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(54) **Title**: FILTER ARRANGEMENT AND METHOD FOR USING THE SAME

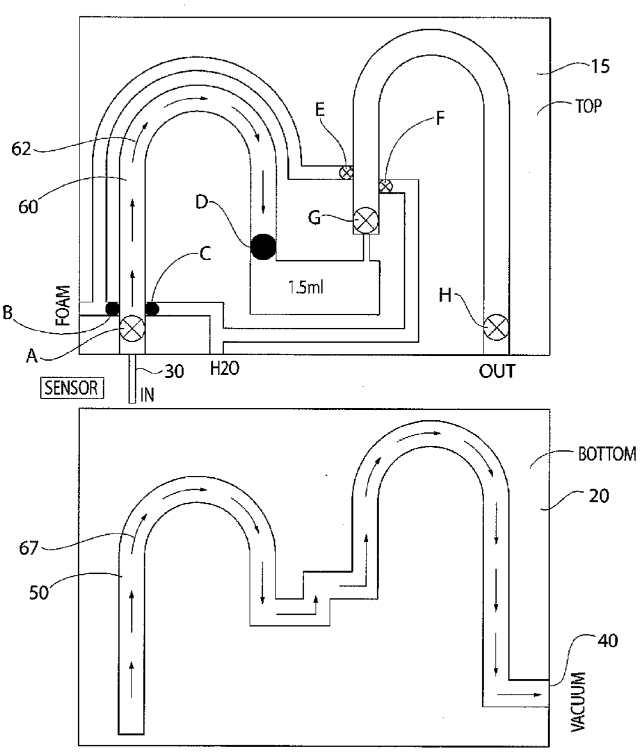

FIG. 3A

(57) **Abstract**: A filter arrangement with a top element and a bottom element and a filter element therebetween captures oversized particles on the upper surface of the filter element and tangentially rinses these particles using an elution fluid to provide a concentration of particles in a relatively low volume of fluid for further analysis. In an intermediate step, the particles captured by the filter may be rinsed with a rinsing fluid such as water to pass additional undersized particles through the filter, thereby providing a purer sample. To improve efficiency, check valves may be used for passageways with one-way flow. Additionally, a configuration of three-way stopcocks may also be utilized. Finally, a sandwich arrangement is possible, wherein a single bottom element is sandwiched between two opposing top elements.

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FILTER ARRANGEMENT AND METHOD FOR USING THE SAME

BACKGROUND OF THE INVENTION

Cross-Reference to Related Applications

[0001] This application claims the benefit of United States Provisional Application Nos. 61/760,954, filed February 5, 2013 and 61/789,027 filed March 15, 2013. The disclosure of each of these documents is hereby incorporated in its entirety by reference.

Field of the Invention

[0002] Mechanical particle filters are used to extract particles for analysis from a fluid/particle mixture. However, now the particles are retained by the filter. The most common technique for removing particles from a filter for analysis is to introduce additional fluid, such as by using a backwashing process. However, ideally, the particles should be contained in the smallest amount of fluid possible while maintaining high retention ratio for ease of analysis. This is especially true when the particles are bacteria. Therefore, while backwashing a filter does remove the particles from the filter, the efficiency of the process is low and the quantity of fluid required may produce a secondary fluid/particle mixture with excessive fluid.

[0003] Furthermore, when using hydrophilic membrane with small pore size and when suction is provided on the downstream side of the filter to draw fluid and undersized particles, often times, the membrane will become a barrier to air after it was wetted.

[0004] A design and method are needed, whereby the particles of interest may be filtered and contained within a small volume of fluid and, furthermore, whereby the filter may be constructed such that, even after the fluid passes, the membranes of the filter will allow more suction using vacuum.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Fig. 1 is an exploded view of a simplified schematic showing the filter arrangement;

[0006] Fig. 2 is an assembled view of a schematic of the filter arrangement in Fig. 1;

[0007] Figs. 3A-8A are schematic views of the top half and bottom half of the filter arrangement illustrating different configurations for the filtering process;

[0008] Figs. 3B-8B are schematics of the filter arrangement in the assembled state showing different configurations for the filtering process;

[0009] Fig. 9 is a photograph illustrating a perspective arrangement of one embodiment of the filter arrangement disassembled and without the filter element;

[0010] Fig. 10 is a photograph of the embodiment of the filter arrangement illustrated in Fig. 9 but with a filter element placed in position;

[0011] Fig. 11A is a schematic view of the top half and bottom half of an alternate embodiment of the filter arrangement utilizing check valves and modified channels to provide dual inlets for the elution and water and dual outlets for the vacuum;

[0012] Fig. 11B is a schematic view of the filter arrangement in Fig. 11A in the assembled state;

[0013] Figs. 12A–17A are schematic views of the top half and bottom half of yet another embodiment of the filter arrangement illustrating different configurations for the filtering process and, furthermore, utilizing stopcock valves to create different fluid paths;

[0014] Figs. 12B-17B are schematic views of the filter arrangement of the embodiment illustrated in Figs. 12A-17A in the assembled state showing different configurations for the filtering process;

[0015] Fig. 18A is a schematic view of a filter arrangement utilizing a sandwiching arrangement, whereby a previously described "top portion" is sandwiched between two "bottom portions" to provide greater filtering capacity; and

[0016] Fig. 18B is a schematic view of the filter arrangement in Fig. 18A in the assembled state.

DESCRIPTION OF THE INVENTION

[0017] For purposes of the description hereinafter, the terms "end", "upper", "lower", "right", "left", "vertical", "horizontal", "top", "bottom", "lateral", "longitudinal" and derivatives thereof shall relate to the invention as it is oriented in the drawing figures. However, it is to be understood that the invention may assume various alternative variations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the invention. Hence, specific dimensions and other physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

[0018] Fig. 1 illustrates a filter arrangement 10 having a top element 15, a bottom element 20, and a filter element 25 therebetween. Fig. 1 is an exploded schematic view, while Fig. 2 is an assembled schematic view of the same parts but with the top element 15 and the bottom element 20 drawn together to compress the filter element 25 therebetween. As an overview, directing attention to Fig. 2, a fluid/particle mixture is introduced through inlet/outlet 30 into channels (not shown) extending through the top element 15. Inlet 35 is closed and a suction outlet 40 provides a vacuum drawing the fluid/particle mixture through the filter element 25, such that oversized particles remain on the upper surface 45 of the filter element 25. Thereafter, the inlet 35 is open and the suction outlet 40 is closed. An elution fluid is then introduced into the inlet 35 to tangentially rinse the upper surface 45 of the filter element 25. This provides a reduced volume fluid/particle mixture that exits the inlet/outlet 30. As an intermediate step, it is possible to close the inlet 35 and to introduce a water/rinse into the inlet/outlet 30, while suction outlet 40 is open, to wash over the particles after the initial filtering step to further filter any remaining particles that were not previously washed through the filter. This water/rinse and undersized particle solution are removed through the suction outlet 40 and discarded. As a result, the oversized particles that were deposited upon the upper surface 45 of the filter element 25 are isolated and collected using a reduced volume elution fluid.

[0019] The elution fluid may be effervescent and contain a foaming agent such as TWEEN. The subject filtering arrangement is most effective when the particles are bacteria. The filter element is preferably a polycarbonate-type filter which is a surface filter and may have pores with openings approximately 0.4 microns wide.

[0020] During the discussion of Figs. 3A-8A, it should be appreciated that the surfaces illustrated for the top element 15 and the bottom element 20 may be transparent and the top element 15 will be placed over the bottom element 20, such that the channels in each of these elements 15, 20 are generally aligned with one another. Therefore, for purposes of discussion, the top element 15 is transparent and the channels illustrated therein will be on the underside 47 of the top element 15, while the bottom channel 50 illustrated in the bottom element 20 is on the upper surface 52 of the bottom element 20. The filter element 25 is not illustrated in Figs. 3A-7A but is located between the top portion element 15 and the bottom element 20 as shown in Figs. 3B-7B.

[0021] Valves A-H are illustrated in the top element 15. Depending upon the configuration of the filter arrangement 10, one or more of these valves will be open and others will be closed. Such closing will be illustrated by darkening the valve symbol.

[0022] For the initial configuration, directing attention to Figs. 3A and 3B, the fluid/particle mixture is introduced through the inlet 30 and travels through the first-stage channel 60 as indicated by arrow 62. Valve A is open while valves B, C, and D are closed. In this configuration, a vacuum will be activated such that the suction outlet 40 draws a vacuum through the entire bottom channel 50. As a result, the fluid/particle mixture is urged against the upper surface 45 of the filter element 25 (Fig. 3B), thereby retaining oversized particles 65 on the upper surface 45 of the filter element 25. Undersized particles, along with fluid, are drawn through the filter element 25 and evacuated along the bottom channel 50 through the suction outlet 40, as indicated by arrows 67. At this point, oversized particles 65 and other miscellaneous particles have been deposited upon the upper surface 45 of the filter element 25. It should be noted that for the arrangement illustrated in Figs. 3A and 3B, no more than one-half of the filter element 25 has been utilized.

[0023] To improve the integrity of the filtering process, the Inventors have learned that additional undersized particles will be washed through the filter element 25 simply by providing a fluid rinse, such as a water rinse, over the particles 65.

[0024] Directing attention to Figs. 4A and 4B, valves A, B, D, and F are closed and water is introduced through water inlet 70 along the water channel 72, as illustrated by arrows 74. Just as with the original fluid/particle mixture, the suction outlet 40 provides a vacuum to the bottom channel 50 such that the water is drawn through the filter element 25 into the bottom channel 50 and follows arrows 76 where it is discharged at the suction outlet 40. This water rinse removes additional undersized particles that may have been retained during the initial filter step.

[0025] Direction attention to Figs. 5A and 5B, valves A, C, E, and G are now closed and the elution fluid, which will also be referred to as foam, is introduced under pressure at the foam inlet 80 where it travels through the foam channel 82 in a path defined by arrows 84 to a collector 85, which now contains a reduced volume fluid/particle mixture, wherein the fluid is the elution fluid. It should be noted that the vacuum is off, such that the bottom channel 50 is inactive and the flow of the elution fluid travels across the upper surface 45 of the filter element 25 to deposit the fluid/particle mixture within the collector 85. This process of passing the fluid across the upper surface 45 of the filter element 25 is known as tangentially rinsing the upper surface 52 and dislodges the particles on the upper surface 45 to mechanically scrape the upper surface 45 and move the particles 65 into the collector 85. By doing so, the relatively large volume of fluid associated with the initial fluid/particle mixture has been significantly reduced.

