrapped inside the agglomerates is substantially overcome as the higher  
15 temperatures achieved at the heat transfer surface 38 of the multi-layer steam grid  
16 30 imparts sufficient heat to keep the agglomerates structurally flexible for a longer  
17 period of time, despite vapourization of free (untrapped) solvent therefrom which  
18 acts to cool the agglomerates. Prolonging the softened state of the agglomerates  
19 permits trapped solvent to be more readily vapourized therefrom.

20 Having reference to Fig. 2, and in an embodiment, the multi-layer  
21 steam grid 30 comprises a plurality of fluidly-connected steam delivery pipes 40.  
22 The steam delivery pipes 40 are arranged in adjacent layers 42, transverse to a  
23 vertical axis X of the vessel 12, forming a vertical stack of layers 42 having the

1 vertical height H. Each of the transverse layers 42 comprises a plurality of the  
2 fluidly-connected steam delivery pipes 40 which are substantially parallel to and  
3 spaced apart from one another within each layer 42. The steam delivery pipes 40  
4 are spaced to permit vapour flow upwardly and feed stream flow downwardly  
5 between the spaced pipes 40.

6 As shown in detail in Figs. 3A and 3B, each of the steam delivery  
7 pipes 40 in the steam grid 30 has the plurality of steam outlets or orifices 34 formed  
8 on a downward-facing surface 44 of the pipe 40 for discharging steam S to the  
9 vessel 12. The orifices 34 are sized to maintain the higher pressure and  
10 correspondingly higher temperature within the steam delivery pipes 40 compared to  
11 the operating pressure and temperature within the vessel 12. As one of skill will  
12 appreciate the orifices 34 must not be sized so small as to be at risk of plugging by  
13 the feed stream F and therefore the pressure in the steam delivery pipes 40 is  
14 dictated by the smallest workable orifice size.

15 Further, each of the adjacent transverse layers 42 have a diametral  
16 extent which extends substantially across the cross-section of the vessel 12. The  
17 steam delivery pipes 40 have the plurality of orifices 34 spaced along a length of the  
18 pipes for distributing steam S across substantially the entirety of cross-section of the  
19 vessel 12 and throughout substantially the entire height H of the steam grid 30.

20 In embodiments, and having reference to Figs. 4A-6B, the orientation  
21 of the steam delivery pipes 40 in each transverse layer 42 are altered, the pipes 40  
22 of one layer 42 being oriented about the axis X of the vessel 12, at an angle relative  
23 to the pipes 40 in the one or more adjacent layers 42. Arranged thus, the layers 42

1 form a vertically extending grid 46 defining through-openings 48 therebetween  
2 through which the feed stream F flows down through the grid 30 (Figs. 4A-4B and  
3 Figs. 5A-5B). Alternatively, the pipes 40 in each layer 42 can be oriented in the  
4 same direction (Figs. 6A-6B). Steam delivery pipes 40 in the adjacent layers 42,  
5 regardless of their orientation, can be spaced to be staggered or laterally offset from  
6 the pipes 40 in the adjacent layers to create a more tortuous path for the feed  
7 stream F (Figs. 5A-5B and Figs. 6A-6B).

8 In an embodiment as shown in Figs. 4A-4B, the pipes in each layer 42  
9 in the vertically extending grid 46 are oriented about 90 degrees to the adjacent  
10 layers 42, being an adjacent upper layer, an adjacent lower layer or both upper and  
11 lower adjacent layers.

12 In an embodiment as shown in Figs. 5A-5B, the pipes in each layer 42  
13 in the vertically extending grid 46 are oriented about 90 degrees to the adjacent  
14 layers 42 being an adjacent upper layer, an adjacent lower layer or both upper and  
15 lower adjacent layers. Further the pipes 40, in each layer 42 that is oriented in the  
16 same direction are offset laterally from one another for forming the grid 46.

17 In embodiments, as shown in Figs. 6A-6B, the pipes 40 in each layer  
18 42 are oriented in the same direction about the axis X of the vessel 12 however, the  
19 pipes 40 in one layer 42 are offset from the pipes 40 in the adjacent one or more  
20 layers 42 for forming a vertically extending grid 46 having tortuous paths therein  
21 through which the feed stream F flows.

22 The layers 42 in the vertically extending grid 46 are spaced evenly  
23 along the vertical height H of the multi-layer steam grid 30. The multi-layer steam

1 grid 30 is positioned in a mid-section of the vessel 12 between the feed inlet 14 and  
2 the tailings outlet 18. The number of layers 42 and overall height H required in the  
3 vertically extending grid 46 is determined by the heat and mass transfer required for  
4 each solvent-containing tailings feed stream F and is related largely to asphaltene  
5 content and the temperature of the feed stream F at the feed inlet 14.

6 The multi-layer steam grid 30 receives the down-coming feed stream  
7 F, the feed stream F falling onto the vertically extending grid 46 and flowing over  
8 and between the fluidly-connected steam delivery pipes 40 therein.

9 Generally, as shown in Figs. 1, 8 and 9, the transverse layers 42 in  
10 the vertically extending grid 46 extend across substantially the entirety of the cross-  
11 section of the vessel 12 for maximizing the spread of the feed stream F onto the  
12 steam delivery pipes 40 as the feed stream F flows through the vertically extending  
13 grid 46. In embodiments, the layers 42 are substantially circular in plan, extending  
14 across the cross-section of the vessel 12.

15 Use of the transverse layers 42 of fluidly-connected steam delivery  
16 pipes 40 to form the vertically extending grid 46 increases the overall surface area  
17 for contacting the feed stream F. The feed stream F becomes evenly distributed  
18 throughout the steam grid 30. Thus, the steam grid 30 acts to provide more effective  
19 heat and mass transfer thereto.

20 Having reference again to Figs. 3A and 3B, in embodiments, the  
21 steam delivery pipes 40 are substantially circular in cross-section. The solvent-  
22 containing tailings feed stream F, which contacts the surface 38 of the steam  
23 delivery pipes 40, is caused to flow or wrap about substantially the entire surface 38

1 of the pipe 40 as the feed stream F flows by gravity through the multi-layer steam  
2 grid 30. Not only does the hot surface 38 of the steam delivery pipe 40 transfer  
3 heat to the feed stream F distributed thereon, the feed stream F also wraps  
4 thereabout to approach the steam outlets 34 where the feed stream F makes direct  
5 contact with the steam S discharging therefrom. Thus, the multi-layer steam grid 30,  
6 according to embodiments of the disclosure, provides better contact between the  
7 feed stream F and the steam S than with conventional internals, such as shed  
8 decks or the like. Thereafter, any remaining steam S rises through the steam grid  
9 30 and the vessel 12, countercurrent to the falling feed stream F, and contacts the  
10 feed stream F therein.

11 As shown in Figs. 7A and 7B, in order to obtain an equivalent surface  
12 area of prior art shed decks 50 to that achieved using the steam delivery pipes 40,  
13 conventional shed decks 50 having an angle  $\theta$  of about  $37^\circ$  and a base dimension  
14 D, equal to the circumference D of the pipes 40, require a height h approximately  
15 1.5 times that of the diameter of the steam delivery pipes 40. For example, for 10  
16 rows of internals designed to achieve equivalent surface areas, using either shed  
17 decks 50 having a base D of 12 inches, or steam delivery pipes 40 having a  
18 circumference D of 12 inches, the sum of the heights h of the shed decks 50 would  
19 be about 1.5m for each 1m of the steam delivery pipes 40.

20 In the case where shed decks 50 having an angle  $\theta$  of  $45^\circ$  are used,  
21 an additional 2 rows of shed decks 50 and the respective increase in height are  
22 required, compared to the number of layers 42 of steam delivery pipes 40 required  
23 to achieve an equivalent surface area.

1                    Advantageously, the vertically extending grid 46 also acts to reduce  
2    foaming in the vessel 12. Foaming is typically generated as vapour V leaves a pool  
3    P of feed stream F which collects in the bottom 20 of the vessel 12 when residual  
4    solvent is vaporized from the pool P. The heated surface 38 of the steam delivery  
5    pipes 40 not only acts to maximize solvent release before the feed stream F  
6    reaches the bottom 20 of the vessel 12, but also causes any foam which may  
7    develop at the surface 38 of the steam delivery pipes 40 to drop to a lower layer 42  
8    through the openings 48 within the vertically extending grid 46. The openings 48  
9    cause the foam to break as it drops therethrough, prior to reaching the pool P.

10                  Further, steam S that condenses inside the steam delivery pipes 40  
11    forms a spray as the condensed steam S exits the plurality of outlets 34 in the  
12    vertically extending grid 46. The spray acts to break the foam and wash residual  
13    feed stream F from the layers 42 of steam delivery pipes 40 therebelow, which may  
14    prevent formation of a fouling film on a surface of the steam delivery pipes 40,.

15                  As will be understood by one of skill in the art, a system for removing  
16    solvent from a solvent-containing feed stream may comprise a single TSRU stage,  
17    using a vessel 12 according to an embodiment of the disclosure.

18                  Further, as shown in Fig. 8, the system may comprise two or more  
19    TSRU stages, using a first vessel 12 and at least a second vessel 12, as is known  
20    in the art. In the case where multiple stages are used, the vessels 12 in each stage  
21    may be operated at different pressures and temperatures.

22                  As an example, the vessel operating pressure in the single or first  
23    vessel 12 may be about 50 KPag resulting in a vessel operating temperature of

1 about 112°C. The pressure of the steam in the steam delivery pipes 40 is  
2 maintained at about 64 KPag which results in a temperature of about 136°C. The  
3 temperature of steam S and condensate exiting the orifices 34 is reduced as a  
4 result of heat transferred therefrom to the feed stream F and as a result of cooling  
5 with expansion to the lower pressure in the vessel 12. Applicant believes that the  
6 steam and condensate exiting the orifices 34 has an exit temperature, being a few  
7 degrees higher than the vessel operating temperature.

8           The vessel operating pressure in the second vessel 12 may be about  
9 20 KPag resulting in a vessel operating temperature of about 105°C. The pressure  
10 of the steam in the steam delivery pipes 40 is maintained at about 34 KPag which  
11 results in a temperature of about 135°C. As with the first vessel 12, Applicant  
12 believes that the steam and condensate exiting the orifices 34 has an exit  
13 temperature, being a few degrees higher than the vessel operating temperature.

14

## 15 EXAMPLES

### 16 Example 1

17           In a TSRU vessel 12, designed and modelled for a feed stream F  
18 having a composition of about 17 wt% solids, 59 wt% water, 16 wt% solvent and 8  
19 wt% bitumen and comprising a multi-layer steam grid 30 according to an  
20 embodiment of the disclosure, the vessel 12 and the steam grid 30 were sized for  
21 maximum solvent removal.

22           Having reference to Fig. 9 and Table 1, a total height of the vessel 12  
23 is about 19m. The vessel 12 comprises a rounded top 16 and a conical bottom 20

1 extending to a dish head 52 and a straight vessel section 54 formed therebetween.  
2 The straight vessel section 54 is about 16.4m in height, has an inside diameter of  
3 about 4.3m and comprises a top section 56, a mid section 58 and a lower section  
4 60.

5 The top section 56, which is about 2.9m in height, houses the  
6 demister pad 24, adjacent an upper end 57, a liquid distribution trough 62 spaced  
7 therebelow for distributing the feed F to the mid section 58 of the vessel 12 and the  
8 feed inlet 14 positioned therebetween.

9 The mid section 58, which is about 7.7m in height, houses the multi-  
10 layer steam grid 30 according to an embodiment and provides sufficient space  
11 therebelow to space the steam grid 30 above a highest liquid level (HHLL) of a  
12 sump 64 in the bottom 20 of the vessel 12. The multi-layer steam grid 30 comprises  
13 twelve (12) layers 42 of fluidly-connected steam delivery pipes 40, forming the  
14 vertically extending grid 46. The twelve layers 42 are evenly spaced vertically over a  
15 total height of about 6.6m.

16

1 Table 1

|                | Component                          | Height              |
|----------------|------------------------------------|---------------------|
|                | Bottom vessel diameter             | 4.27m               |
|                | Top vessel diameter                | 4.27m               |
|                | Top vessel cross-sectional area    | 14.32m <sup>2</sup> |
| TOP<br>SECTION | Top water spray                    | 1050mm              |
|                | Demister pad                       | 200mm               |
|                | Bottom water spray                 | 450mm               |
|                | Feed inlet                         |                     |
|                | Liquid distribution trough typical | 600mm               |
|                | Antifoam injection allowance       | 600mm               |
|                |                                    |                     |
| INTERNALS      | Internal 12                        | ---                 |
|                | Internal 11                        | 600mm               |
|                | Internal 10                        | 600mm               |
|                | Internal 9                         | 600mm               |
|                | Internal 8                         | 600mm               |
|                | Internal 7                         | 600mm               |
|                | Internal 6                         | 600mm               |
|                | Internal 5                         | 600mm               |
|                | Internal 4                         | 600mm               |
|                | Internal 3                         | 600mm               |
|                | Internal 2                         | 600mm               |
|                | Internal 1                         | 600mm               |
|                |                                    |                     |
|                |                                    |                     |
|                |                                    | 1100mm              |
|                |                                    |                     |
| SUMP           | HHLL                               | 1000mm              |
|                | HLL                                | 1500mm              |
|                | NLL                                | 2000mm              |
|                | LLL                                | 1000mm              |
|                | LLLL                               | 300mm               |
|                | Conical section straight height    | 2000mm              |
|                | Bottom sump straight height        | 600mm               |
|                | Dish Head                          |                     |
|                | Total Vessel Height                | 19000mm             |
|                |                                    |                     |

2

3

1                   The sump 64 comprises about 5.8m of the straight vessel section 54  
 2   in combination with the remaining lower conical section 60 having a height of about  
 3   2.6m. The total height of the sump 64 is therefore about 8.4m above the dish head  
 4   52 and is designed for storing various levels of liquid therein, particularly the highest  
 5   liquid level (HHLL). Liquid levels can vary therein between a nominal liquid level  
 6   (NLL), a lowest liquid level (LLLL), a low liquid level (LLL), a high liquid level (HLL)  
 7   and the highest liquid level (HHLL)

8                   As shown in Fig. 10, each layer 42 comprises a manifold pipe 66  
 9   which extends substantially across the diameter of the vessel 12, the manifold pipe  
 10   66 being fluidly connectable to a steam supply. In the twelve layers 42, each odd  
 11   numbered layer 42o is paired with an even numbered layer 42e and the manifold  
 12   pipes 66 of the paired odd and even layers 42o,42e are connected at a first end 68  
 13   to a nozzle 70 external to the vessel 12 for connection to the steam supply. Each  
 14   manifold pipe 66 is closed at a second end 72. A plurality of evenly spaced steam  
 15   delivery pipes 40 extend 90° to the manifold pipe 66 and are fluidly-connected  
 16   thereto at a first end 74 and are closed at a second end 76 adjacent the vessel wall  
 17   78.