[0026] What has been described so far is a single-stage filtering process that provides a significant reduction in the volume of fluid associated with filtered particles to improve the ease of subsequent examination of the particles. Only a portion of the filter element 25, which extends essentially across the width of the bottom element 20, has been utilized.

[0027] The Inventors have realized that it is possible to provide a dual-stage filter with relative ease to further reduce the volume of fluid in the fluid/particle mixture or to further remove undesired small particles.

[0028] Directing attention to Figs. 6A and 6B, with the refined fluid particle sample in the collector 85, valves B, C, E, F, and H are closed and suction is introduced to the bottom channel 50 such that fluid from the collector 85 is drawn into the second-stage channel 90 along arrows 92, where the undersized particles and the fluid are drawn through the filter element 25 into the bottom channel 50 and discharged through the suction outlet 40 along arrows 92. Additionally, valves A and D are open so that air can come in to permit fluid to be pulled out of reservoir 85. Once again, particles 65 are deposited upon the upper surface 45 of the filter element 25 but now the elution fluid and undersized particles are passed through the filter element 25 into the bottom channel 50 and out the suction outlet 40.

[0029] Directing attention to Figs. 7A and 7B, valves C, E, G, and H are closed and water is introduced into the water channel 72 through the water inlet 70 and then into the second-stage channel 90 along arrows 94. With suction provided in the bottom channel 50, any undersized particles and the elution fluid remains are again drawn through the filter 25 into the bottom channel 50 where they follow the flow of arrows 96 and are discharged through the suction outlet 40.

[0030] Finally, directing attention to Figs. 8A and 8B, valves B, G, and F are closed and elution fluid is provided by the foam inlet 80 along the foam channel 82, as indicated by arrows 98. Just as before, the elution fluid moves transversely across the upper surface 45 of the filter element 25 and scrapes the particles 65 from the upper surface 45 of the filter element 25, where they are then transported through the outlet 35 into a secondary collector to provide a fluid/particle mixture, wherein the fluid has an exceptionally low fluid volume relative to the particle concentration, thereby allowing analysis of the particles to proceed with greater ease.

[0031] Overall, Figs. 3-8 illustrate the filter arrangement 10 for isolating particles 65 from a fluid/particle mixture. The filter arrangement is made of a top element 15 having at least one open 60 channel extending thereacross connecting a top element inlet 30 to a first collector 85, wherein the channel 60 is open on the underside 47 of the top element 15. A bottom element 20 having at least one open channel 50 extending thereacross connected to a bottom element outlet, or suction outlet, 40. The channel 50 is open on the upper side 52 of the bottom element 20. The top element 15 is secured to the bottom element 20 such that the underside 47 of the top element 15 is secured against the upper side 52 of the bottom element 20 and wherein the channels 60, 50 align with one another. The filter element 25 is generally flat and is positioned between the top element 15 and the bottom element 20 and overlaps with the channels 60, 50.

[0032] The top element inlet 30 of the filter arrangement 10 is connected to a fluid/particle supply and top element inlets 80A and 80B to an elution fluid supply, wherein the bottom element outlet 40 is connected to a suction supply. As discussed, the filter arrangement provides a valve arrangement with at least two flow configurations.

[0033] With suction applied to the bottom element outlet 40, the fluid/particle mixture is introduced into the top channel 60 and over the filter element 25 thereby depositing retentate particles 65 upon the filter element 25 and passing permeate particles through the filter element 25. Thereafter, with suction discontinued to the bottom element outlet 40, the elution fluid is introduced into the top channel 60 and over the filter element 25 such that the retentate particles deposited upon the filter element 25 are tangentially rinsed and collected through the top element outlet 35 into a first collector 85.

[0034] A second collector may be positioned within the path of the open channel 60 of the top element 15 to define a first stage channel 60 on one side of the first collector 85 and a second stage channel on the other side of the first collector 85. The valve arrangement described with respect to the first collector 85 for the first stage channel is repeated for the second stage channel thereby providing a two-stage filter arrangement with retentate initially deposited within the first collector and thereafter finally being deposited within the second collector.

[0035] Prior to introducing the elution fluid and after introducing the fluid/particle mixture, with suction applied to the bottom element outlet 40, the rinsing solution is introduced into the top channel 60 and through the filter element 25.

[0036] Figs. 9 and 10 illustrate one embodiment of the filter arrangement 100 having a top element 120 and a bottom element 115 with a filter element 125 (Fig. 10) therebetween. Each of these figures is illustrated with a filter arrangement 110 in a disassembled state. However, it can be appreciated that the four bolts 126a, 126b, 126d, 126d may be secured within the bores 127a, 127b, 127c, 127d, respectively, with the filter element 125 therebetween to assemble the filter arrangement 100. The filter arrangement 100 illustrated in Figs. 9 and 10, is a single-stage filter and the suction outlet 135 provides suction to the bottom channel 160. The top element 120 has an inlet/outlet 140 and an inlet 138, on the opposite side of inlet/outet 140, with a channel 150 therebetween. The filter element 125 is positioned between the top element 120 and the bottom element 115. In operation, suction is provided at the suction outlet 135 such that there is a vacuum created in the bottom channel 160. The fluid/particle mixture is introduced through the inlet/outlet 140 of the top element 120 where it travels over the filter element 125 and oversized particles are retained on the upper surface 145 of the filter element 125. The fluid and undersized particles travel through the filter element 125 into the bottom channel 160 and are removed through the suction outlet 135. The oversized particles remain on the upper surface 145 of the filter element 125. Thereafter, suction is discontinued and elution fluid, under pressure, is introduced through the inlet 138 and into the channel 150 where it traverses the upper surface 145 and flushes the oversized particles into the outlet 140 where they are retained in a collector (not shown) for further analysis. The arrangement illustrated in Figs. 9 and 10 does not include the intermediate step of rinsing the particles retained on the filter element 125 with water.

[0037] What has so far been described is a filter arrangement utilizing on/off valves A-H to provide different configurations of the subject filter arrangement. In an alternate embodiment, certain of the valves A-H illustrated in Figs. 3A-7A may be replaced with check valves since there is flow in only a single direction through certain valves. By substituting check valves for these on/off valves where possible, the number of controlled elements may be reduced, thereby not only making control of the filter arrangement easier, but such check valves are less expensive than the on/off valves and, as a result, it is possible to fabricate a disposable filter arrangement that will cost less.

[0038] The reference characters associated with the elements in Fig. 11A and Fig. 11B are similar to those reference characters found in Figs. 3A and 3B, for example, with the exception, however, that each of the valve identifiers, while utilizing the same capital letter, introduces the suffix "1" while the other elements utilize a suffix "A" or, in the event the previous element has now been made into two parts, the suffix "B" will also be used.

[0039] With respect to Figs. 3A and 3B, Figs. 11A and 11B include a first bottom channel 50A and a second bottom channel 50B as opposed to a single bottom channel 50 illustrated in Fig. 3A. Additionally, each bottom channel 50A, 50B includes a suction outlet 40A, 40B to direct fluid in the direction indicated by arrows 67A, 67B, respectively. Additionally, with respect to Fig. 5A, Fig. 11A includes a first foam inlet 80A and a second foam inlet 80B as opposed to a single foam inlet 80. With respect to Fig. 4A and water inlet 70, Fig. 11A includes two separate water inlets 70A, 70B. By enabling different elution/rinsing fluids within each of the two water inlets 70A, 70B and foam inlets 80A, 80B, it is possible to enable different elution and rinsing fluids in a first cycle and in a separate second cycle. This will allow buffer exchange between the first cycle and the second cycle. Additionally, through the use of separate suction outlets 40A, 40B, it is possible for the second suction outlet 40B to be used to draw the elution fluid into the second chamber.

[0040] Directing attention to Fig. 11A, while valves A1-H1 are illustrated in the top element 15A, it should be appreciated that valves A1-C1 and E1-G1 are check valves, while valves D1 and H1 are on/off valves. For those lines in which flow occurs only in a single direction, the inventor has realized that a single check valve may be substituted for an on/off valve, thereby relieving the operator of the duty of adjusting a valve for operation.

[0041] As previously discussed with respect to Figs. 3A-7A, the filter arrangement 10 may be configured for six separate stages. These stages will hereinafter be referred to as: 1) aspirate sample; 2) first rinse; 3) first extraction; 4) second aspiration; 5) second rinse; and 6) final extraction.

[0042] For the initial configuration to aspirate the sample, the fluid/particle mixture is introduced through the inlet 30A and travels through the first stage channel 60A. Valve D1 is closed and the vacuum is activated such that the suction outlet 40A draws a vacuum through the bottom channel 50A, thereby depositing particles 65. With particles 65A deposited upon the upper surface 45A of the filter 25A, the first rinse stage begins. Water is introduced at water inlet 70A through check valve C1 and into the first stage channel 60A while the suction provided by the suction outlet 40A pulls the water/particle mixture through the filter 25A filtering additional particles that may not have been filtered during the initial step. The vacuum from the suction outlet 40A is discontinued and the on/off valve D1 is opened. At this point, elution is introduced under pressure at the foam inlet 80A where the liquid proceeds past the check valve B1 into the first stage channel 60A where it wipes the particles 65 from the top upper surface 45A of the filter element 25A into the collector 85A.

[0043] Any positive pressure that may be caused by the elution foam breaking down into a liquid may be vented through check valve G1.

[0044] At this point, the second aspiration stage begins with vacuum provided at the suction outlet 40B and valve H1 in the closed position. The particle/liquid solution is drawn from the collector 85A and past valve G1 into the second stage channel 90A where it then passes through the filter element 25A into the bottom channel 50B where the elution fluid and undersized particles are removed while the oversized particles 65A remain on the upper surface 45A of the filter element 25A.

[0045] In the second rinse stage, the suction outlet 40B is still energized but water is now introduced into the second stage channel 90A through the water inlet 70B. The water is pulled through the filter 25A and washes additional particles from the upper surface 45A of the filter element 25A through the suction outlet 40B where it is disposed.