18                  In this example, the manifold 66 and the steam delivery pipes 40 are  
 19   10" Schedule 40 steel pipe having an outer diameter of about 273mm. In each layer  
 20   42, the steam delivery pipes 40 are spaced apart about 454mm from centre of pipe  
 21   to centre of pipe leaving about 181mm of open spacing therebetween.

22                  In each odd numbered layer 42o, a first pipe P1 and last pipe P1 of a  
 23   total of nine steam delivery pipes 40 are spaced apart having the centre of the first

1 and last pipes P1 about 317mm from the vessel wall 78. In each even numbered  
2 layer 42e, the first pipe P6 and last pipe P6 of a total of eight steam delivery pipes  
3 40 are spaced apart having the centre of the first and last pipes P6 spaced about  
4 545mm from the vessel wall 78. Thus, when stacked for forming the multi-layer  
5 steam grid 30, all of the steam delivery pipes 40 are oriented in the same direction  
6 in all of the layers 42 however the steam delivery pipes 40 in the even numbered  
7 layers 42e are offset laterally from the steam delivery pipes 40 in the odd numbered  
8 layers 42o. The closed ends 76 of the steam delivery pipes 40 are spaced about  
9 50mm from the inside wall 78 of the vessel 12.

10 As shown in Figs. 10 and 11, the length of each of the steam delivery  
11 pipes 40 in each layer 42 varies to conform to the shape of the vessel 12. The  
12 plurality of outlets or orifices 34 are formed in the downward facing surface or lower  
13 wall 44 of each of the pipes 40 for delivery of steam S therefrom. The orifices 34 are  
14 evenly spaced along the length of the steam pipe 40. In the example shown, the  
15 orifices 34 are 12.7mm holes. The number of the plurality of orifices 34 along each  
16 steam pipe 40 varies from four orifices in the shortest pipes 40 to nine orifices in the  
17 longest pipes 40 for the odd numbered layers 42o and from six orifices 34 in the  
18 shortest pipes to nine orifices 34 in the longest pipes 40 in the even numbered  
19 layers 42e.

20 As shown in Fig. 11, the steam delivery pipes 40 in each layer 42 are  
21 offset from the steam delivery pipes 40 in the adjacent layers 42. The feed slurry F  
22 wraps about the steam delivery pipes 40 where heat is transferred thereto and flows  
23 from the pipes 40 in each layer 42 through the opening or spaces 48 in the vertically

1 extending grid 46 to directly contact steam S released from the orifices 34 and to  
2 contact pipes 40 and steam in the layers 42 therebelow.

3 The layers 42 of steam delivery pipes 40 in this example are spaced  
4 from the adjacent layers 42 at about 600mm from a centre of the steam delivery  
5 pipes 40 in one layer 42 to the centre of the steam delivery pipes 40 in the adjacent  
6 layer 42. The resulting space between a lower surface 44 of the steam delivery  
7 pipes 40 in an upper layer 42 to a top surface 45 of the steam delivery pipes 40 in  
8 the adjacent lower layer 42 is about 327mm.

9  
10 Example 2

11 Having reference to Figs. 12A and 12B, a vessel 12 according to an  
12 embodiment (Fig. 12A) and a vessel 12' incorporating prior art shed decks 50 (Fig.  
13 12B) were modelled. The two vessels 12,12' were designed to have internals to  
14 achieve substantially the same objectives.

15 In the case of the vessel 12' with prior art shed decks 50, a heat  
16 transfer coefficient was estimated based on the Baffle Tray/Shower Deck Design  
17 Guideline published by Fractionation Research, Inc. (FRI) (FRI Handbook, Section  
18 9 Baffle Tray Design, Feb 15, 2010 published by Fractionation Research Inc.) The  
19 estimated heat transfer coefficient is  $9.91 \text{ Btu}/(\text{hr})(\text{ft}^2)(^\circ\text{F})$ . The number of trays  
20 required to achieve the design heat transfer is 16.

21 Correlations for mass transfer efficiency of shed decks 50 have not  
22 been developed by FRI. The efficiency data obtained from FRI experimental unit on  
23 baffle trays of various designs was used to predict a TSRU Column mass transfer

1 efficiency. The experimental mass transfer efficiency is about 15% for the  
2 hydrocarbon system, however in the TSRU feed, the solvent is entrapped inside the  
3 asphaltene aggregates with much higher viscosity and therefore 10% mass  
4 transfer efficiency is assumed for the TSRU Column design. The number of  
5 theoretical stages is 2. The number of actual TSRU Column trays required is 20, set  
6 by mass transfer requirements.

7               In the case of a vessel 12 using a multi-layer steam grid 30 for heat  
8 and mass transfer according to an embodiment of the disclosure, a heat transfer  
9 coefficient was estimated based on Chilton, Colburn, Genereux and Vernon  
10 correlation (Process Heat Transfer; Donald Q. Kern; pp 217, McGraw-Hill, Inc.). The  
11 estimated heat transfer coefficient is  $21.53 \text{ Btu}/(\text{hr})(\text{ft}^2)(^\circ\text{F})$ , approximately 2.2 times  
12 more than the shed-decks design.

13               In accordance with the Chilton-Colburn analogy (Principles and  
14 Modern Applications of Mass Transfer Operations; Benitez, Jaime; pp. 116; John  
15 Wiley & Sons, Inc.), based on experimental data to relate heat and mass transfer,  
16 the predicted mass transfer efficiency for the multi-layer steam grid 30 is also  
17 concluded to be approximately 2.2 times more than the shed deck 50 design. The  
18 number of theoretical stages is 2 and the estimated mass transfer efficiency is  
19 about 22%. The minimum number of actual layers required is nine. To be  
20 conservative, 12 layers of steam delivery pipes 40 are to be installed to provide an  
21 additional 30% design margin.

22               As shown in Table 2 below, the vessel 12' incorporating the prior art  
23 shed decks 50 required an additional eight rows of shed decks 50 compared to the

1 layers 42 of steam delivery pipes 40 to achieve the same objectives. The prior art  
2 vessel 12' required additional height to accommodate the increase in rows of  
3 internals.

4 Applicant believes that effective solvent recovery is achieved in  
5 embodiments of the disclosure, using the shorter steam delivery grid 30 in a vessel  
6 12 of reduced height. Further, Applicant believes that solvent recovery is enhanced  
7 beyond that which is predictable by the surface area of the multi-layer steam grid 30  
8 alone, as described herein.

9 In greater detail, as shown in Figs. 12A and 12B, TSRU vessels were  
10 designed for a feed stream F having a composition of about 17 wt% solids, 59 wt%  
11 water, 16 wt% solvent and 8 wt% bitumen and incorporating 2 stages of TSRU. The  
12 vessel 12 shown in Fig. 12A comprises a multi-layer steam grid 30 according to an  
13 embodiment. The vessel 12' shown in Fig. 12B comprises layers of shed decks 50  
14 according to the prior art. In the vessel 12 shown in Fig. 12A, the steam grid 30 was  
15 sized for maximum solvent removal. In the vessel 12' shown in Fig. 12B, the  
16 number of layers of shed decks 50 was determined to achieve substantially the  
17 same objectives as that of the vessel 12 shown in Fig. 12A.

18 Having reference to Fig. 12A and Table 2, a total height of the vessel  
19 12 is about 24m. The vessel 12 comprises a rounded top 16 and a conical bottom  
20 20 extending to a dish head 52 and a straight vessel section 54 formed  
21 therebetween. The straight vessel section 54 is about 21m in height, has an inside  
22 diameter of about 4.3m and comprises a top section 56, an internals section 59 and  
23 a sump 64.

1 Table 2

|             | Component                          | Vessel with multi-layer steam grid | Vessel with conventional shed decks |
|-------------|------------------------------------|------------------------------------|-------------------------------------|
|             |                                    | Height                             | Height                              |
|             | Bottom vessel diameter             | 4.27m                              | 4.27m                               |
|             | Top vessel diameter                | 4.27m                              | 4.27m                               |
|             | Top vessel cross-sectional area    | 14.32m <sup>2</sup>                | 14.32m <sup>2</sup>                 |
| TOP SECTION | Top water spray                    | 1050mm                             | 1050mm                              |
|             | Demister pad                       | 200mm                              | 200mm                               |
|             | Bottom water spray                 | 450mm                              | 450mm                               |
|             | Feed inlet                         |                                    |                                     |
|             | Liquid distribution trough typical | 1450mm                             | 1450mm                              |
|             | Antifoam injection allowance       | 900mm                              | 900mm                               |
| INTERNALS   | Internal 20                        | ---                                |                                     |
|             | Internal 19                        | ---                                | 762mm                               |
|             | Internal 18                        | ---                                | 762mm                               |
|             | Internal 17                        | ---                                | 762mm                               |
|             | Internal 16                        | ---                                | 762mm                               |
|             | Internal 15                        | ---                                | 762mm                               |
|             | Internal 14                        | ---                                | 762mm                               |
|             | Internal 13                        | ---                                | 762mm                               |
|             | Internal 12                        | ---                                | 762mm                               |
|             | Internal 11                        | 914mm                              | 762mm                               |
|             | Internal 10                        | 914mm                              | 762mm                               |
|             | Internal 9                         | 914mm                              | 762mm                               |
|             | Internal 8                         | 914mm                              | 762mm                               |
|             | Internal 7                         | 914mm                              | 762mm                               |
|             | Internal 6                         | 914mm                              | 762mm                               |
|             | Internal 5                         | 914mm                              | 762mm                               |
|             | Internal 4                         | 914mm                              | 762mm                               |
|             | Internal 3                         | 914mm                              | 762mm                               |
|             | Internal 2                         | 914mm                              | 762mm                               |
|             | Internal 1                         | 914mm                              | 762mm                               |
|             |                                    | 1200mm                             | 650                                 |
|             | Steam sparger                      | -----                              | 650                                 |
| SUMP        | HHLL                               | 1000mm                             | 1000mm                              |
|             | HLL                                | 1500mm                             | 1500mm                              |
|             | NLL                                | 2000mm                             | 2000mm                              |
|             | LLL                                | 1000mm                             | 1000mm                              |
|             | LLLL                               | 300mm                              | 300mm                               |
|             | Conical section straight height    | 2000mm                             | 2000mm                              |
|             | Bottom sump straight height        | 600mm                              | 600mm                               |
|             | Dish Head                          |                                    |                                     |
|             | Total Vessel Height                | 23708mm                            | 28228mm                             |
|             | Total height of straight portion   | 21108mm                            | 25628mm                             |

2

1           The top section 56, which is about 4m in height, houses at least a  
2 demister pad 24 adjacent an upper end 57, a liquid distribution trough 62 spaced  
3 therebelow for distributing the feed F to the internals section 59 and a feed inlet 14  
4 positioned therebetween.

5           The mid or internals section 59, which is about 10m in height, houses  
6 a multi-layer steam grid 30 according to an embodiment and provides sufficient  
7 space therebelow to space the steam grid 30 above the highest liquid level (HHLL)  
8 of the sump 64 in the bottom 20 of the vessel 12.

9           The sump 64 comprises about 5.8m of the straight vessel section 54  
10 in combination with the remaining conical section 60 having a height of about 2.6m,  
11 The total height of the sump 64 is therefore about 8.4m above the dish head 52 and  
12 is designed for storing various levels of liquid therein, particularly the HHLL.

13           Having reference to Fig. 12B and Table 2, a total height of the vessel  
14 12' is about 28.3m, being about 4.5m taller than the vessel shown in Fig. 12A. The  
15 vessel 12' also comprises a rounded top 16 and a conical bottom 20 extending to a  
16 dish head 52 and a straight vessel section 54 formed therebetween. The straight  
17 vessel section 54 is about 26m in height, being about 4.3m taller than the vessel 12  
18 shown in Fig. 12A.

19           The top section 56 of vessel 12' is substantially the same as the top  
20 section 56 of the vessel 12 shown in Fig. 12A.

21           The mid or internals section 59, which is about 14.5m in height,  
22 houses a plurality of layers of shed decks 50 according to the prior art and a steam  
23 sparger 61 for the addition of steam S to the vessel 12'. Sufficient space is provided

1 therebelow to space the steam sparger 61 above the HHLL of the sump 64 in the  
2 bottom 20 of the vessel 12'. The internals section 59 is about 4.5m taller than the  
3 vessel 12 shown in Fig. 12A, so as to accommodate the additional eight layers of  
4 shed decks 50 required to achieve the design objectives and to include the separate  
5 steam sparger 61.

6 The sump 64 is substantially the same as that shown in Fig. 12A.

7 Having reference again to Figs. 10, 11 and 12A, the multi-layer steam  
8 grid 30 comprises twelve layers 42 of fluidly-connected steam delivery pipes 40.  
9 The twelve layers 42 are evenly spaced vertically over a total height of about 10m.  
10 Each layer 42 comprises a manifold pipe 66 which extends substantially across the  
11 diameter of the vessel 12, the manifold 66 being fluidly connectable to a steam  
12 supply. In the twelve layers, each odd numbered layer 42o is paired with an even  
13 numbered layer 42e and the manifold pipes 66 of the paired even and odd layers  
14 42e,42o are connected at a first end 68 to a nozzle 70 external to the vessel 12 for  
15 connection to the steam supply. Each manifold pipe 66 is closed at a second end  
16 72. A plurality of evenly spaced steam delivery pipes 40 extend 90° to the manifold  
17 pipe 66 and are fluidly-connected thereto at a first end 74 and are closed at a  
18 second end 76 adjacent the vessel wall 78.

19 In this example, shown in Fig. 10, the manifold 66 and the steam  
20 delivery pipes 40 are 8" Schedule 40 steel pipe having an outer diameter of about  
21 219mm. In each layer 42, the steam delivery pipes 40 are spaced apart about  
22 413mm from centre of pipe to centre of pipe 40 leaving about 194mm of open  
23 spacing therebetween.

1                   In each odd numbered layer 42o, a first pipe P1 and last pipe P1 of a  
2   total of nine steam delivery pipes 40 are spaced apart having the centre of the first  
3   and last pipes P1 about 450mm from the vessel wall 78. In each even numbered  
4   layer 42e, the first pipe P6 and last pipe P6 of a total of eight steam delivery pipes  
5   40 are spaced apart having the centre of the first and last pipes P6 spaced 656mm  
6   from the vessel wall 78.

7                   Thus, having reference again to Fig. 11, when stacked for forming the  
8   multi-layer steam grid 30, all of the steam delivery pipes 40 are oriented in the same  
9   direction in all of the layers 42 however the steam delivery pipes 40 in the even  
10   numbered layers 42e are offset from the steam delivery pipes 40 in the odd  
11   numbered layers 42o. The closed ends 76 of the steam delivery pipes 40 are  
12   spaced about 50mm from the inside wall 78 of the vessel 12.

13                  The layers 42 of steam delivery pipes 40 in the example shown are  
14   spaced from the adjacent layers 42 at about 914mm from a centre of the steam  
15   delivery pipes 40 in one layer to a centre of the steam delivery pipes 40 in the  
16   adjacent layer 42. The resulting space between a lower surface 44 of the steam  
17   delivery pipes 40 in an upper layer 42 to a top surface 45 of the steam delivery  
18   pipes 40 in the adjacent lower layer 42 is about 695mm.

19                  Having reference again to Figs. 10 and 11, the length of each of the  
20   steam delivery pipes 40 in each layer 42 varies to conform to the shape of the  
21   vessel 12. A plurality of outlets or orifices 34 are formed in the lower surface 44 of  
22   each of the pipes 40 for delivery of steam therefrom. The plurality of orifices 34 are  
23   evenly spaced along the length of the steam pipe 40. In this example, the orifices 34

1 are 12.7 mm holes. The number of orifices 34 along each steam pipe 40 varies from  
2 4 orifices in the shortest pipes to 9 orifices in the longest pipes 40 for the odd  
3 numbered layers 42o and from 6 orifices in the shortest pipes to 9 orifices in the  
4 longest pipes 40 in the even numbered layers 42e.

5

### 6 Example 3

7 Testing was performed to determine an optimum configuration for the  
8 vertically extending grid 46 of steam delivery pipes 40 which forms the steam grid  
9 30 according to embodiments described herein and to compare the performance to  
10 a prior art vessel internal configuration.

11 In a test vessel, solvent recovery for three different configurations, as  
12 shown in Figs. 13A to 13C, was tested. The feed F is delivered to a top of the test  
13 vessel. Solvent vapour V is removed from the top of the vessel and liquid L is  
14 removed from the bottom of the test vessel.

15 Configuration #1 (Fig. 13A) utilizes a prior art arrangement of internals  
16 having a vertically extending array of flat plates with steam S delivered below the  
17 vertical array.

18 Configuration #2 (Fig. 13B) utilizes internals according to an  
19 embodiment described herein. Substantially round, steam delivery pipes are  
20 arranged in layers, the layers forming a vertical stack of layers, the pipes in each  
21 layer being oriented in the same direction as the pipes in the adjacent layers and  
22 staggered relative thereto. Steam is delivered throughout the internals; and

1 Configuration #3 (Fig. 13C) utilizes internals according to another  
2 embodiment described herein. Substantially round, steam delivery pipes arranged  
3 in layers, the layers forming a vertical stack of layers, the pipes in each layer being  
4 oriented at a 90 degree angle relative to the steam pipes in the adjacent layers and  
5 being staggered relative thereto. Steam is delivered throughout the internals.

6 A mixture of about 9 wt% methanol in water was used as the feed F,  
7 which was fed to the vessel at about 10 kg/min. Low-pressure steam S was  
8 delivered at a rate of about 1.5 kg/min. Methanol levels in the vessel overflow and  
9 underflow were determined based upon density at 25°C. Mass balance was  
10 calculated and compared for each of the three configurations.

11 Linear regression analysis was used to determine methanol recovery  
12 and overflow rates under standard process conditions and to determine the inter-  
13 relationships between the different configurations and operating conditions.

14

15 Conclusions:

16 Applicant believes that results for Configuration #1 as shown in Fig. 14  
17 include outliers, the sampling in one of the tests being unreliable. Thus, methanol  
18 recovery greater than 23 wt% for configuration #1 were excluded for the final  
19 comparisons.

20 As shown in Fig. 14, configuration #2 recovers about 27% more  
21 methanol than configuration #1. Configuration #3 recovers about 55% more  
22 methanol than configuration #1. Configurations #2 and #3 produce 12% and 24%  
23 more overflow, respectively, than configuration #1.

1                   For configuration #3, which demonstrated the highest wt% recovery of  
2   methanol, the average feed rate was 10.02 kg/min; the average feed temperature  
3   was 73°C; the average steam flow rate was 0.57 kg/min; the average steam  
4   pressure was 3.4 psi; the average steam temperature was 105°C; the average  
5   overflow rate was 0.82 kg/min; the average overflow temperature was 93°C; the  
6   average underflow flow rate was 10.49 kg/min; and the average underflow  
7   temperature was 96°C.

8                   Further, based on linear regression analysis, it was also demonstrated  
9   that internal configuration, water-methanol feed rates and feed temperature have a  
10   statistically significant effect on methanol recovery and overflow mass transfer.

11

12

1                   **THE EMBODIMENTS OF THE INVENTION FOR WHICH AN**  
2 **EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS**  
3 **FOLLOWS:**  
4

5                   1.     A method for recovering solvent from a non-homogeneous  
6 solvent-containing tailings feed stream in a vessel having internals therein, the  
7 method comprising:

8                         flowing the solvent-containing tailings feedstream from a top of the  
9 vessel, about the internals and to a bottom of the vessel;

10                        discharging steam to the vessel at a plurality of locations throughout  
11 the internals, the steam flowing countercurrent to the solvent-containing tailings  
12 feedstream in the vessel;

13                        removing solvent vapour from the top of the vessel; and

14                        discharging a solvent-depleted tailings stream from the bottom of the  
15 vessel;

16                        wherein the steam flows throughout the internals at a pressure greater  
17 than a vessel operating pressure for heating the internals to a temperature greater  
18 than a vessel temperature.

19

20

1                   2.     The method of claim 1 wherein the internals comprise a  
2     plurality of fluidly-connected pipes, the method further comprising:

3                   conducting the steam within the plurality of fluidly-connected pipes at  
4     a pressure greater than the vessel operating pressure for heating a surface of the  
5     plurality of fluidly-connected pipes to the temperature greater than a vessel  
6     temperature; and

7                   discharging steam from the plurality of fluidly-connected pipes to the  
8     vessel at the plurality of locations.

9

10                  3.     The method of claim 2 wherein the plurality of fluidly-connected  
11     pipes are arranged in a vertically stacked layers for forming a vertically extending  
12     grid, the method further comprising:

13                  delivering steam to the vertically extending grid of fluidly-connected  
14     pipes at a pressure greater than the vessel pressure for flowing therethrough and  
15     discharging from the plurality of locations.

16

17                  4.     The method of claim 3 further comprising:

18                  discharging the steam from a plurality of outlets formed in the fluidly-  
19     connected pipes, the outlets being sized for maintaining the steam flowing therein at  
20     the pressure greater than the vessel pressure.

21

1                   5.     The method of claim 3 or 4 wherein the steam grid comprises  
2     two or more vertically stacked layers of parallel, spaced apart fluidly-connected  
3     pipes, the method comprising:

4                   aligning the fluidly-connected pipes in the two or more layers in the  
5     same direction relative to an axis of the steam grid; and

6                   spacing the fluidly connected pipes in each of the two or more layers  
7     to be laterally offset relative to one or more adjacent layers of the two or more  
8     layers.

9

10                  6.     The method of claim 3 or 4 wherein the steam grid comprises  
11     two or more vertically stacked layers of parallel, spaced apart fluidly-connected  
12     pipes, the method comprising:

13                  aligning the fluidly-connected pipes in one or more of the two or more  
14     adjacent layers at an angle about a vertical axis of the vessel relative to the plurality  
15     of pipes in one or more adjacent layers of the two or more layers.

16

17                  7.     The method of claim 6 further comprising:

18                  spacing the fluidly connected pipes in each of the two or more layers  
19     to be laterally offset relative to one or more layers of the two or more layers.

20

21

1                   8.     The method of any one of claims 2 to 7, wherein the fluidly-  
2     connected pipes are substantially circular in cross-section, further comprising:  
3                   discharging the steam from a plurality of outlets formed in a  
4     downward-facing surface of the fluidly-connected pipes; and  
5                   flowing the feedstream about the substantially circular pipes toward  
6     the outlets.

7  
8                   9.     The method of any one of claims 1 to 8 wherein the vessel is a  
9     first vessel, the method comprising:  
10                  discharging the solvent-depleted tailings stream from the bottom of the  
11     first vessel to a second vessel; and  
12                  operating the second vessel at an operating pressure and temperature  
13     different than the first vessel.

14  
15                  10.    A tailings solvent recovery unit comprising:  
16                  a substantially vertical vessel having an operating pressure and  
17     temperature;  
18                  a feed inlet adjacent a top of the vessel for receiving a non-  
19     homogeneous solvent-containing tailings feed stream therethrough;  
20                  internals extending vertically along the vessel, steam being conducted  
21     through the internals at a pressure greater than the vessel operating pressure, the  
22     steam being discharged therefrom at a plurality of locations therethrough and  
23     flowing countercurrent to the feed stream;

1                   a vapour outlet at a top of the vessel for removing solvent vapour  
2 released from the solvent-containing tailings feed stream; and

3                   a solvent-depleted tailings outlet at the bottom of the vessel, for  
4 removing the solvent-depleted tailings stream.

5                   wherein a surface of the internals is heated by the steam to a  
6 temperature greater than the vessel operating temperature, the feed stream  
7 contacting the surface of the internals for heat transfer thereto as the feed stream  
8 flows about the internals.

9

10                  11. The tailings solvent recovery unit of claim 10 wherein the  
11 internals further comprise:

12                  a plurality of fluidly-connected steam delivery pipes for conducting the  
13 steam therethrough at the pressure greater than the vessel operating pressure; and

14                  a plurality of outlets in the plurality of fluidly connected steam delivery  
15 pipes for delivering the steam at the plurality of locations, wherein

16                  the plurality of outlets are sized for flowing steam therein at the  
17 pressure greater than the vessel's operating pressure.

18

19

1                   12. The tailings solvent recovery unit of claim 11 wherein the  
2 plurality of fluidly-connected steam delivery pipes are arranged in a vertically-  
3 extending grid for forming a steam grid, the steam grid comprising:

4                   two or more adjacent layers of the fluidly-connected steam delivery  
5 pipes, the two or more adjacent layers extending transverse to a vertical axis of the  
6 vessel substantially across a cross-section of the vessel and spaced along a vertical  
7 height for forming a vertical stack of adjacent layers.

8

9                   13. The tailings solvent recovery unit of claim 12 wherein the steam  
10 grid further comprises:

11                   one or more inlets for delivering steam to the fluidly-connected steam  
12 delivery pipes at the pressure greater than the vessel operating pressure.

13

14                   14. The tailings solvent recovery unit of claim 12 or 13 wherein the  
15 fluidly-connected steam delivery pipes in each of the two or more adjacent layers  
16 comprises a plurality of parallel, spaced apart steam delivery pipes.

17

18                   15. The tailings solvent recovery unit of claim 14 wherein the  
19 plurality of parallel, spaced apart pipes in each of the two or more adjacent layers  
20 are oriented in the same direction, the pipes in one or more adjacent layers of the  
21 two or more layers being spaced to be laterally offset relative to the pipes in an  
22 adjacent layer.

23

1                   16.    The tailings solvent recovery unit of claim 14 wherein the  
2    plurality of pipes in one or more of the two or more adjacent layers are angled about  
3    the vertical axis of the vessel relative to the plurality of pipes in one or more  
4    adjacent layers.

5

6                   17.    The tailings solvent recovery unit of claim 16 wherein the  
7    plurality of parallel, spaced apart pipes in each of the two or more adjacent layers  
8    are spaced to be laterally offset relative to the pipes in one or more layers having  
9    the plurality of pipes angled in the same direction.

10

11                  18.    The tailings solvent recovery unit of any one of claims 11 to 17  
12    wherein the plurality of steam outlets are spaced along a downward-facing surface  
13    of the fluidly-connected steam delivery pipes.

14

15                  19.    The tailings solvent recovery unit of claim 18 wherein the  
16    fluidly-connected pipes are substantially circular in cross-section for flowing a  
17    feedstream thereover toward the plurality of steam outlets for contacting the steam  
18    discharged therefrom.

19

20

21

1                   20.    A steam grid adapted for delivering steam to a tailings solvent  
2 recovery vessel having an operating pressure and temperature, comprising:  
3                   a vertically-extending grid of fluidly-connected steam delivery pipes for  
4 conducting steam at a pressure greater than vessel pressure, the steam grid having  
5                   a vertical height and a diametral extent; and  
6                   a plurality of steam outlets distributed therein, along the vertical  
7 height and across the diametral extent of the steam grid for discharging  
8 steam therefrom along substantially an entirety of the vertical height and  
9 substantially an entirety of a cross-section of the vessel, wherein  
10                  the outlets are sized for conducting steam within the steam delivery  
11 pipes at a pressure greater than the vessel's operating pressure, heating an outer  
12 surface of the steam delivery pipes to a temperature greater than the vessel's  
13 operating temperature.

14

15                  21.    The steam grid of claim 20 wherein the fluidly-connected steam  
16 delivery pipes further comprise:  
17                  two or more adjacent layers of the fluidly-connected steam delivery  
18 pipes, the two or more adjacent layers being spaced along the vertical height for  
19 forming a vertical stack of adjacent layers.

20

21                  22.    The steam grid of claim 21 wherein the fluidly-connected steam  
22 delivery pipes in each of the two or more adjacent layers comprises a plurality of  
23 parallel, spaced apart steam delivery pipes.