[0046] The last stage is the final extraction, whereby there is no suction provided through the bottom channel 50B but elution fluid is introduced through foam inlet 80B where it travels into the second stage channel 90A. Valve H1 is open such that the elution fluid displaces the particles 65A from the upper surface 45A of the filter element 25A and moves them past the open valve H1 into a final receptacle (not shown). By doing this, particles are provided in a relatively low volume elution fluid which thereafter may be further analyzed with greater ease.

[0047] The embodiment just discussed in general replaced a number of on/off valves with check valves to make control of the multiple stages of the filter arrangement easier and to reduce costs.

[0048] Figs. 12A-17A and 12B-17B illustrate yet another embodiment, whereby a series of three-way stopcock valves M, N, O, P are utilized to configure the filter arrangement for different stages. Once again, the discussion will be directed to the six stages previously discussed including: 1) aspirate sample; 2) first rinse; 3) first extraction; 4) second aspiration; 5) second rinse; and 6) final extraction.

[0049] Figs. 12A and 12B are directed to the stage of aspirating the sample, wherein the bacteria sample is introduced through inlet 30C and valves M, N, and O are oriented such that the flow is directed through passageways 210, 230, 250, and 290 and into the first stage channel 60C. Vacuum is applied to the bottom channel 50C such that particles 65C are retained on the upper surface 45C of the filter element 25C. The liquid and particles that pass through the filter element 25C are discarded.

[0050] Directing attention to Figs. 13A and 13B, with the particles 65C retained on the upper surface 45C of the filter element 25C, water is introduced by orienting valves M, N, and O such that water enters at the water inlet 70C and travels through passageways 220, 230, 250, and 290 into the first stage channel 60C. With a vacuum applied in bottom channel 50C, the water and undersized particles travel through the filter element 25C and are discarded, thereby providing additional filtering of undersized particles.

[0051] With particles 65C deposited upon the upper surface 45C of the filter element 25C, those particles may now be extracted. Directing attention to Figs. 14A and 14B, elution is introduced through the first stage channel 60C and valves O and N are oriented such that the flow proceeds through passageways 290, 250, and 240 into the collector 85C. The elution moves the particles 65C across the upper surface 45C of the filter element 25C and into the passageway 290. In this manner, a relatively low volume of elution is mixed with the particles 65C and deposited within the collector 85C.

[0052] Any positive pressure that may be caused by the elution foam breaking down into a liquid may be vented through the top of the collector, which is open.

[0053] The elution/particle mixture now deposited in the collector 85C may be processed through a second filtering procedure which includes a second stage of aspirating. Directing attention to Figs. 15A and 15B, valves N, O, and P are oriented such that the elution/particle mixture in the collector 85C through a vacuum applied to the bottom channel 50D, is moved through passageways 240, 250, 270, and 280 into the second stage channel 60D and, once again, particles 65C are deposited on the upper surface 45C of the filter element 25C.

[0054] The second rinse stage, illustrated in Figs. 16A and 16B, may now be initiated. In particular, with valves M, N, O, and P oriented as illustrated, water may be introduced at the water inlet 70C such that it travels through passageways 220, 230, 250, 270, and 280 and into the second stage channel 60D. There the water and smaller particles pass through the filter element 25C and are discarded to provide a better sampling of particles 65C.

[0055] Now the second stage may be completed with a final extract as indicated in Figs. 17A and 17B. In particular, with the particles 65C deposited upon the upper surface 45C of the filter element 25C, elution under pressure is introduced into the second stage channel 60D, thereby displacing the particles 65C from the upper surface 45C. With valve P oriented as shown, the particles and the elution are washed through the second stage channel 60D into passageway 280 through valve P where they travel through passageway 260 into a final collector (not shown), providing a high quality sample of particles 65C mixed within a relatively low volume of liquid.

[0056] Figs. 12A-17A and 12B-17B illustrate a filter arrangement having two separate channels 60C, 60D each capable of accepting an independent supply of elution and, furthermore, a series of valves M, N, O, and P permit the original particle liquid sample to be directed to either the first stage channel 60C or the second stage channel 60D. Furthermore, this configuration permits water through inlet 70C to be introduced into either the first stage channel 60C or the second stage channel 60D.

[0057] Overall, Figs 12A-17A and 12B-17B illustrate an alternate filter arrangement for isolating particles 65 from a fluid/particle mixture. The filter arrangement is made of a top element having at least one open 60C channel extending thereacross in fluid communication with a top channel inlet/outlet 62C to a first collector 85C, wherein the channel 60C is open on the underside 47A of the top element 15. A bottom element 20A having at least one open channel 50C extending thereacross connected to a bottom element outlet, or suction outlet, 40A. The channel 50C is open on the upper side 52A of the bottom element 20A. The top element 15A is secured to the bottom element 20A such that the underside 47A of the top element 15A is secured against the upper side 52A of the bottom element 20A and wherein the channels 60C, 50C align with one another. The filter element 25A is generally flat and is positioned between the top element 15A and the bottom element 20A and overlaps with the channels 60C, 50C.

[0058] The top channel inlet/outlet 62C of channel 60C of the filter arrangement is connected to a fluid/particle supply and an elution fluid supply, wherein the bottom element outlet 40A is connected to a suction supply. As discussed, the filter arrangement provides a valve arrangement with at least two flow configurations.

[0059] With suction applied to the bottom element outlet 40A, the fluid/particle mixture is introduced through the top channel inlet/outlet 62C into the top channel 60C and over the filter element 25C thereby depositing retentate particles 65C upon the filter element 25C and passing permeate particles through the filter element 25C. Thereafter, with suction discontinued on the bottom element outlet 40A, the elution fluid is introduced into the top channel 60C and over the filter element 25C such that the retentate particles deposited upon the filter element 25C are tangentially rinsed through the top channel inlet/outlet 62C and collected into collector 85C.

[0060] The top element 15C may have a second stage channel 60D extending thereacross in fluid communication with another top channel inlet/outlet 62D to define a first stage channel 60C on one side of the top element 15C and a second stage channel 60D on the other side of the top element 15C such that the valve arrangement described in parts 1) and 2) for the first stage channel 60C is repeated for the second stage channel 60D thereby providing a two-stage filter arrangement with retentate initially deposited within the collector 85C and thereafter being processed again and finally being redeposited within the collector 85C.

[0061] The top element inlet 70C may be connected to a rinsing solution supply. Under these circumstances, the valve arrangement may have an additional configuration.

[0062] In particular, prior to introducing the elution fluid and after introducing the fluid/particle mixture, with suction applied to the bottom element outlet 35, the rinsing solution is introduced into the top channel 60D at the top channel inlet/outlet 62D and through the filter element 25C.

[0063] Just as before and as described with respect to the first stage channel 60C, the second stage channel 60D may have a similar valve configuration such that the processing of fluid retained in the collector 85C from the first stage channel 60C may be introduced into the second stage channel 60D for further processing and refinement, after which the refined particles are redeposited within the collector 85C.

[0064] While predefined steps utilizing this filter arrangement have been described herein, it should be appreciated that depending upon the specific need, there may be a single stage utilized or multiple stages and the individual steps or the sequence of steps may be different.

[0065] In a further embodiment, a dual filtering arrangement is possible as illustrated in Figs. 18A and 18B. In particular, Fig. 18A illustrates a top sandwich element 300 identical to the bottom element 20A illustrated in Fig. 11A and illustrates a middle sandwich element 305 similar to the top element 15A illustrated in 11B. However, the channels 60A, 90A of the middle sandwich element 305 extend completely through the thickness of the middle sandwich element 305. The channels 60A, 90A are in fluid communication with a collector 85C. Furthermore, a bottom sandwich element 310 is identical to the top sandwich element 300. However, the channels 350A, 360A are on the underside 347 of the top sandwich element 300 while the channels 350B, 360B are on the upper side of the bottom sandwich element 310.

[0066] As previously discussed, it should be appreciated that the view of the top sandwich element 300 is a transparent view and, in actuality, the channels are on the underside of the top sandwich element 300. Additionally, the channels in the bottom sandwich element 310 are on the upper side of the bottom sandwich element 310 such that, directing attention to Fig. 19, when the top sandwich element 300, the middle sandwich element 305, and the bottom sandwich element 310 are placed together, the channels are aligned with one another. Placed between the top sandwich element 300 and the middle sandwich element 305 is a top filter element 315 and placed between the middle sandwich element 305 and the bottom sandwich element 310 is a bottom filter element 320. By utilizing this configuration, the top filter element 315 and the bottom filter element 320 provide twice the membrane surface with the same channel volume.

[0067] Any positive pressure that may be caused by the elution foam breaking down into liquid may be vented through the check valve immediately downstream of the collector 85C.

[0068] Additionally, the filter elements discussed herein may be made up of a hydrophobic membrane to allow the passage of trapped air to the vacuum side.

[0069] Finally, a flow sensor may be added to the vacuum side to sense when all of the sample has been aspirated, thereby alleviating the need to have a sensor on the "clean side" of the disposable filter.

[0070] The method disclosed herein provides for the use of wet foam to remove microorganisms from a membrane surface and resuspend them in a fluid of choice. It is also possible to provide high recovery for low concentration specimens while maintaining consistency regardless of the specimen source.

[0071] The filter element provides 0.4 micron filtration of permeate and removes proteins, soluble materials and cell fractions. Additionally, by rinsing the filter element with rinsing solution, it is possible to remove small surface hanging particles and droplets from the original matrix while the use of wet foam allows extraction of the microorganisms from the surface of the filter.

[0072] Through the use of foam, which may be 80-90% gas, during the foam extraction the empty space is filled without contributing to the final sample volume. Additionally, the foam has a higher viscosity which prevents channeling and creates a more uniform flow across the filter surface. The foam produces micro bubbles which behave as deformable solids, effectively squeegeeing the particles off of the surface of the filter element. Overall, the filter based separation of particles in combination with the wet foam extraction into a matrix provides a superior filtering system.

[0073] While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. The presently preferred embodiments described herein are meant to be illustrative only and not limiting as to the scope of the invention which is to be given the full breadth of the appended claims and any and all equivalents thereof.

THE INVENTION CLAIMED IS

1. Using a fluid/particle mixture and a filter element that captures over-sized particles and allows undersized particles to pass through, a method for separating the particles from a fluid/particle mixture comprising the steps of:

a) filtering the fluid/particle mixture through the filter element so that the over-sized particles are deposited on an upper surface of the filter element;

b) tangentially rinsing the upper surface of the filter element with an elution fluid to displace the entrapped particles; and

c) collecting the displaced particles and the elution fluid.

2. The method of claim 1, further including, after the step of filtering the fluid/particle mixture, of rinsing additional particles through the filter element with water.

3. The method of claim 1, wherein filtering the fluid/particle mixture through the filter element is done using suction from the top of the filter element to the bottom of the filter element.

4. The method according to claim 1, wherein the elution fluid is effervescent.

5. The method according to claim 1, further including repeating steps a) through c) to provide a second stage of filtering.

6. The method according to claim 1, wherein the particles are bacteria.

7. The method according to claim 1, wherein the filter element is a polycarbonate-type filter element which is a surface filter.

8. The method according to claim 7, wherein the filter element has pores with openings approximately 0.4 microns wide.

9. The method according to claim 1, wherein the elution fluid is effervescent.

10. The method according to claim 1, wherein the elution fluid is made up of PBS.

11. The method according to claim 1, wherein the elution fluid contains a foaming agent.

12. The method according to claim, wherein the foaming agent is TWEEN.

13. A filter arrangement for isolating particles from a fluid/particle mixture comprised of:

a) a top element having at least one open channel extending thereacross connecting a top element inlet to a first collector, wherein the channel is open on the underside of the top element;

b) a bottom element having at least one open channel extending thereacross connected to a bottom element outlet for providing suction, wherein the channel is open on the upper side of the bottom element;

c) wherein the top element is secured to the bottom element such that the underside of the top element is secured against the upper side of the bottom element and wherein the channels align with one another;

d) a filter element which is generally flat and is positioned between the top element and the bottom element and overlapping with the channels.

14. The filter arrangement according to claim 13, wherein the top element inlet is connected to a fluid/particle supply and an elution fluid supply, wherein the bottom element outlet is connected to a suction supply and wherein the arrangement further comprises:

e) a valve arrangement providing at least two flow configurations comprising:

1) with suction applied to the bottom element outlet, introducing the fluid/particle mixture into the top channel and over the filter element thereby depositing retentate particles upon the filter element and passing permeate particles through the filter;

2) thereafter, with suction discontinued to the bottom element, introducing the elution fluid into the top channel and over the filter element such

that the retentate particles deposited upon the filter are tangentially rinsed and collected into a first collector.

15. The filter arrangement according to claim 14, wherein a second collector is positioned at a top element outlet within the path of the open channel of the top element to define a first stage channel on one side of the first collector and a second stage channel on the other side of the first collector such that the valve arrangement described in parts 1) and 2) for the first stage channel is repeated for the second stage channel thereby providing a two-stage filter arrangement with retentate initially deposited within the first collector and thereafter finally being deposited within the second collector.

16. The filter arrangement according to claim 14, wherein the top element inlet is further connected to a rinsing solution supply and wherein the valve arrangement in e) has an additional configuration comprising:

3) prior to introducing the elution fluid and after introducing the fluid/particle mixture, with the bottom element outlet suction applied, introducing the rinsing solution into the top channel and through the filter element.

17. The filter arrangement according to claim 16, wherein a second collector is positioned at a top element outlet within the path of the open channel of the top element to define a first stage channel on one side of the first collector and a second stage channel on the other side of the first collector such that the valve arrangement described in parts 1), 2) and 3) for the first stage channel is repeated for the second stage channel thereby providing a two-stage filter arrangement with retentate initially deposited within the first collector and thereafter finally being deposited within the second collector.

18. The filter arrangement according to claim 13, wherein the retentate is bacteria.

19. The filter arrangement according to claim 13, wherein the filter element is a polycarbonate-type filter element.

20. The filter arrangement according to claim 19, wherein the filter element is capable of filtering particles as small as 0.4 microns.

21. The filter arrangement according to claim 13, wherein the elution fluid is effervescent.

22. The filter arrangement according to claim 13, wherein the elution fluid is PBS.

23. The filter arrangement according to claim 13, wherein the elution fluid is a foaming agent.

24. The filter arrangement according to claim 23, wherein the foaming agent is TWEEN.

25. A filter arrangement for isolating particles from a fluid/particle mixture with elements arranged in a sandwiched relationship comprised of:

a) a middle sandwich element having a thickness and at least one open channel extending thereacross connecting a middle sandwich element inlet to a first collector and extending through the thickness;

b) a top sandwich element having at least one open channel extending thereacross connected to a top sandwich element outlet for providing suction, wherein the channel is open on the underside of the top sandwich element;

c) a bottom sandwich element having at least one open channel extending thereacross connected to a bottom sandwich element outlet for providing suction; wherein the channel is open on the upper side of the bottom sandwich element;

d) wherein the top sandwich element is secured to the middle sandwich element such that the underside of the top sandwich element is secured against the upper side of the bottom element and wherein the channels align with one another;

e) wherein the bottom sandwich element is secured to the middle sandwich element such that the upper side of the bottom sandwich element is secured against the underside of the bottom sandwich element and wherein the channels align with one another;

f) a top filter element which is generally flat and is positioned between the top sandwich element and the middle sandwich element and overlapping with the channels; and

g) a bottom filter element which is generally flat and is positioned between the top element and the middle sandwich element and overlapping with the channels, thereby using a common middle sandwich element to provide a configuration capable of preforming two separate filtering operations simultaneously.

26. A filter arrangement for isolating particles from a fluid/particle mixture comprised of:

a) a top element having at least one open channel extending thereacross in fluid communication with a top channel inlet/outlet and a collector, wherein the channel is open on the underside of the top element;

b) a bottom element having at least one open channel extending thereacross connected to a bottom element outlet for providing suction; wherein the channel is open on the upper side of the bottom element;

c) wherein the top element is secured to the bottom element such that the underside of the top element is secured against the upper side of the bottom element and wherein the channels align with one another;

d) a filter element which is generally flat and is positioned between the top element and the bottom element and overlapping with the channels.

27. The filter arrangement according to claim 26, wherein the top channel inlet/outlet is connected to a fluid/particle supply and an elution fluid supply, wherein the bottom element outlet is connected to a suction supply and wherein the arrangement further comprises:

e) a valve arrangement providing at least two flow configurations comprising:

1) with suction applied to the bottom element outlet, introducing the fluid/particle mixture through the top channel inlet/outlet into the top channel and over the filter element thereby depositing retentate particles upon the filter element and passing permeate particles through the filter;

2) thereafter, with suction discontinued to the bottom element outlet closed, introducing the elution fluid into the top channel and over the filter element such that the retentate particles deposited upon the filter element are tangentially rinsed through the top channel inlet/outlet and collected into a collector.

28. The filter arrangement according to claim 27, wherein the top element has a second stage channel extending thereacross in fluid communication with the top channel inlet/outlet within the path of the open channel of the top element to define a first stage channel on one side of the top element and a second stage channel with another top channel inlet/outlet on the other side of the top element such that the valve arrangement described in parts 1) and 2) for the first stage channel is repeated for the second stage channel thereby providing a two-stage filter arrangement with retentate initially deposited within the first collector and thereafter being process again and finally being redeposited within the collector.

29. The filter arrangement according to claim 27, wherein the top element inlet is further in fluid connection with a rinsing solution supply and wherein the valve arrangement in e) has an additional configuration comprising:

3) prior to introducing the elution fluid and after introducing the fluid/particle mixture, with the bottom element outlet suction applied, introducing the rinsing solution into the top channel by the top channel inlet/outlet and through the filter element.

30. The filter arrangement according to claim 29, wherein the collector is in fluid communication with the top channel inlet/outlet within the path of the open channel of the top element to define a first stage channel on one side of the top element and a second stage channel with another top channel inlet/outlet on the other side of the top element such that the valve arrangement described in parts 1), 2) and 3) for the first stage channel is repeated for the second stage channel thereby providing a two-stage filter arrangement with retentate initially deposited within the collector and thereafter finally being redeposited within the collector.

31. The filter arrangement according to claim 26, wherein the retentate is bacteria.

32. The filter arrangement according to claim 26, wherein the filter element is a polycarbonate-type filter element.

33. The filter arrangement according to claim 32, wherein the filter element is capable of filtering particles as small as 0.4 microns.