1                   23.    The steam grid of claim 22 wherein the plurality of parallel,  
2 spaced apart steam delivery pipes in each of the two or more adjacent layers are  
3 oriented in the same direction, the plurality of steam delivery pipes in one or more  
4 adjacent layers of the two or more layers being spaced to be laterally offset relative  
5 to the steam delivery pipes in an adjacent layer.

6

7                   24.    The steam grid of claim 22 wherein the plurality of steam  
8 delivery pipes in one or more of the two or more adjacent layers are angled relative  
9 to the plurality of steam delivery pipes in one or more adjacent layers.

10

11                  25.    The steam grid of claim 24 wherein the plurality of parallel,  
12 spaced apart steam delivery pipes in each of the two or more adjacent layers are  
13 spaced to be laterally offset relative to the steam delivery pipes in an adjacent layer  
14 having the plurality of steam delivery pipes angled in the same direction.

15

16                  26.    The steam grid of claim 24 wherein the plurality of steam  
17 delivery pipes in one or more of the two or more adjacent layers are angled 90  
18 degrees relative to the plurality of steam delivery pipes in the one or more adjacent  
19 layers.

20

21                  27.    The steam grid of any one of claims 20 to 26 wherein the  
22 plurality of steam outlets are positioned in a downward-facing surface of the fluidly-  
23 connected steam delivery pipes.

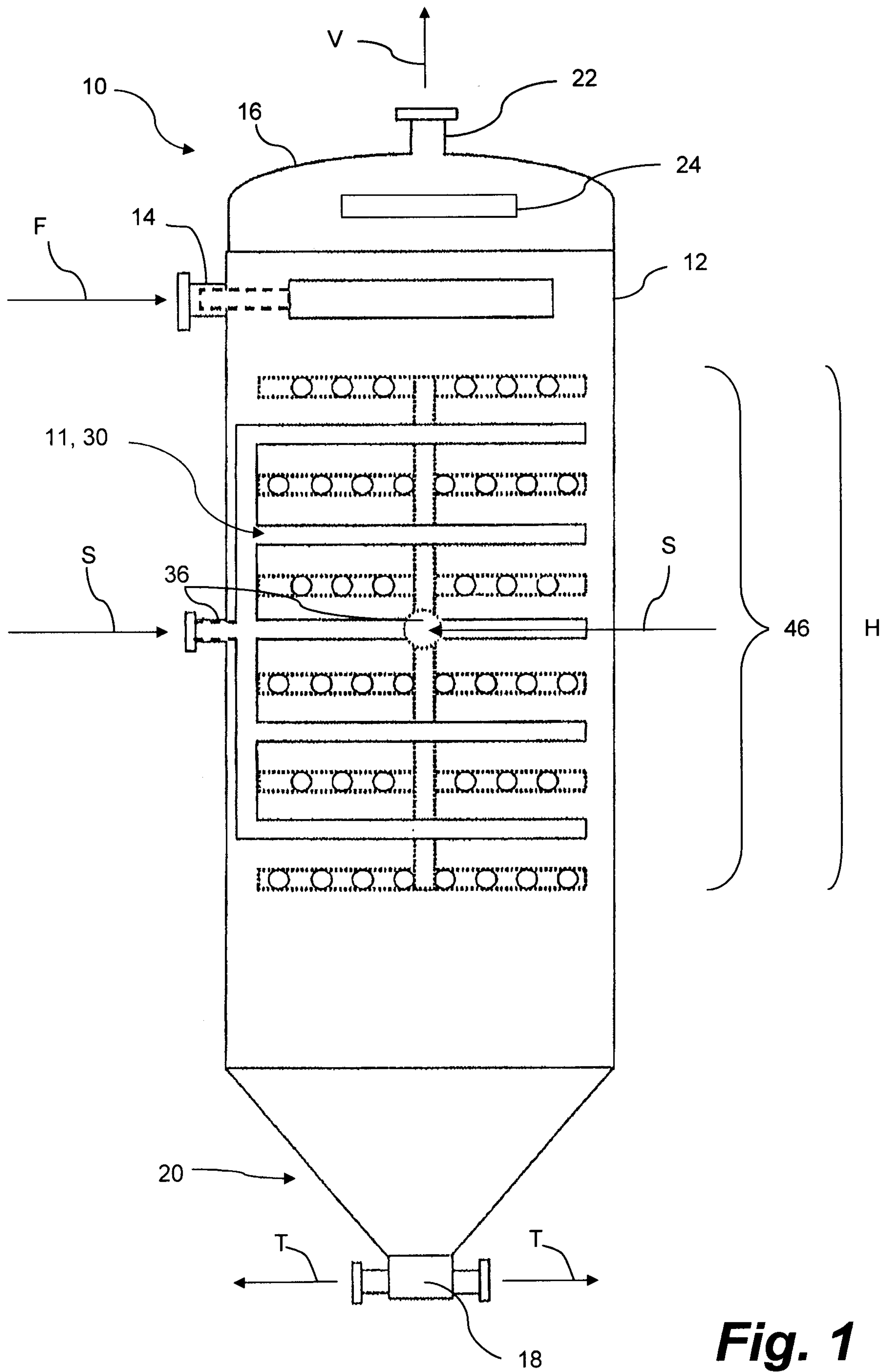
1                   28.    The steam grid of claim 27 wherein the plurality of fluidly-  
2   connected steam delivery pipes are substantially circular in cross-section for flowing  
3   a feedstream thereover toward the plurality of steam outlets on the downward-  
4   facing surface.

5

6                   29.    The steam grid of any one of claims 20 to 28 further  
7   comprising:

8                   one or more inlets for delivering steam to the fluidly-connected steam  
9   delivery pipes at the pressure greater than the vessel's operating pressure.