34. The filter arrangement according to claim 26, wherein the elution fluid is effervescent.

35. The filter arrangement according to claim 26, wherein the elution fluid is PBS.

36. The filter arrangement according to claim 26, wherein the elution fluid is a foaming agent.

37. The filter arrangement according to claim 36, wherein the foaming agent is TWEEN.

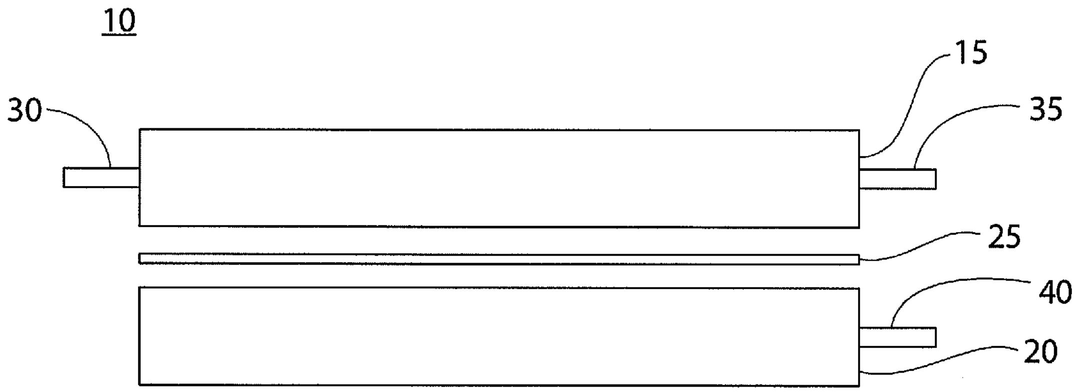


FIG. 1

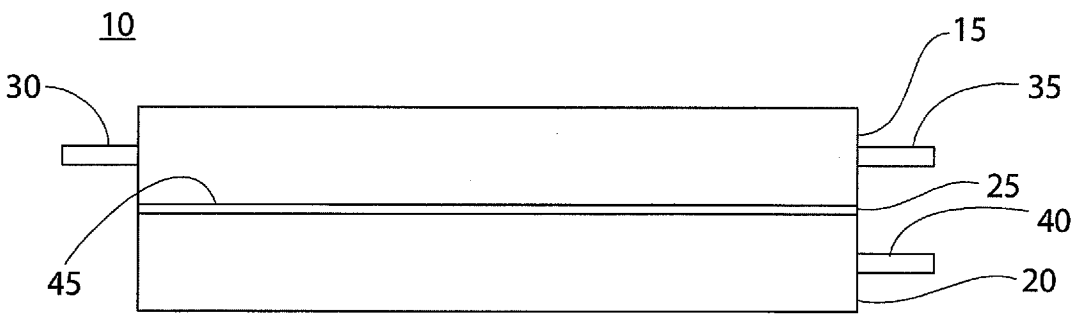


FIG. 2

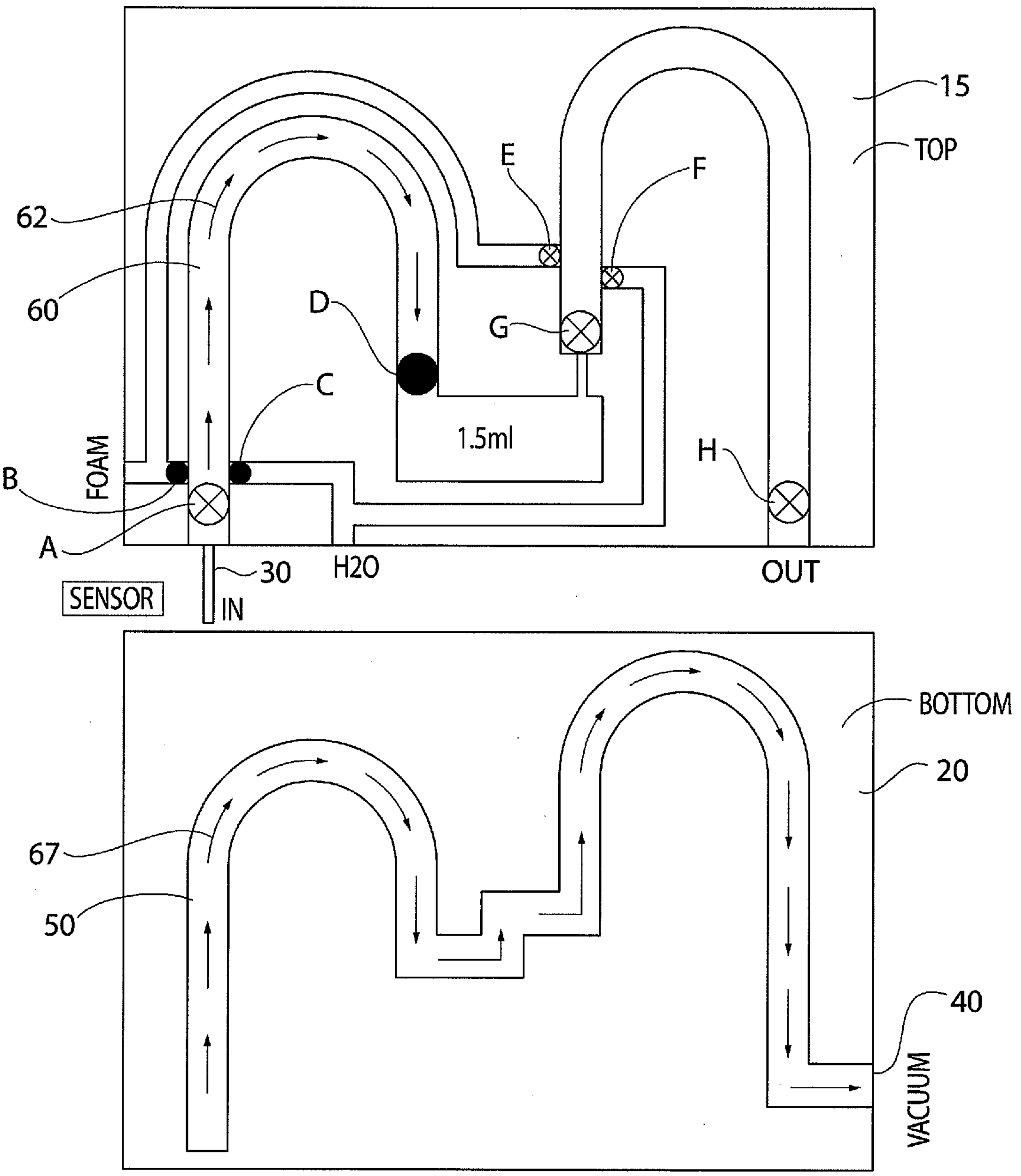

15
TOP
E
F
62
60
D
G
C
1.5ml
FOAM
B
H
A
30
H2O
OUT
SENSOR
IN
BOTTOM
20
67
50
40
VACUUM

FIG. 3A

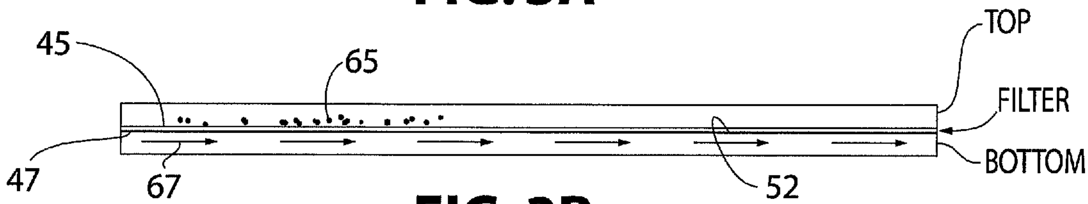
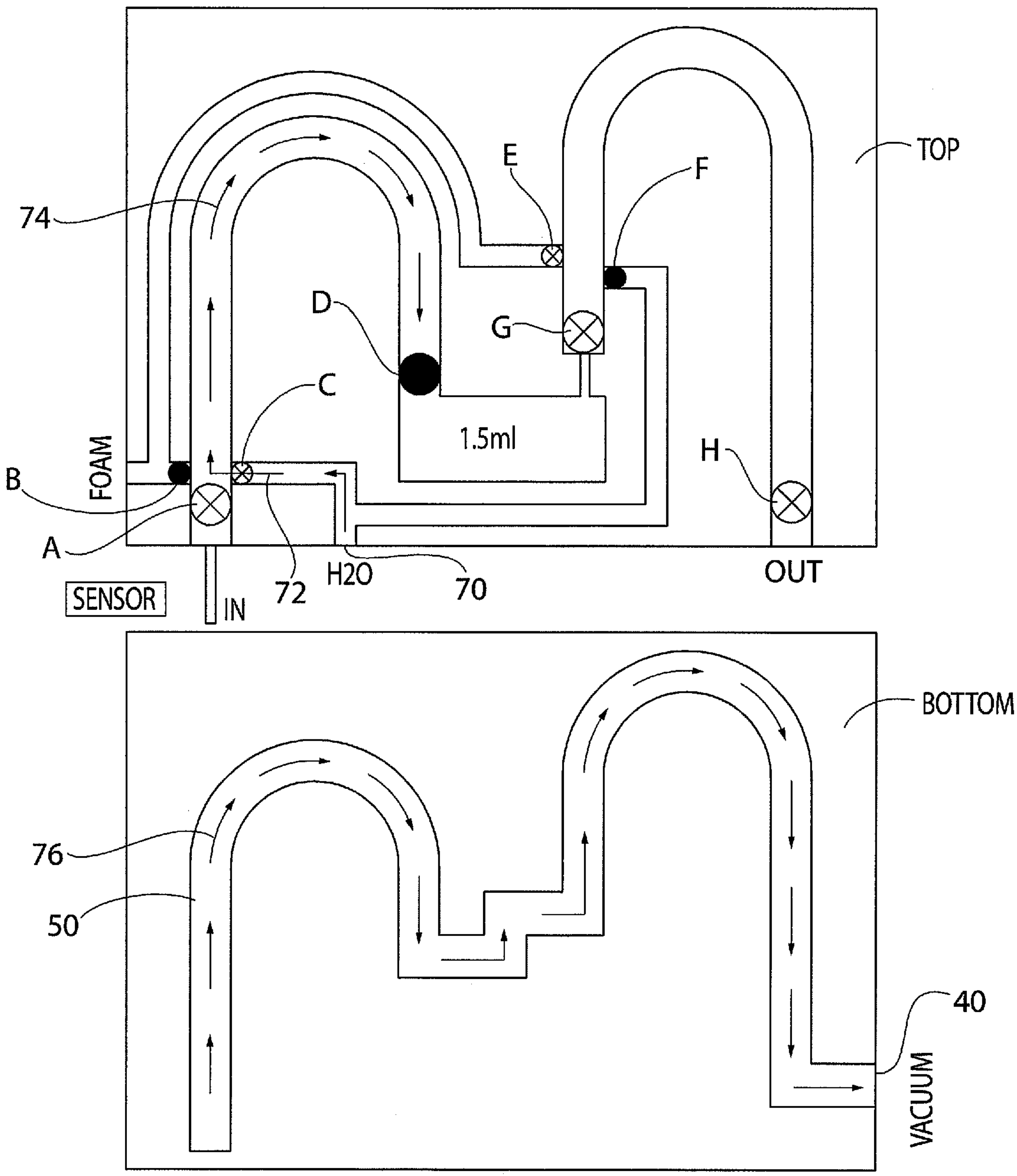

45
65
TOP
FILTER
BOTTOM
47
67
52

FIG. 3B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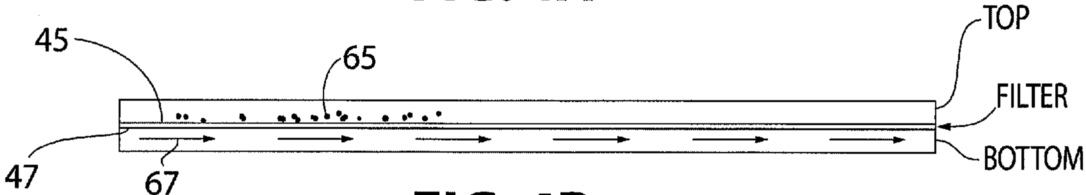
E
F
74
D
G
C
1.5ml
FOAM
H
B
A
72
H20
70
OUT
SENSOR
IN
BOTTOM
76
50
40
VACUUM