10

**Fig. 1**

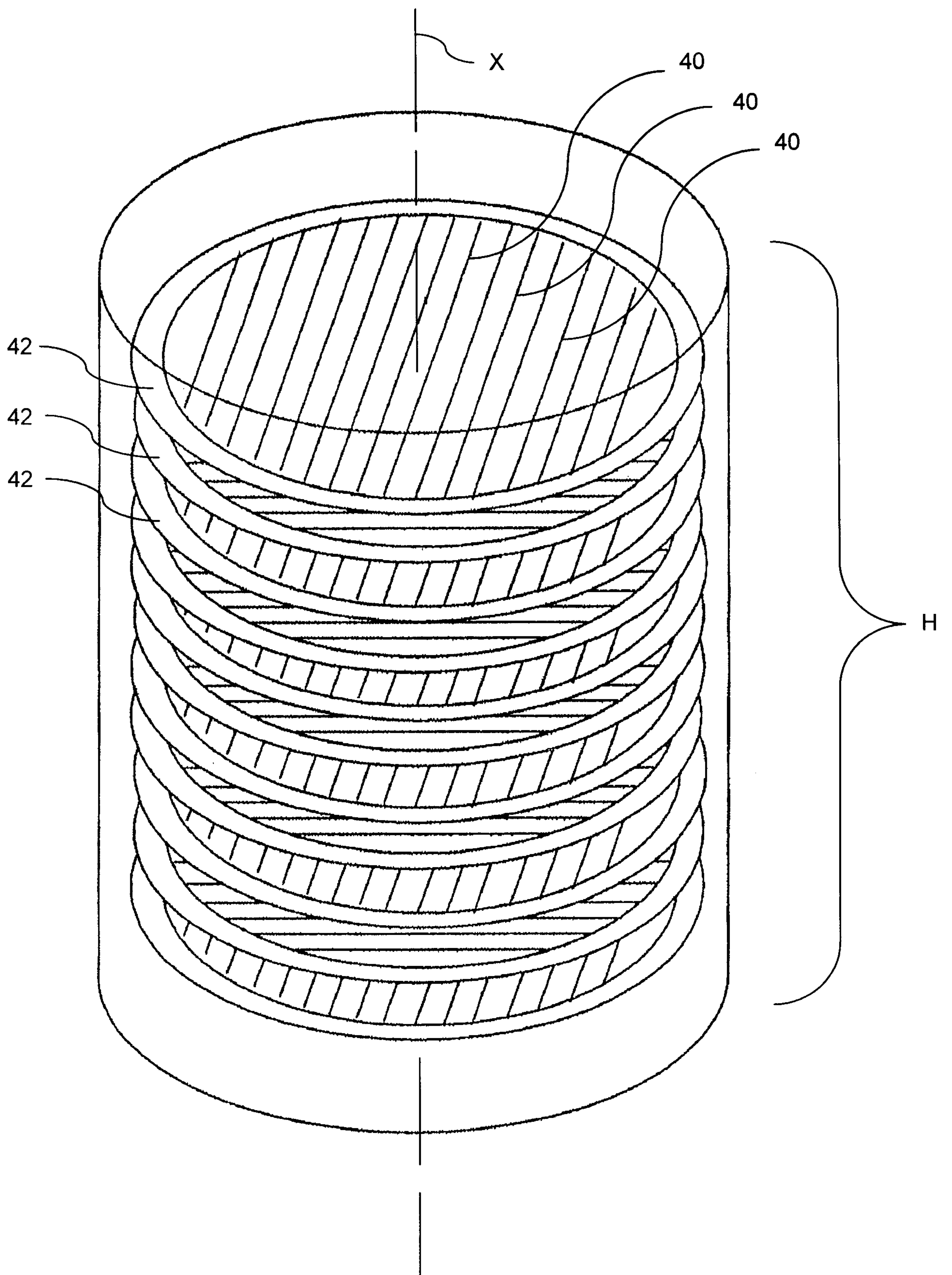


**Fig. 2**

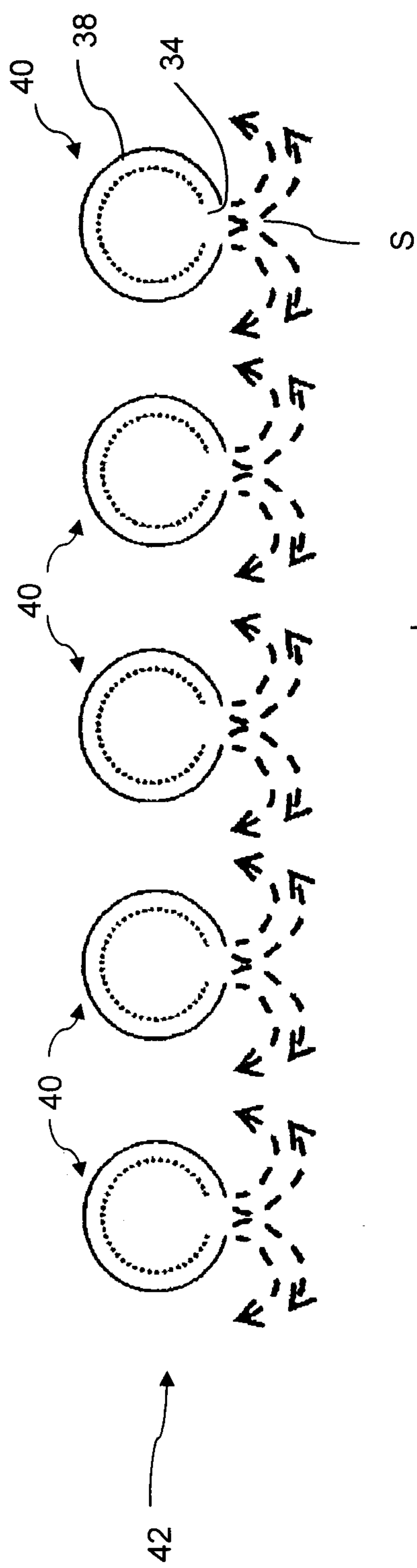


**Fig. 3A**

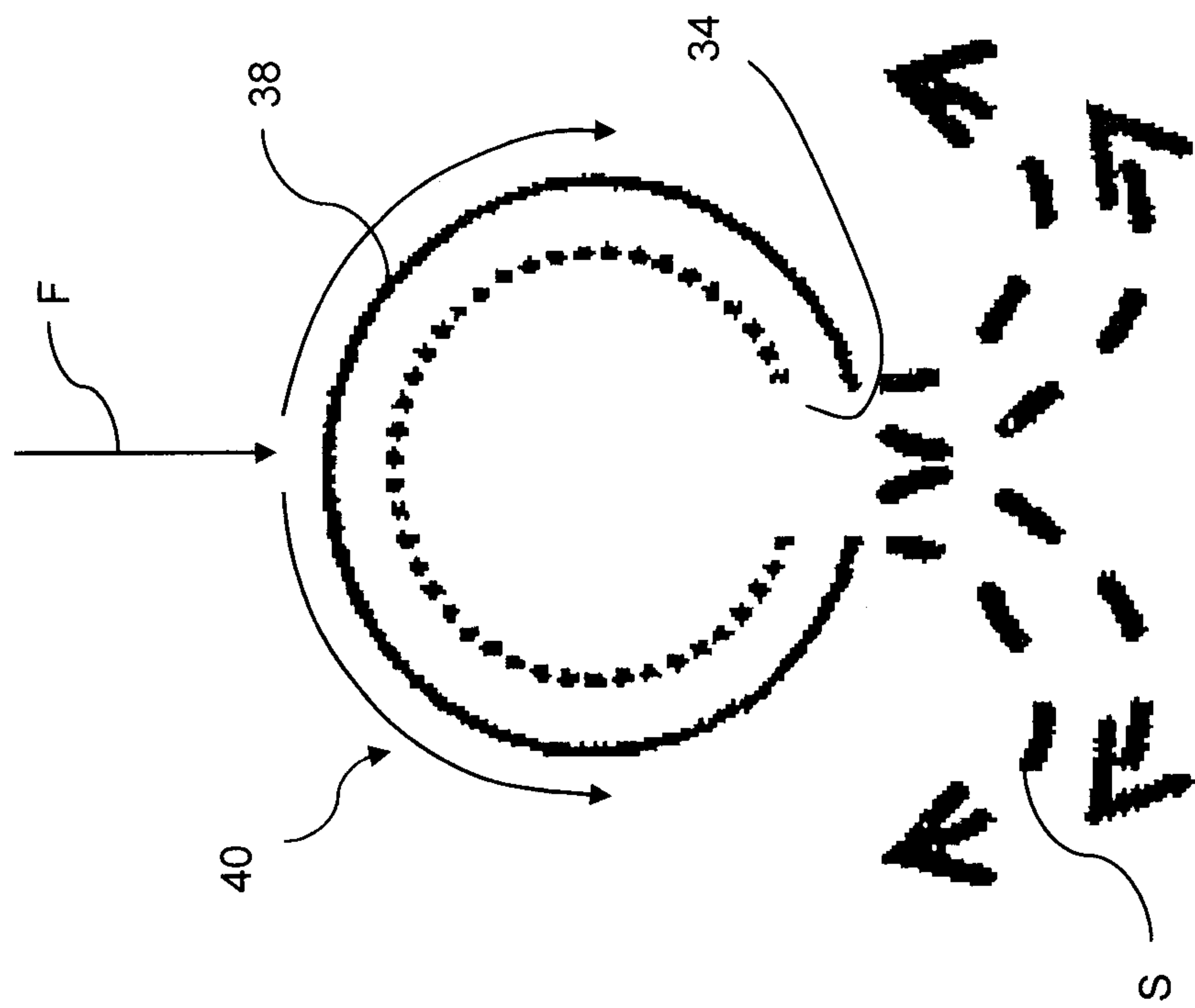


**Fig. 3B**

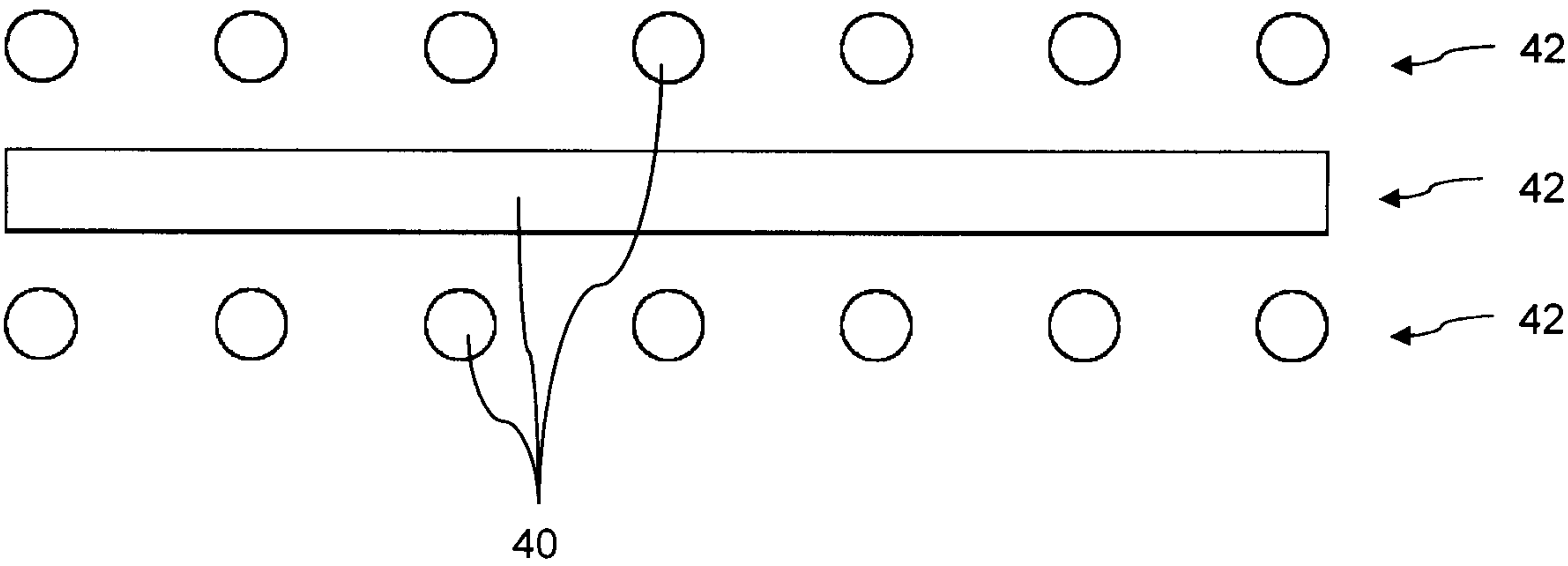


**Fig. 4A**

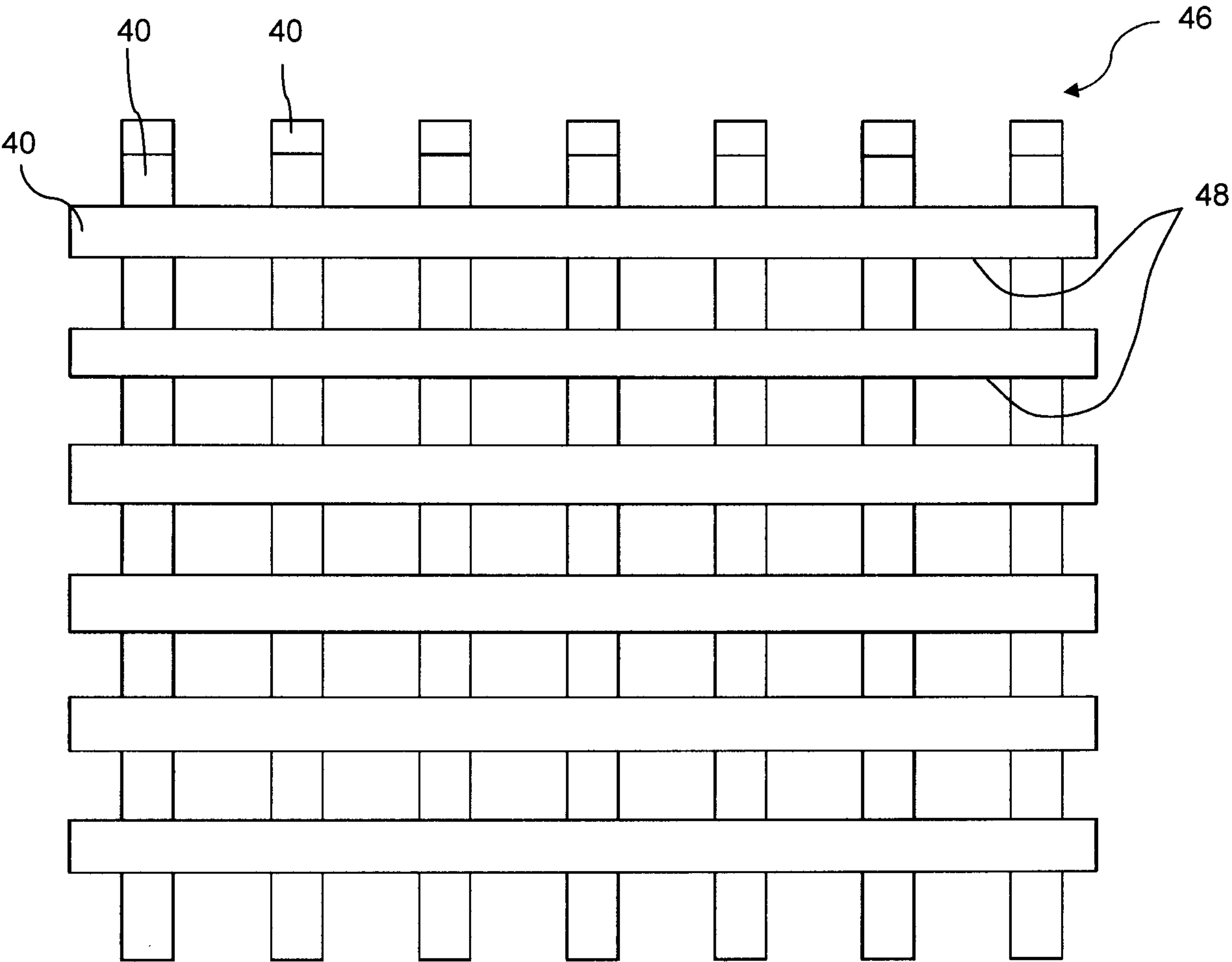