FIG. 4A


TOP
45
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FILTER
47
67
BOTTOM

FIG. 4B

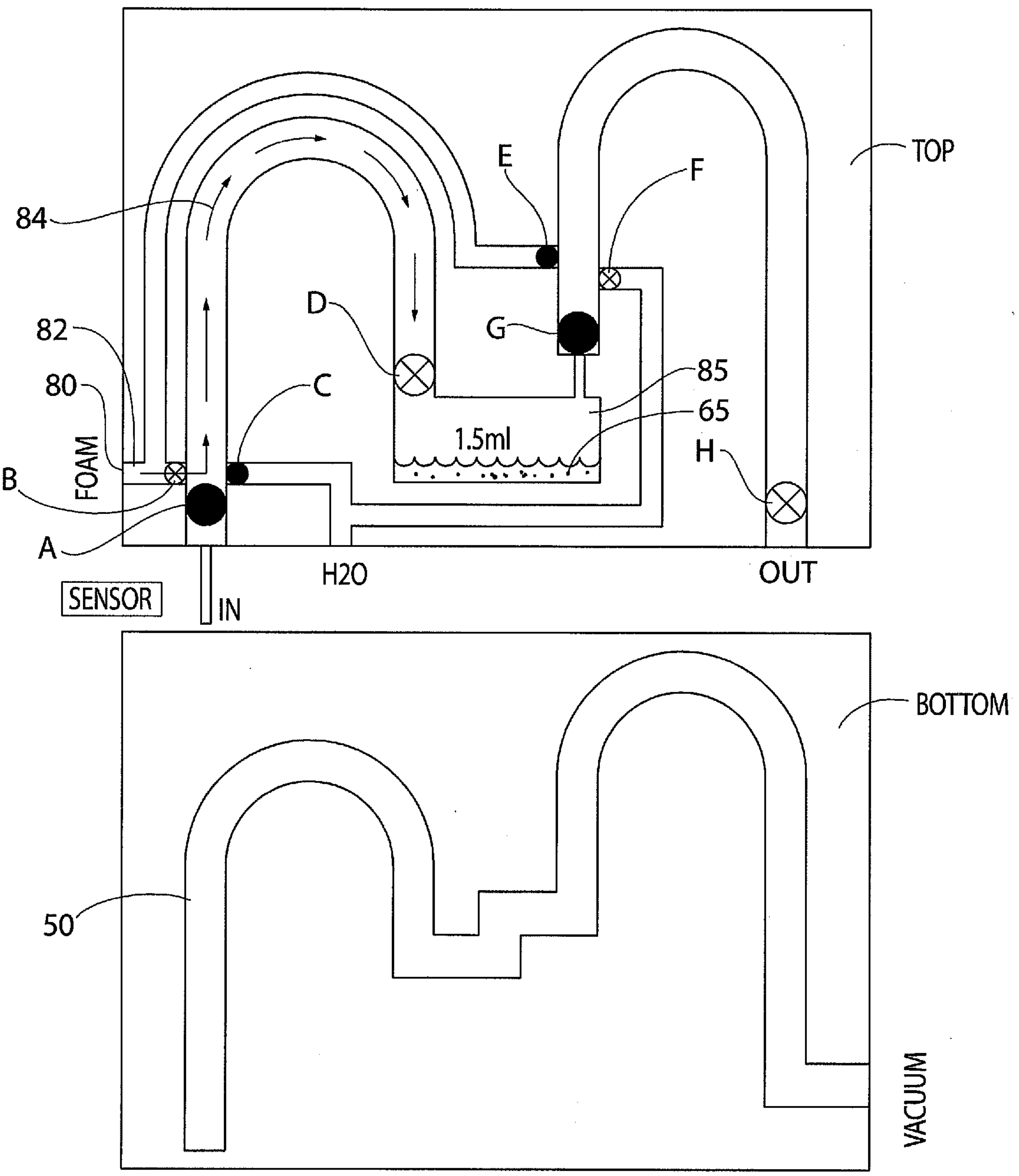
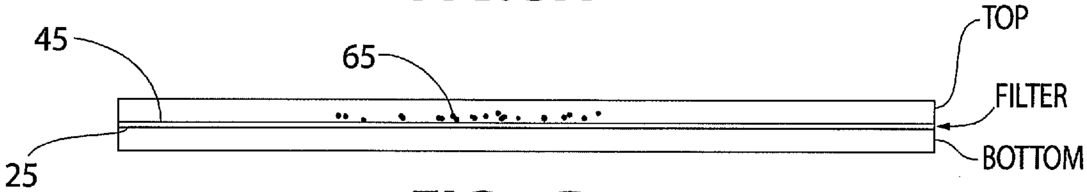

TOP
E
F
84
D
G
82
85
80
C
65
1.5ml
FOAM
H
B
A
H2O
OUT
SENSOR
IN
BOTTOM
50
VACUUM

FIG. 5A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65
TOP
FILTER
BOTTOM
25

FIG. 5B

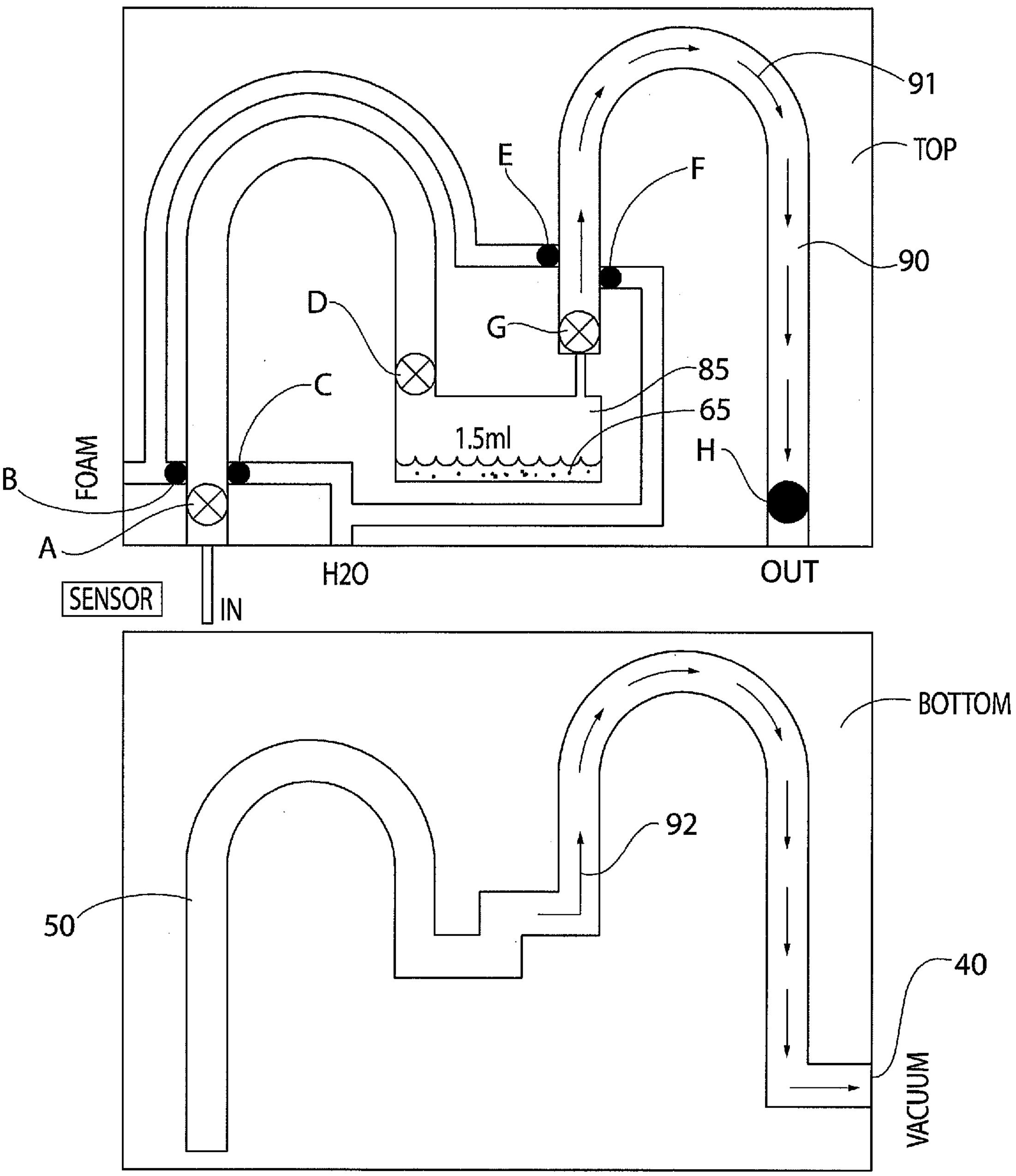

91
TOP
E
F
90
D
G
85
C
65
1.5ml
FOAM
H
B
A
H2O
OUT
SENSOR
IN
BOTTOM
92
50
40
VACUUM

FIG. 6A

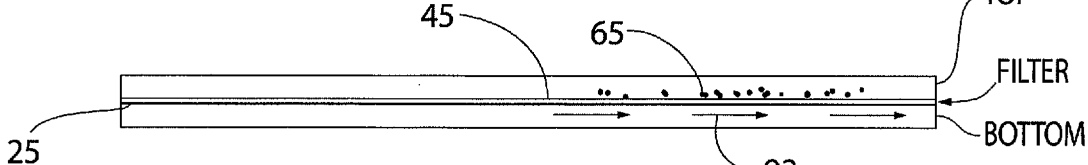
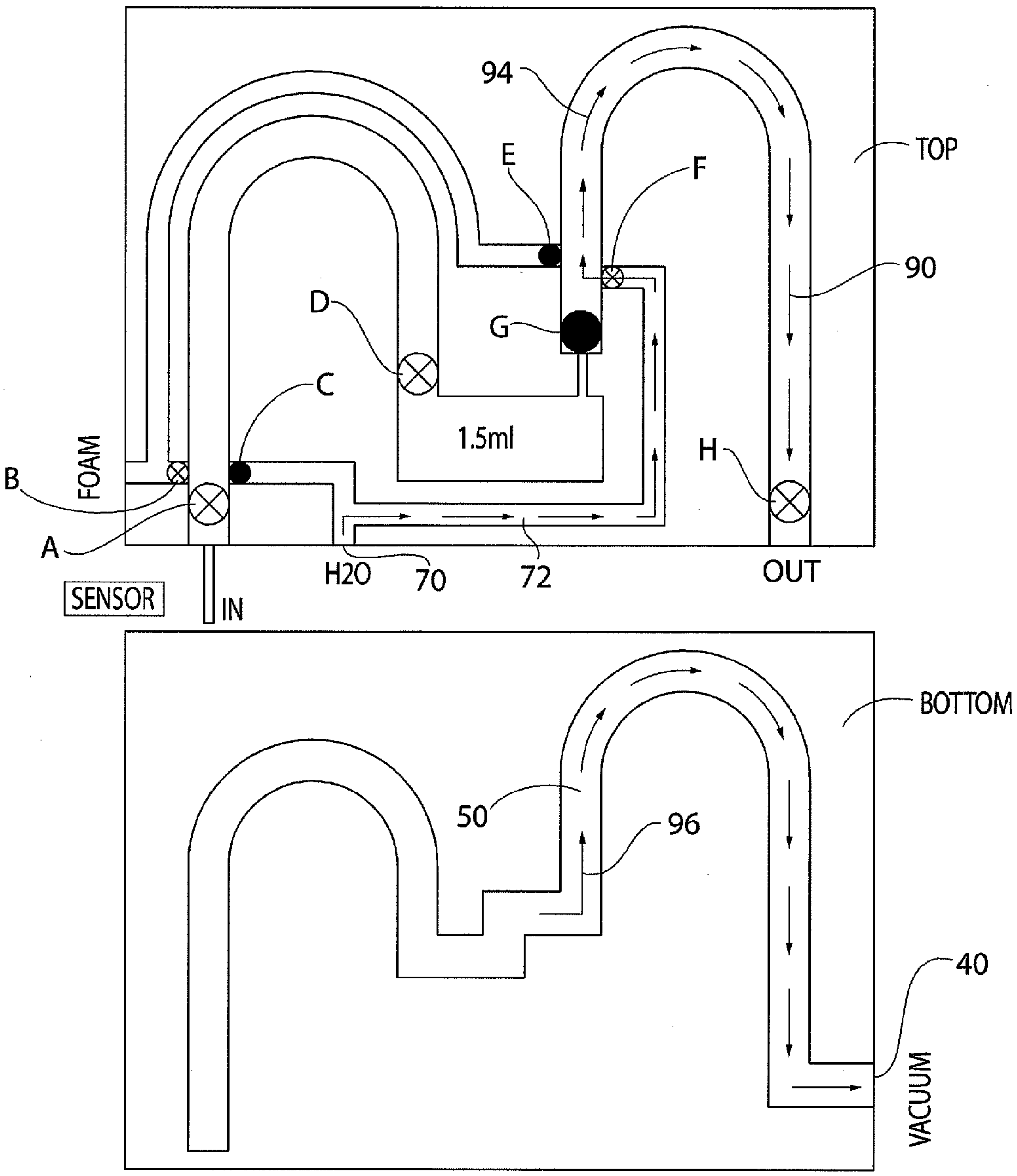
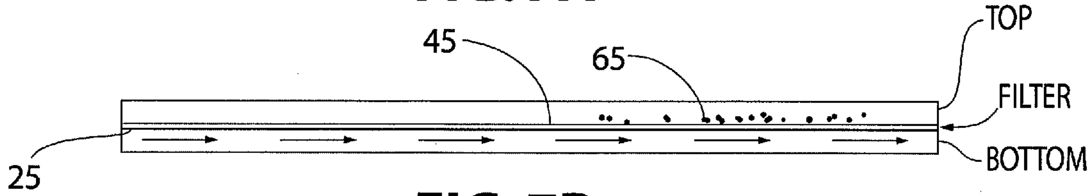