**Fig. 4B**

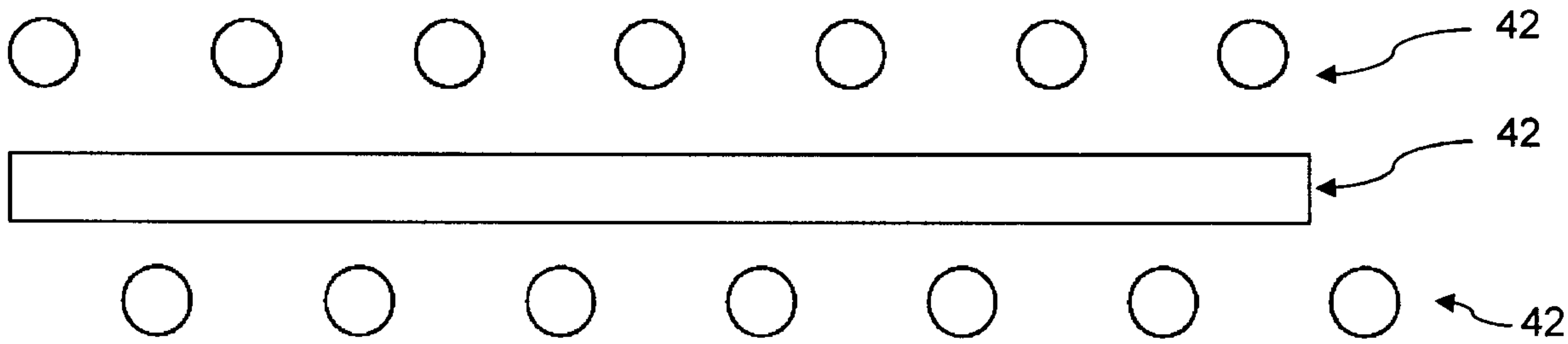


**Fig. 5A**

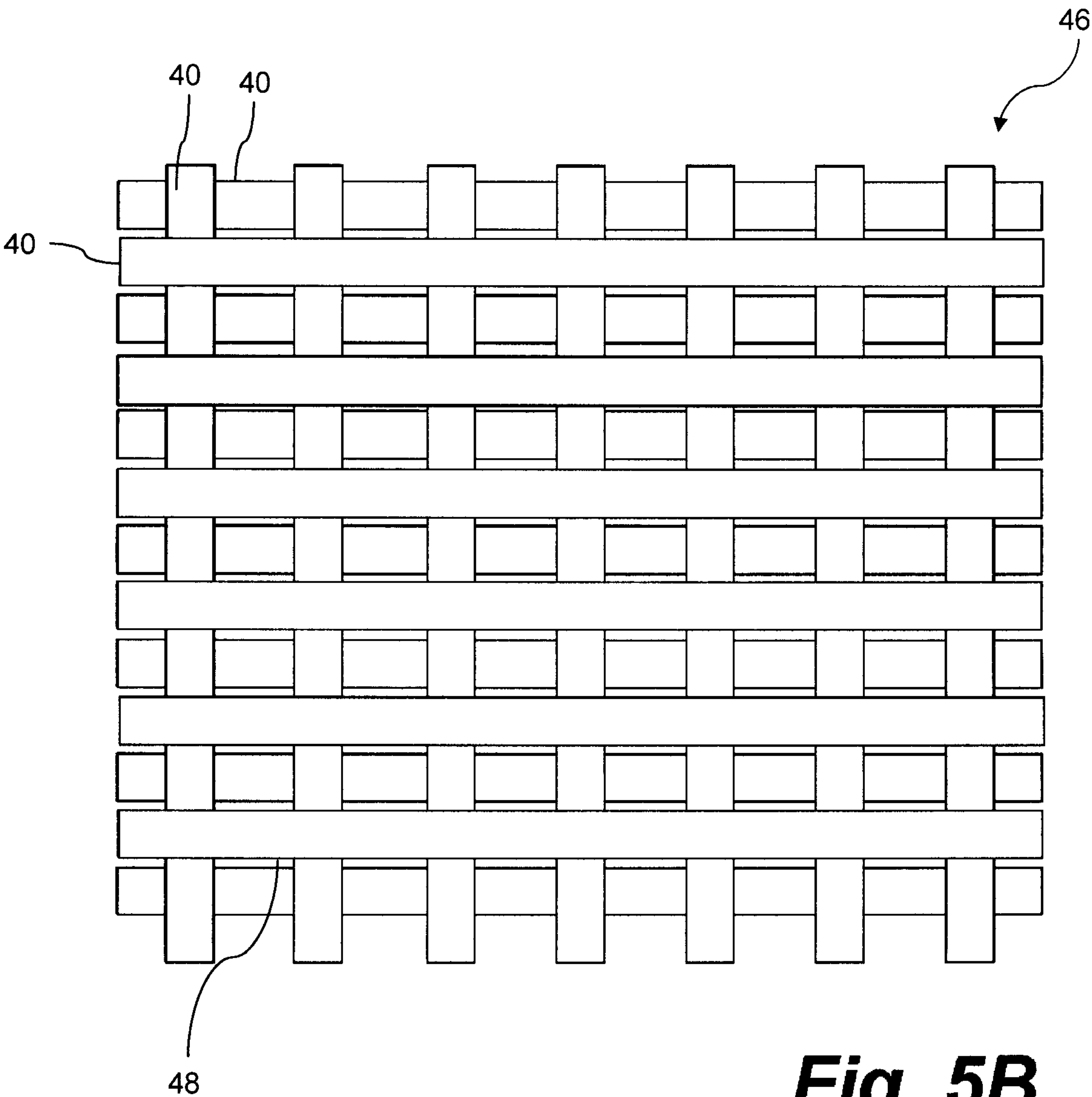


**Fig. 5B**

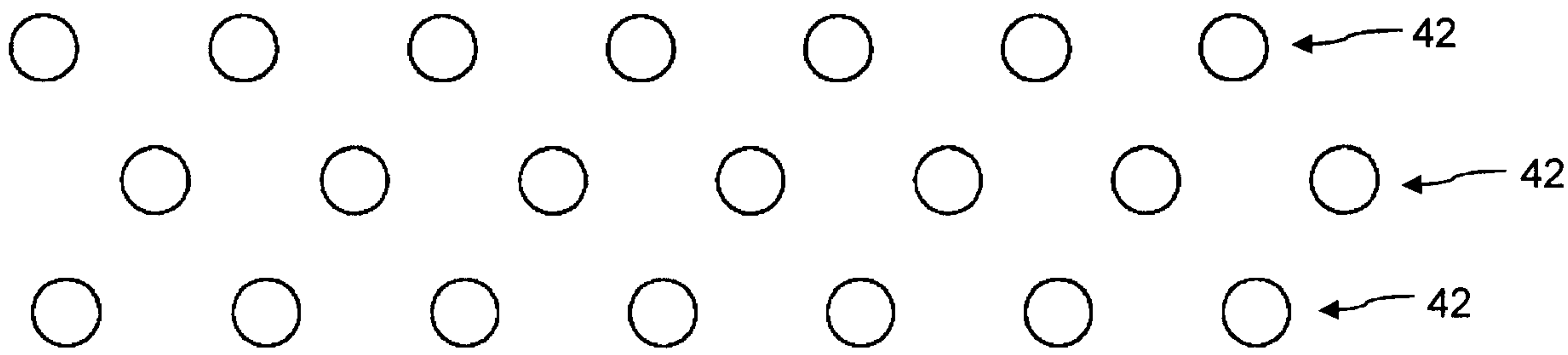


**Fig. 6A**

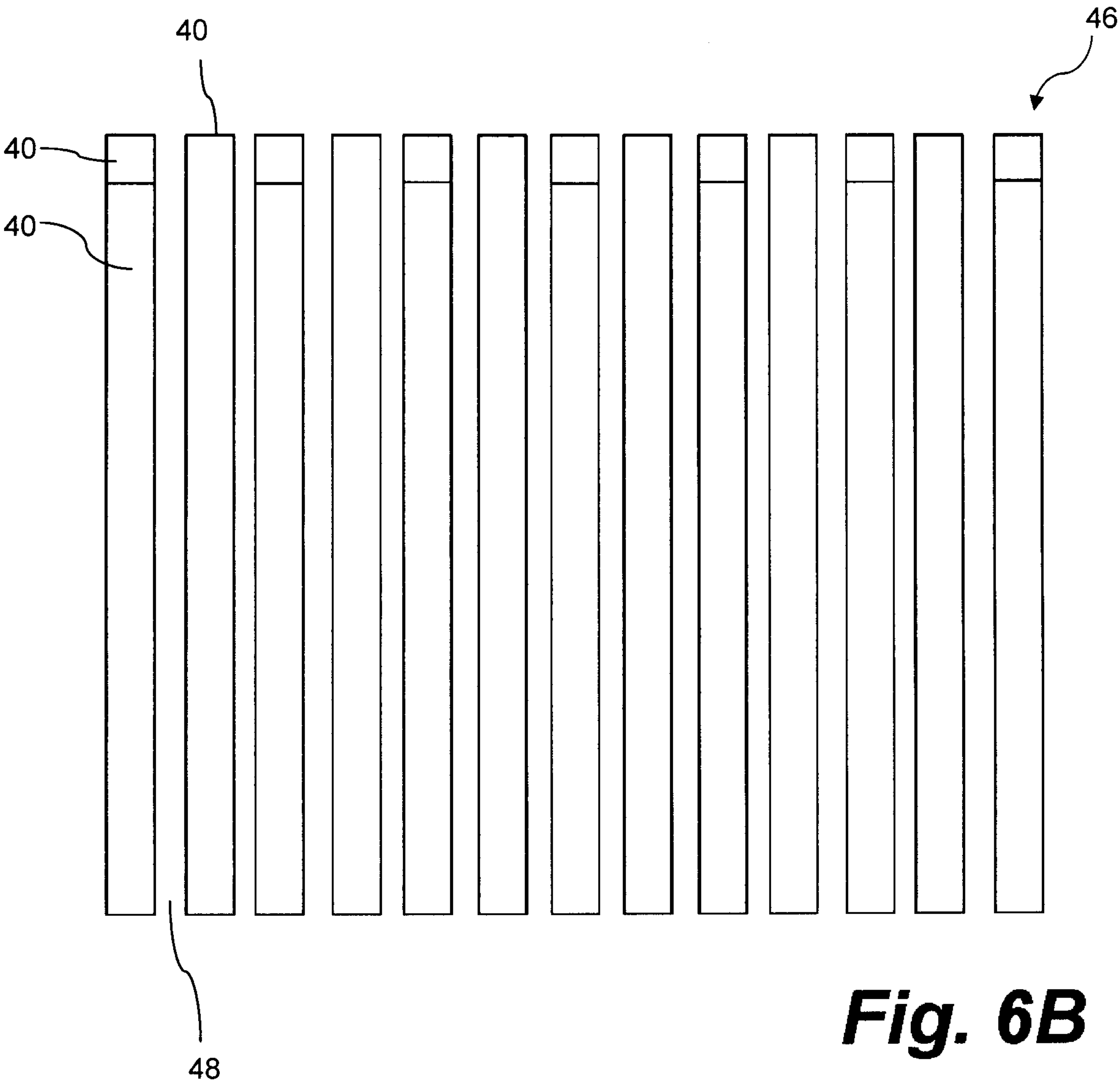


**Fig. 6B**

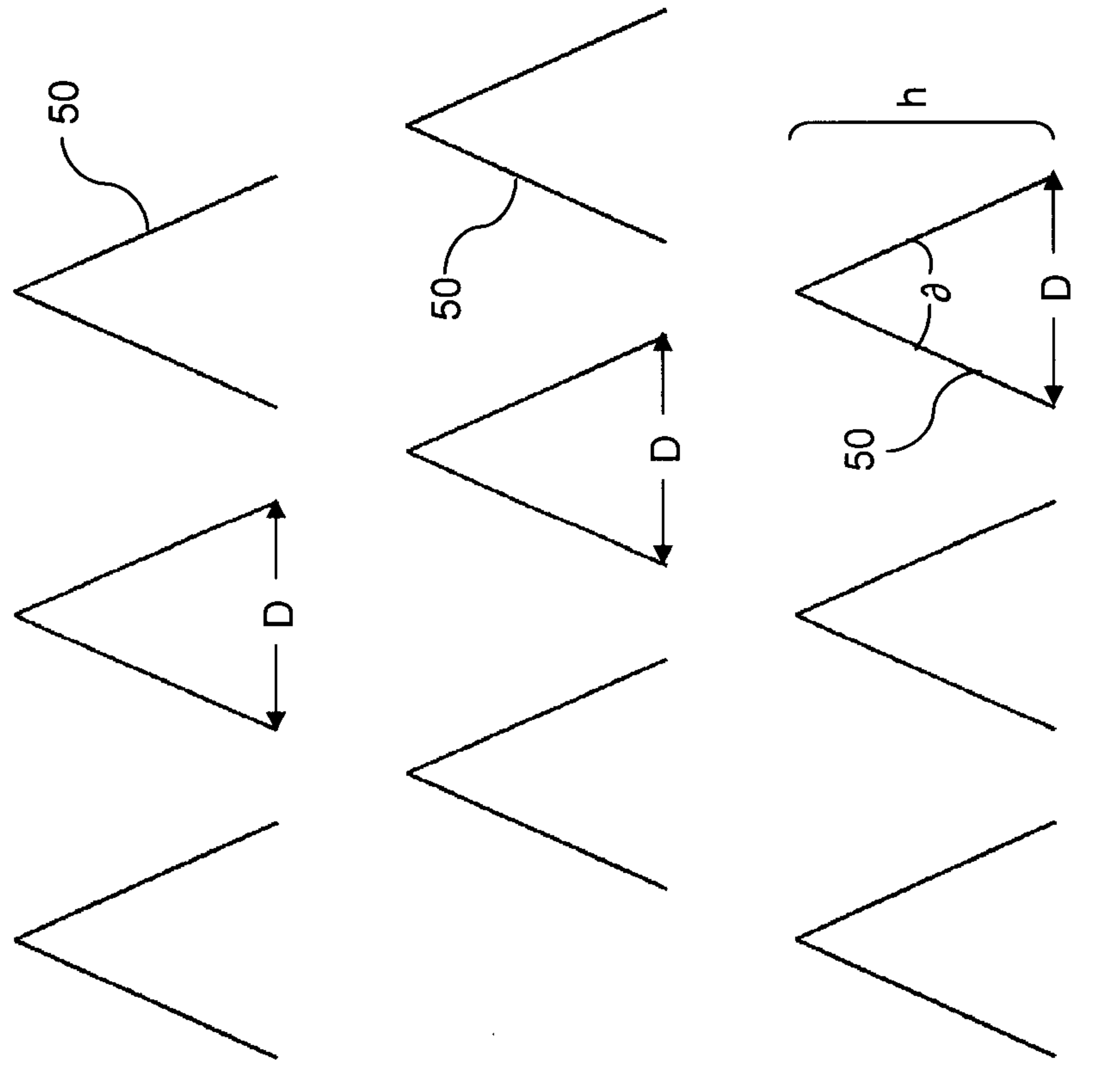


**Fig. 7A**  
**PRIOR ART**

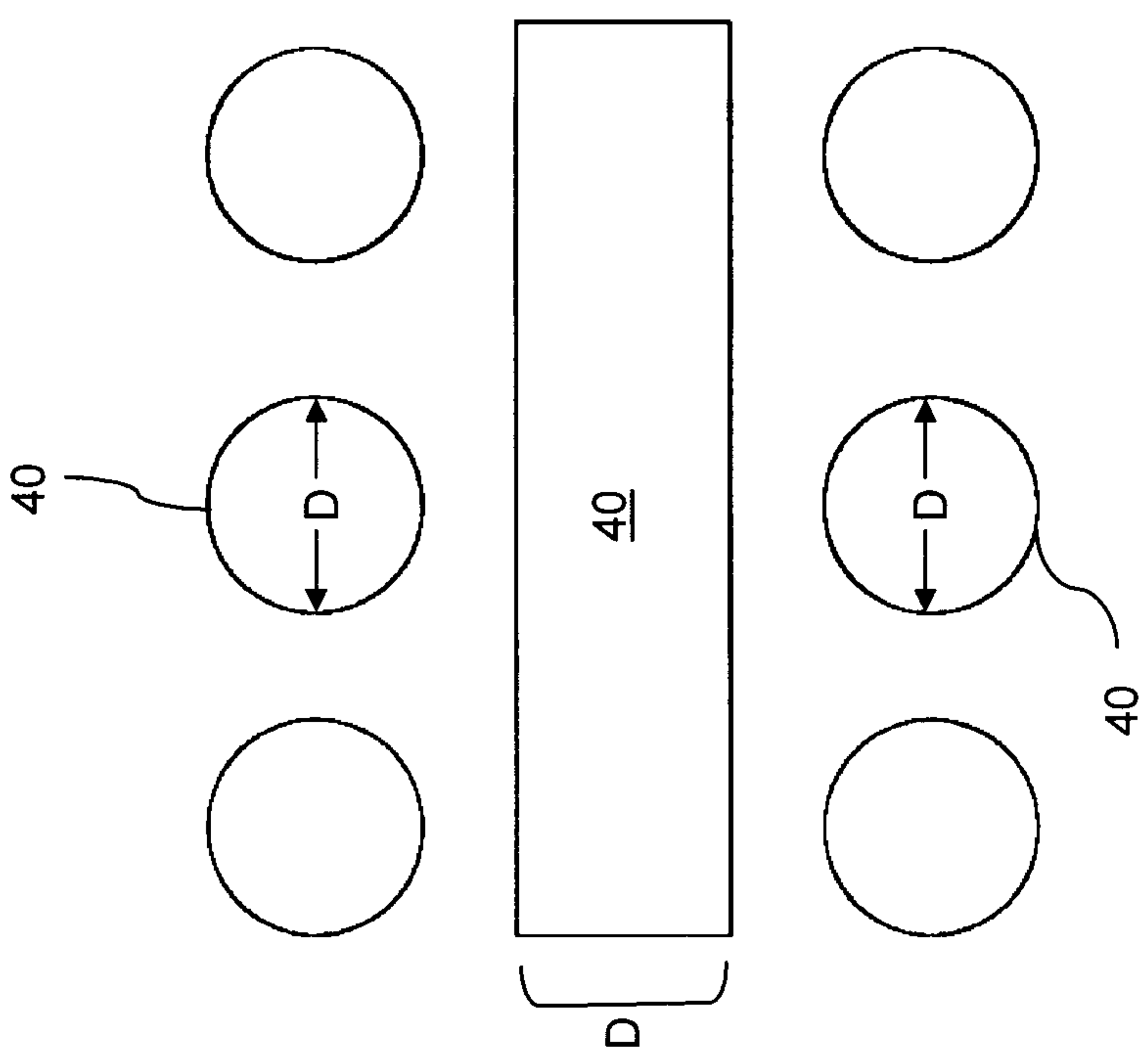
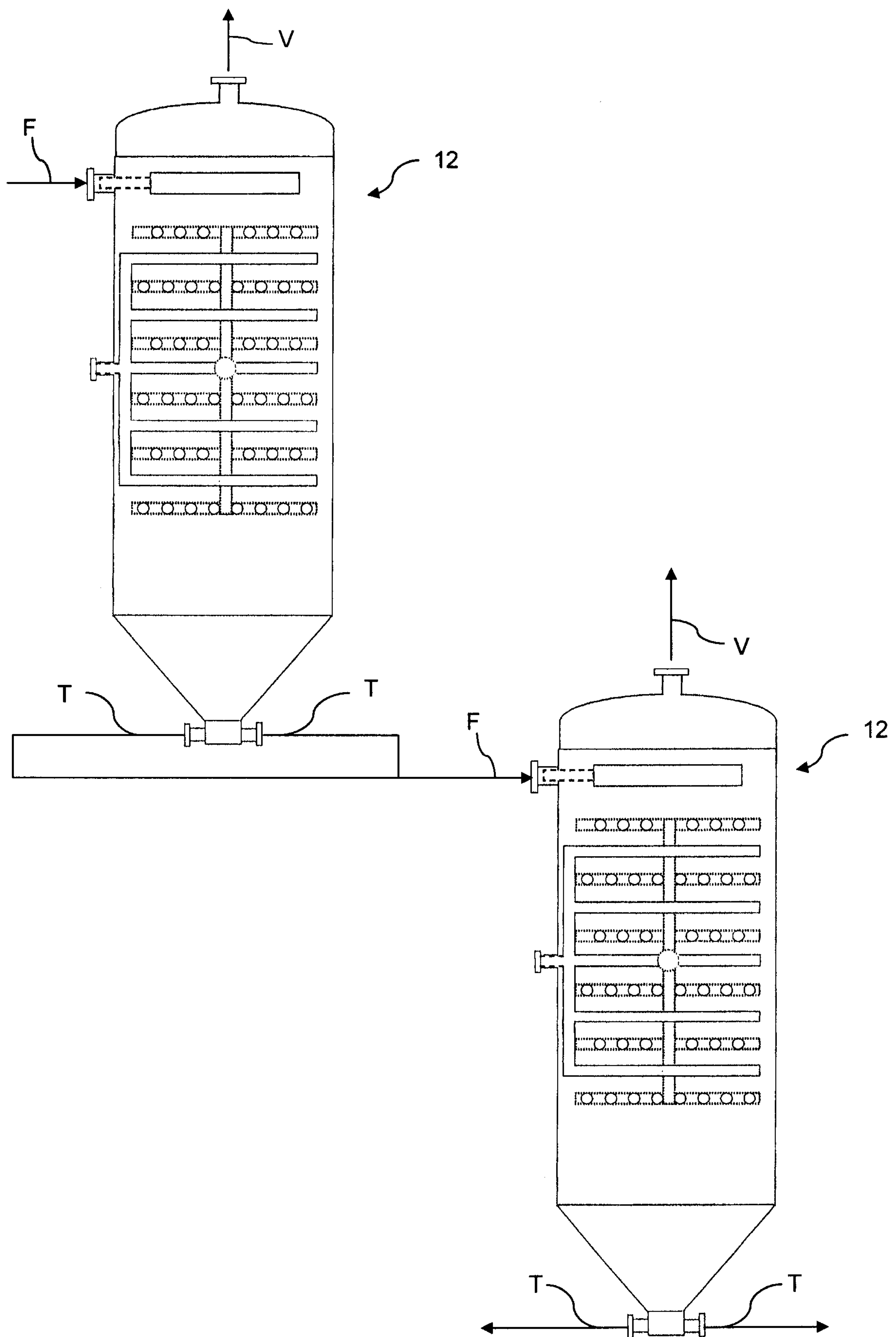
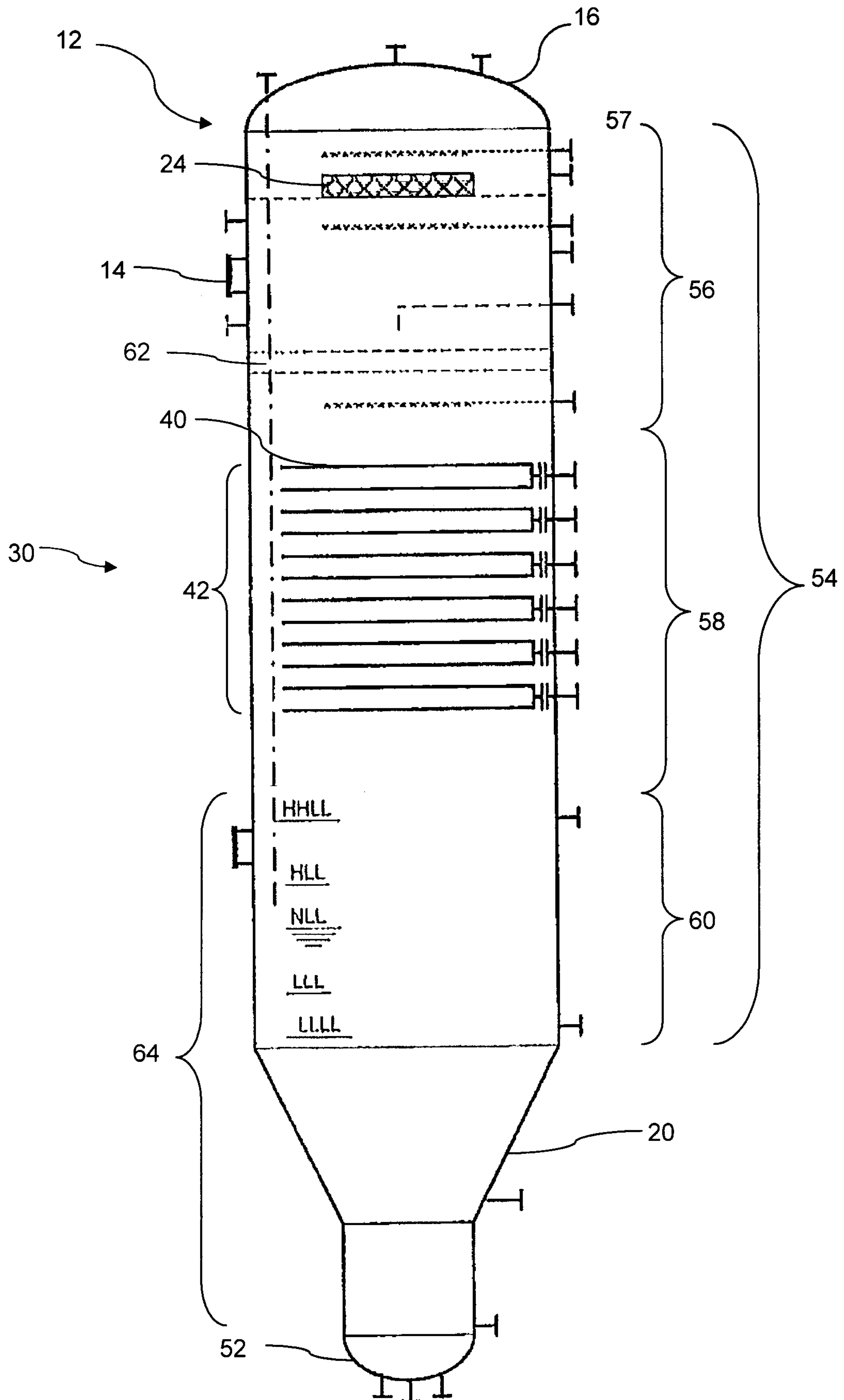
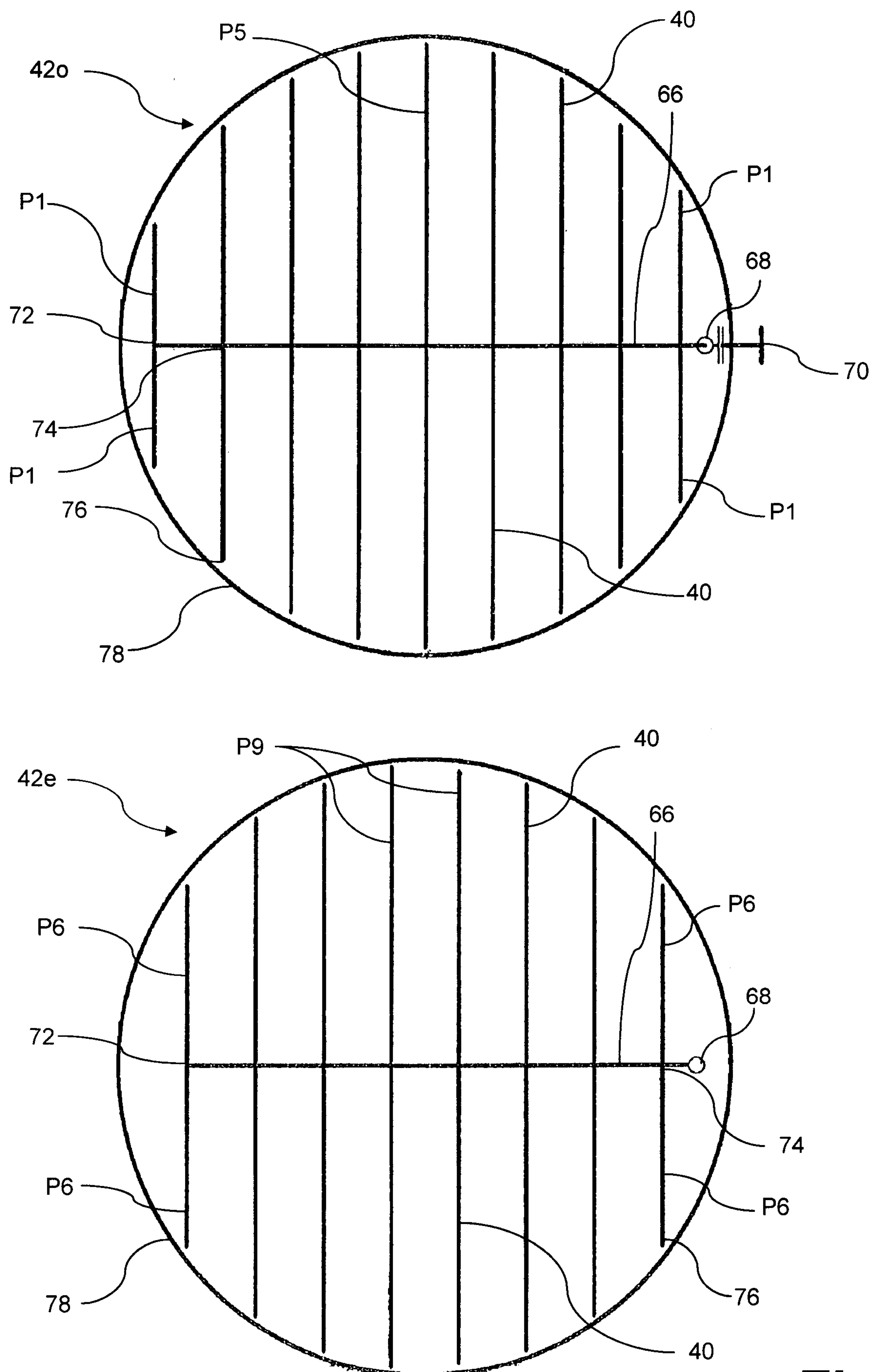
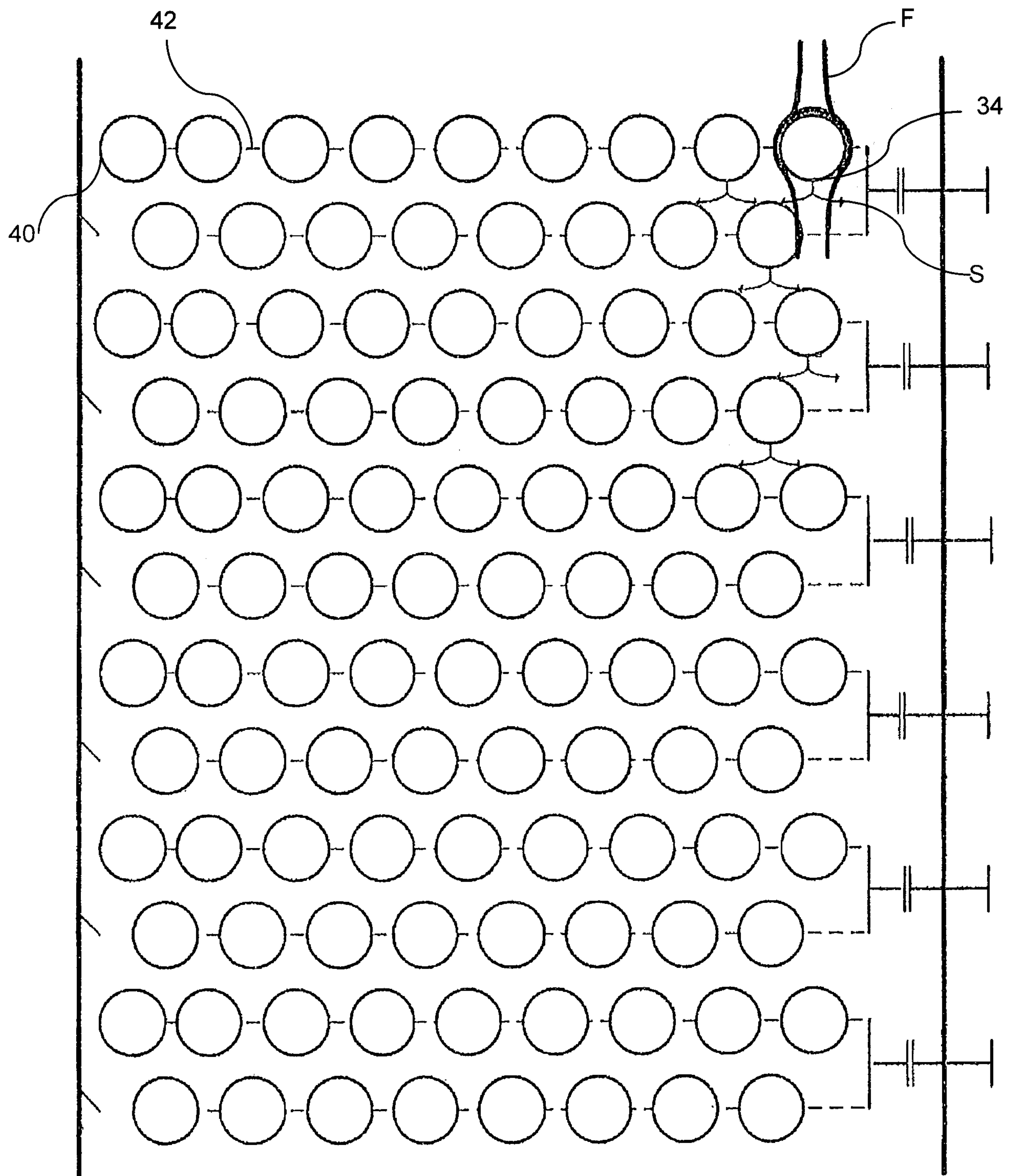


**Fig. 7B**

**Fig. 8**

**Fig. 9**

**Fig. 10**

**Fig. 11**

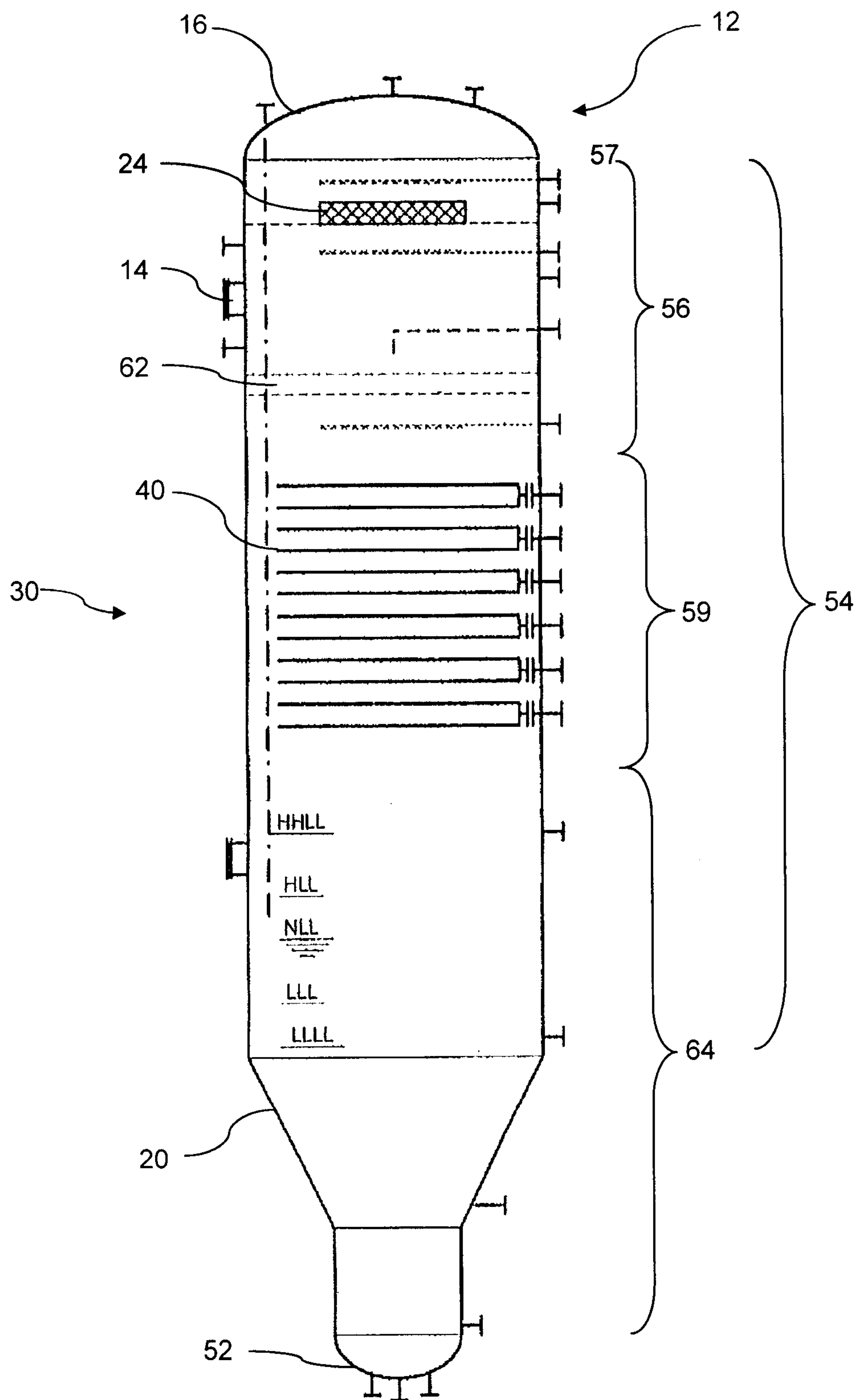
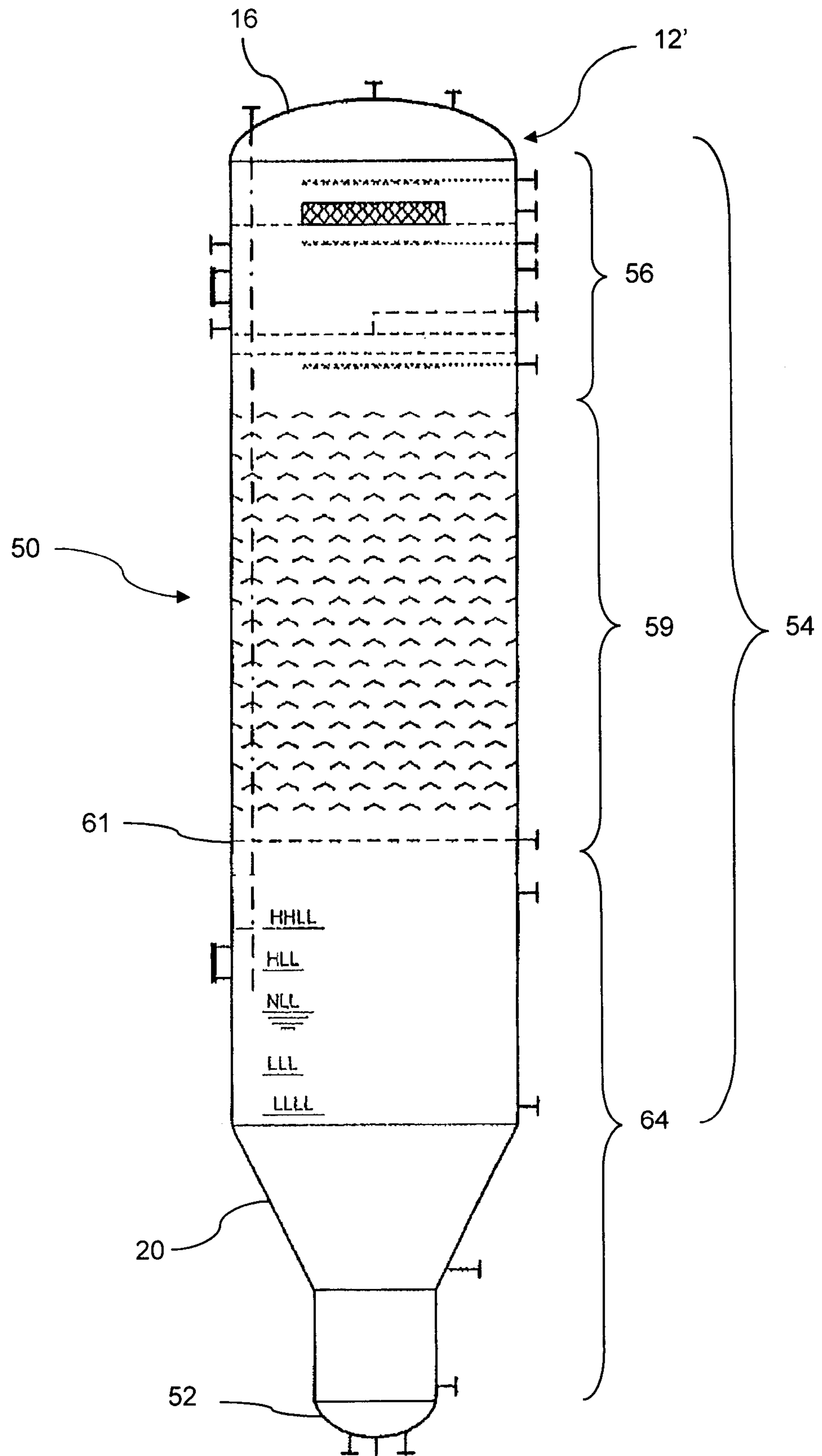


**Fig. 12A**

**Fig. 12B**

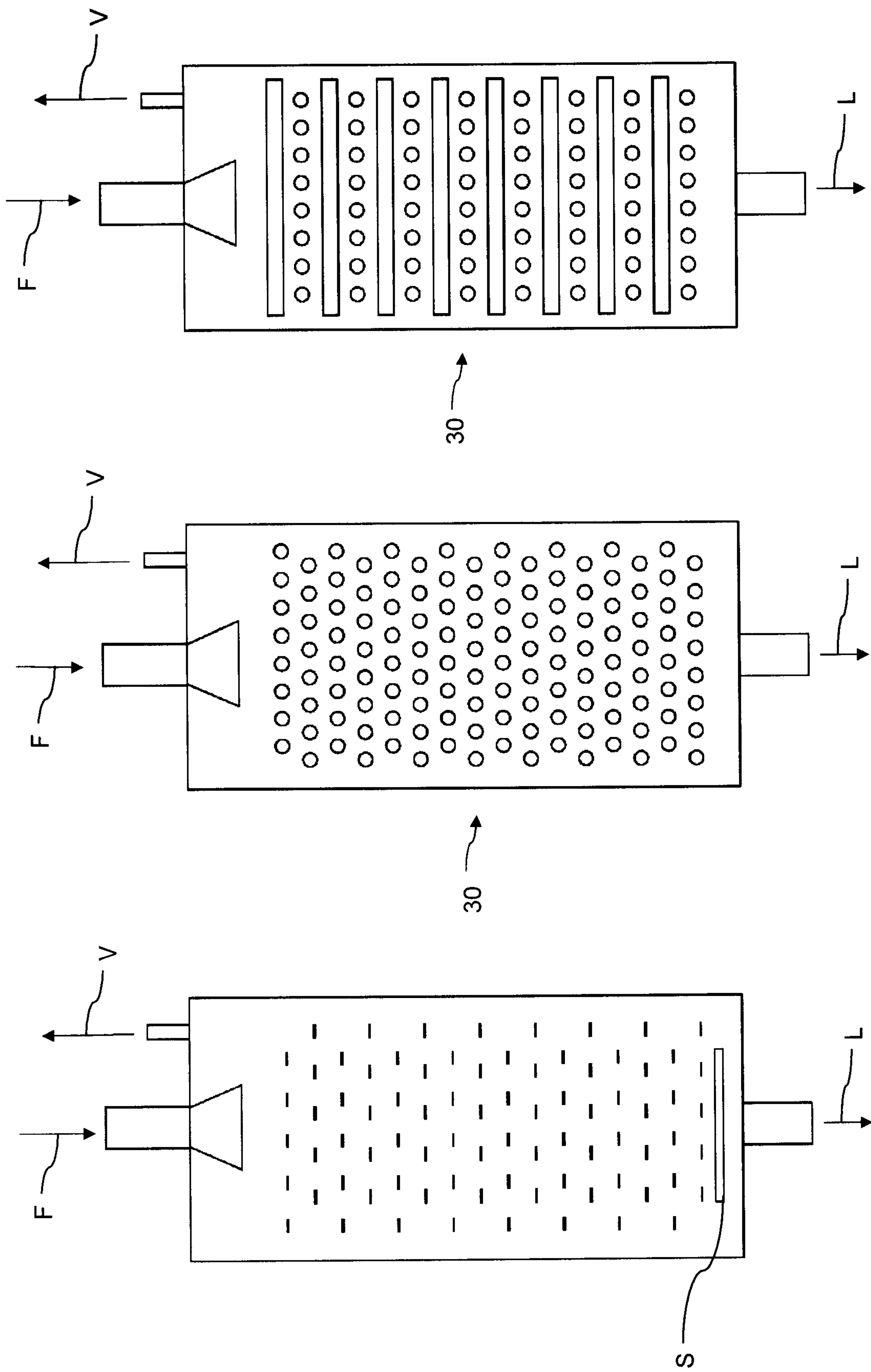


**FIG. 13A**  
**PRIOR ART**

**FIG. 13B**

**FIG. 13C**

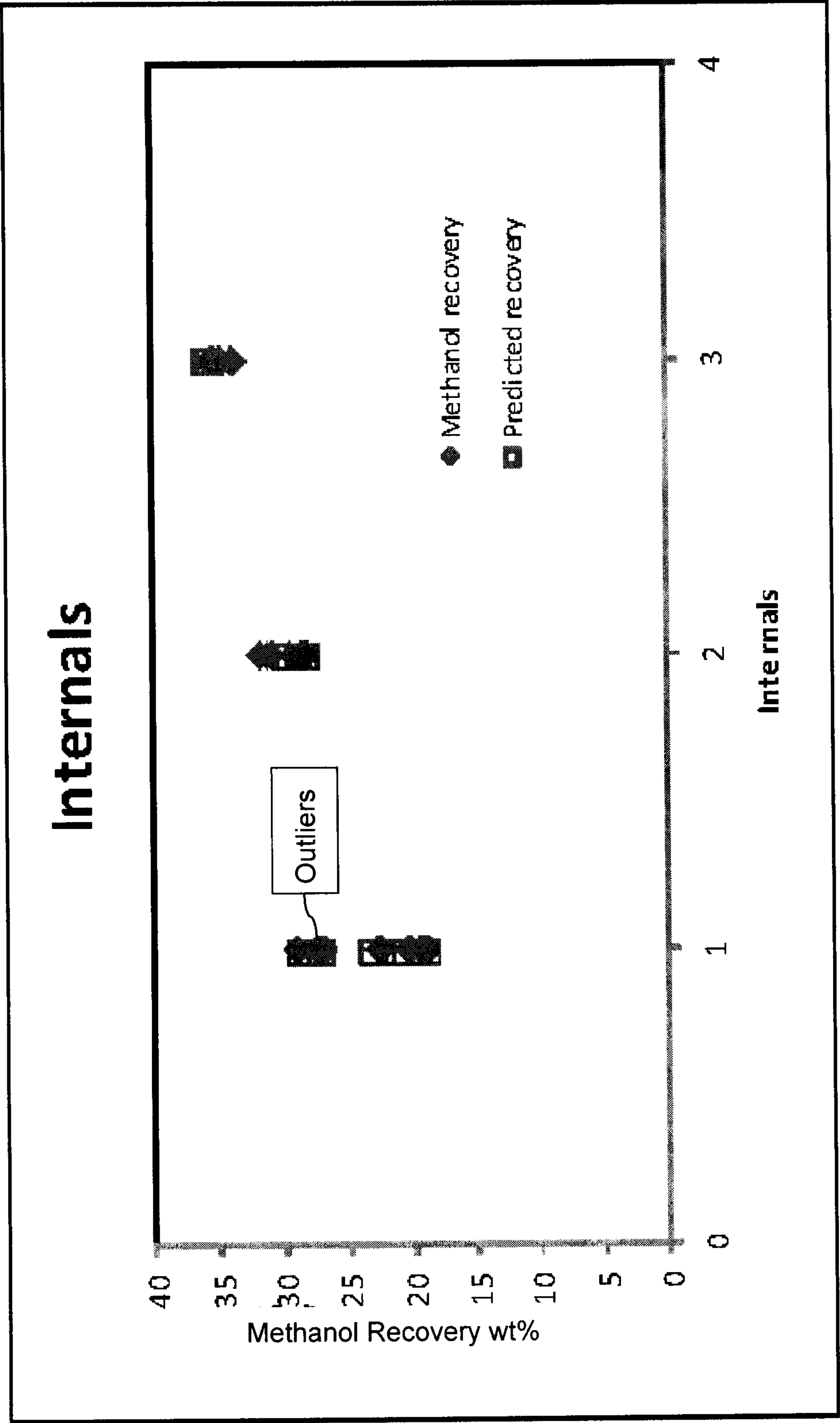


**Fig. 14**