TOP
45
65
FILTER
BOTTOM
25
92

FIG. 6B



94
TOP
E
F
90
D
G
C
1.5ml
FOAM
B
H
A
H2O
70
72
OUT
SENSOR
IN
BOTTOM
50
96
40
VACUUM

FIG. 7A



45
65
TOP
FILTER
BOTTOM
25

FIG. 7B

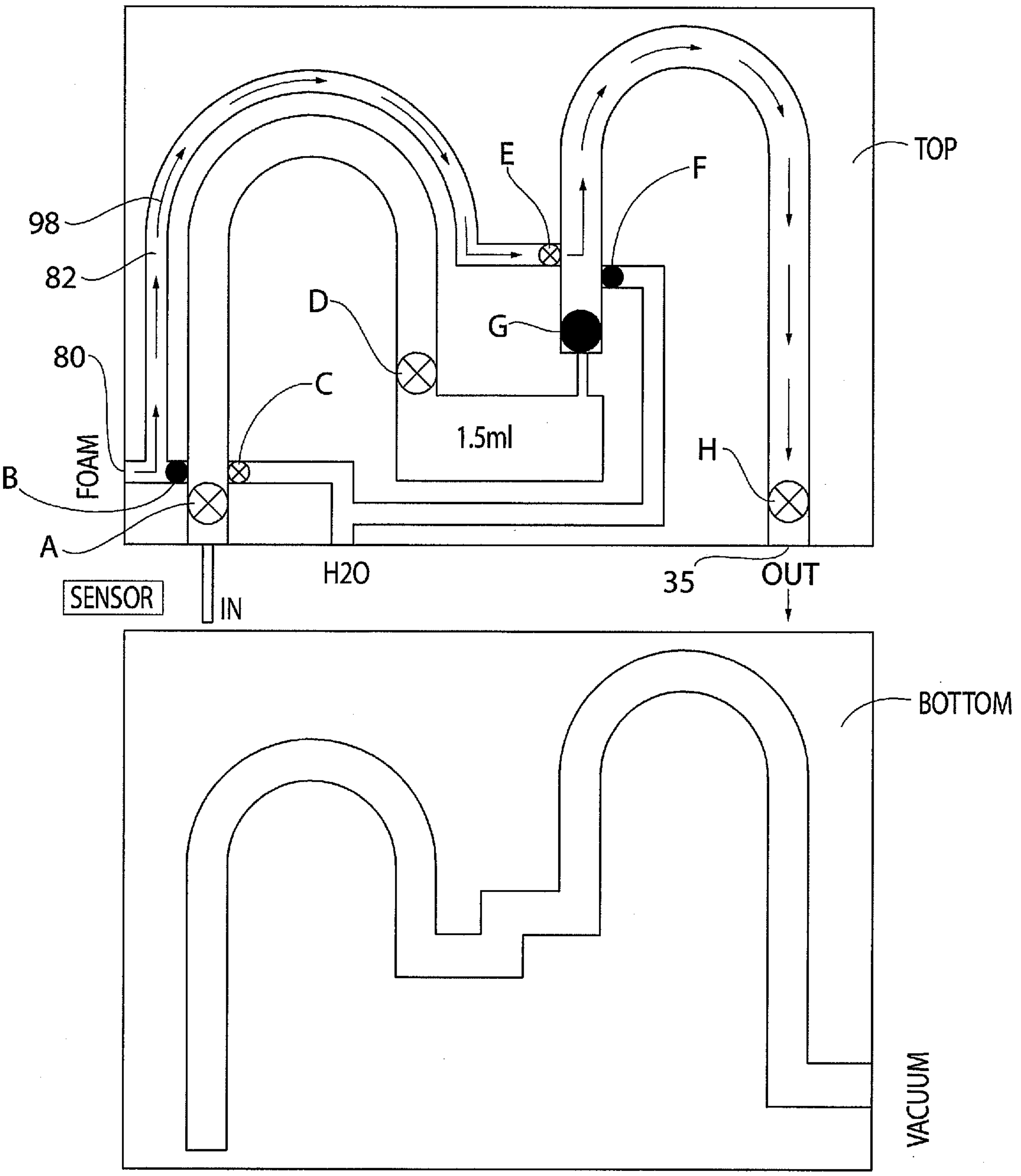

TOP
E
F
98
82
D
G
80
C
1.5ml
H
FOAM
B
A
H2O
35
OUT
SENSOR
IN
BOTTOM
VACUUM

FIG. 8A

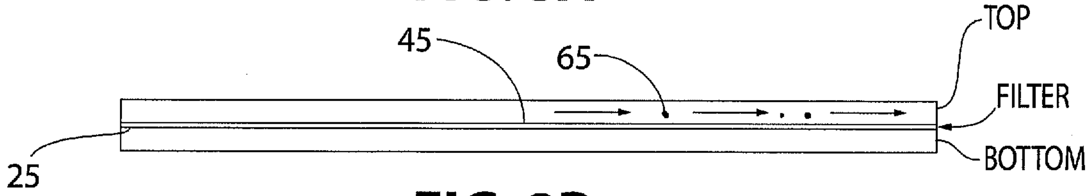

TOP
45
65
FILTER
25
BOTTOM

FIG. 8B

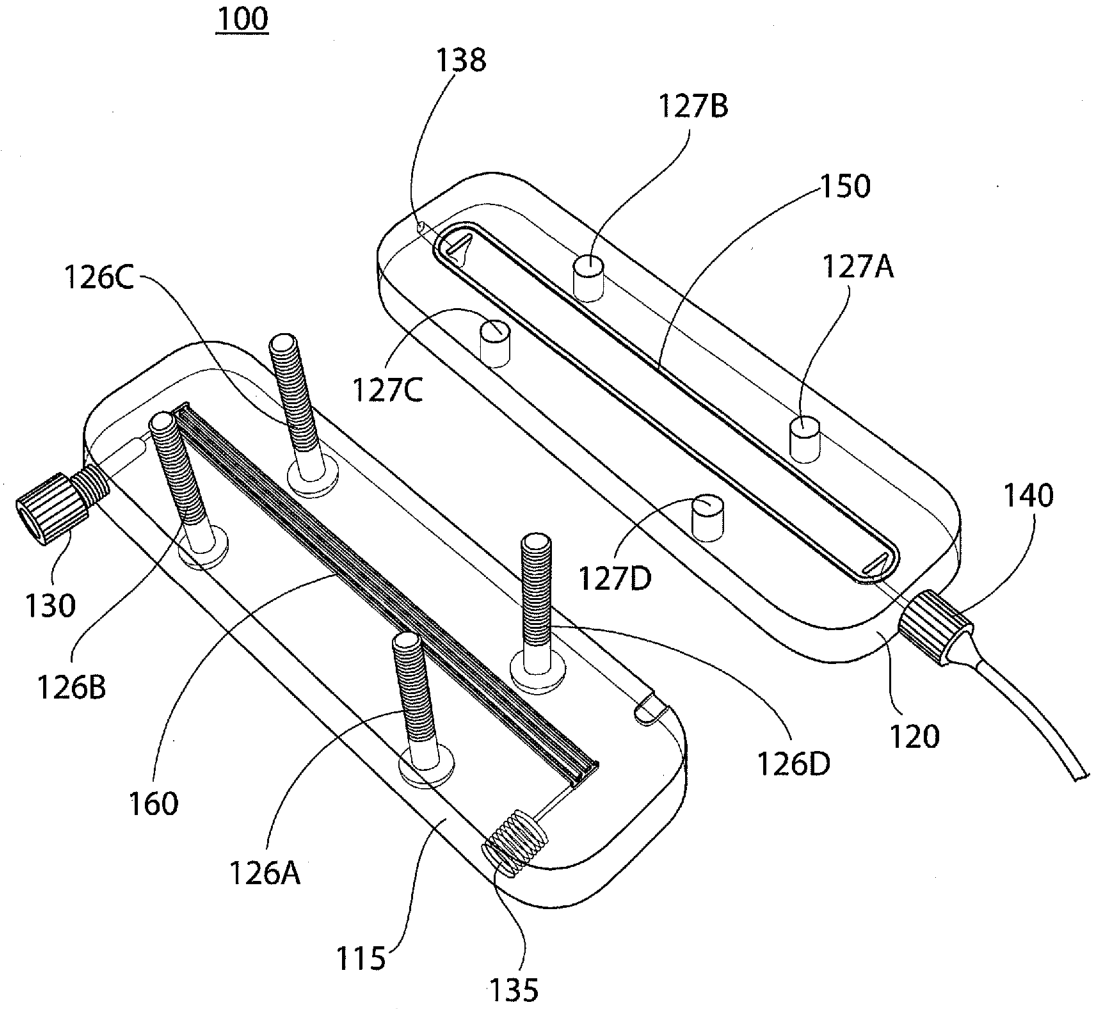

100
138
127B
150
127A
126C
127C
140
127D
130
126B
160
126A
126D
120
115
135

FIG. 9

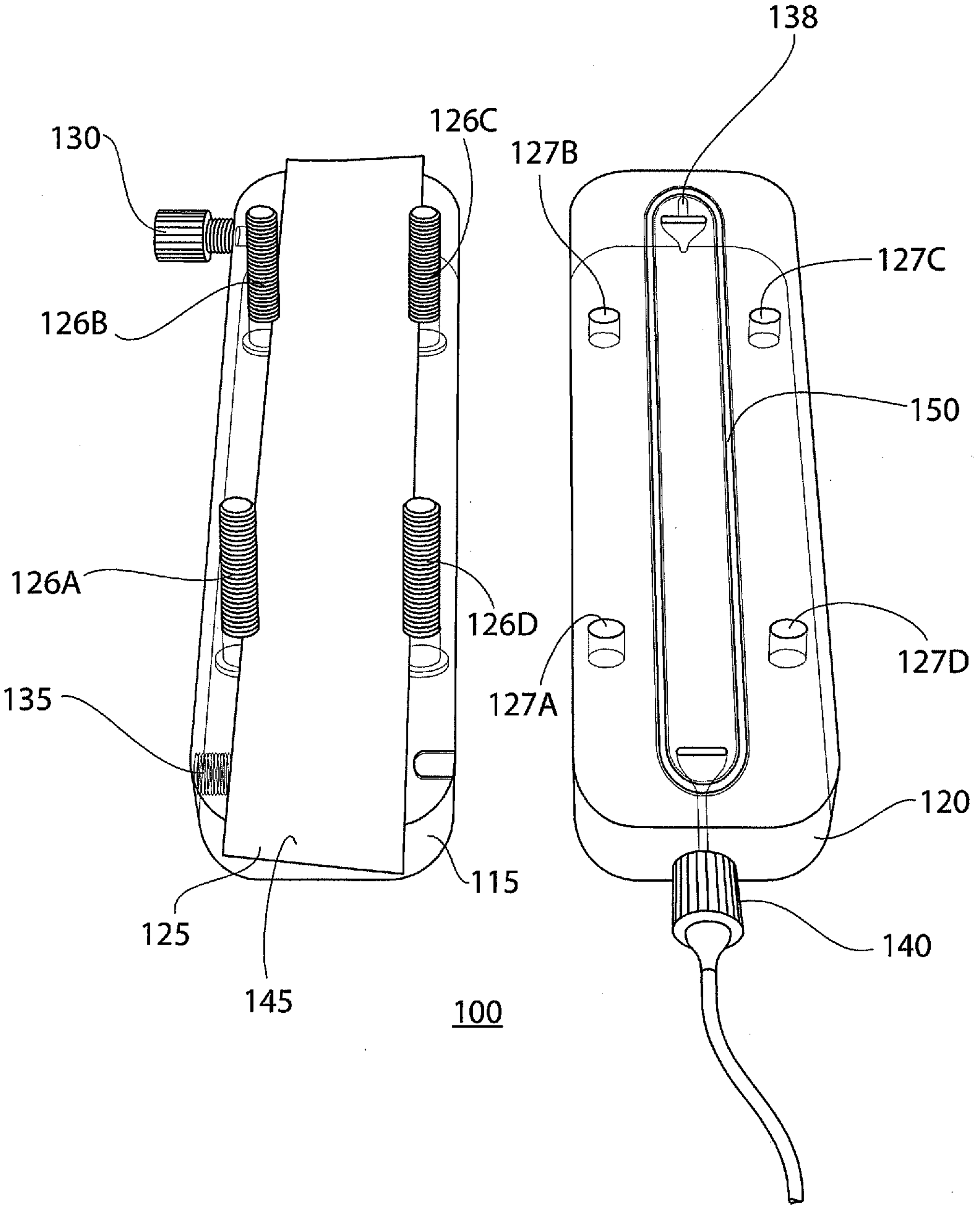

138
130
126C
127B
127C
126B
150
126A
126D
127D
127A
135
120
115
125
140
145
100

FIG. 10

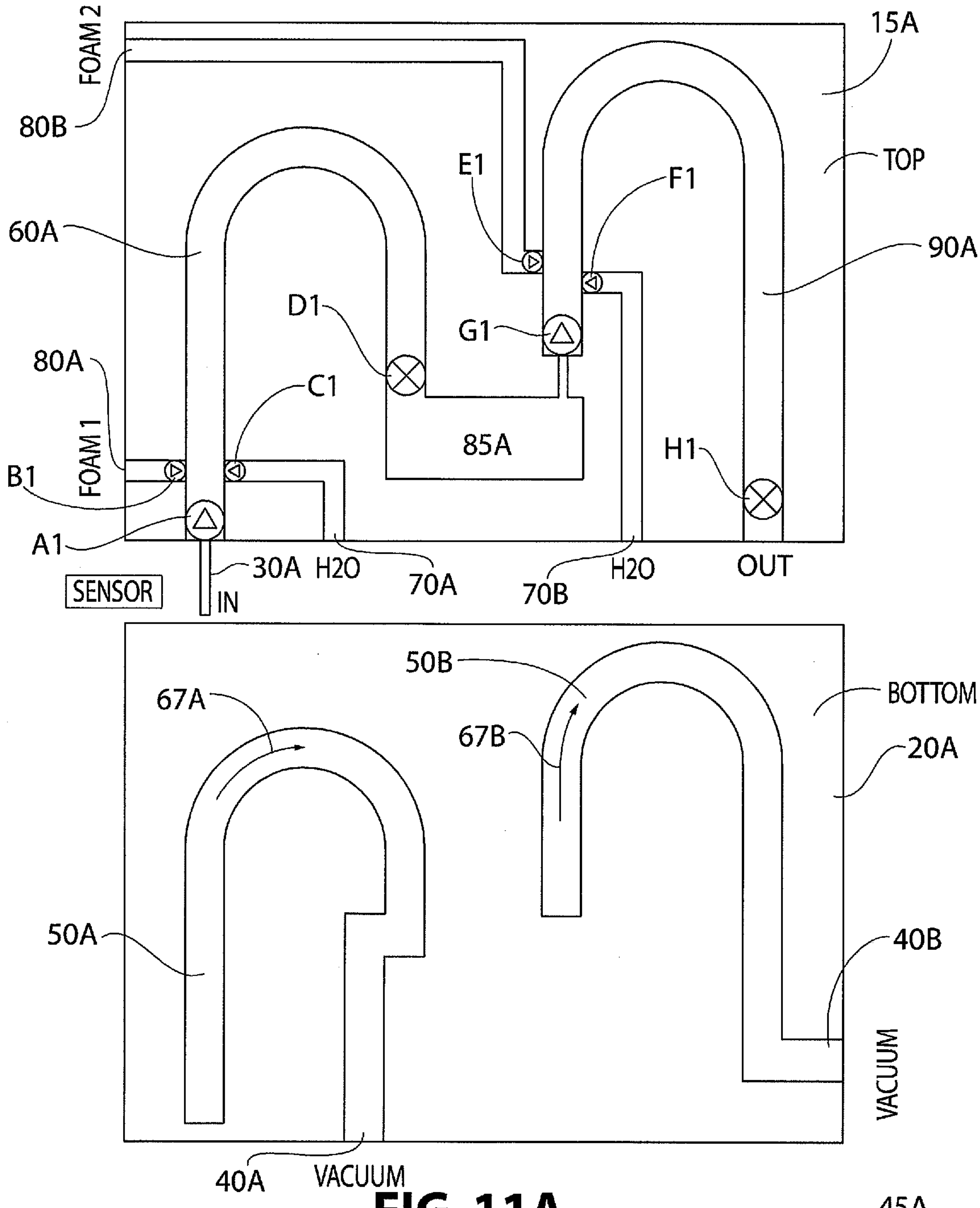


FIG. 11A

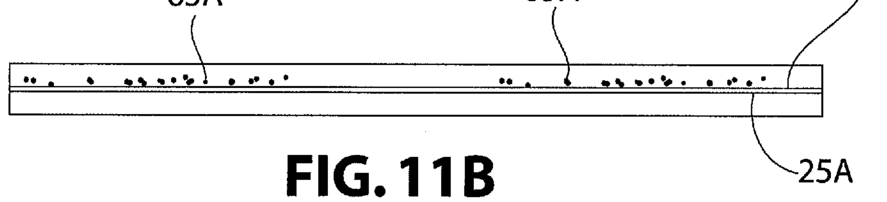


FIG. 11B

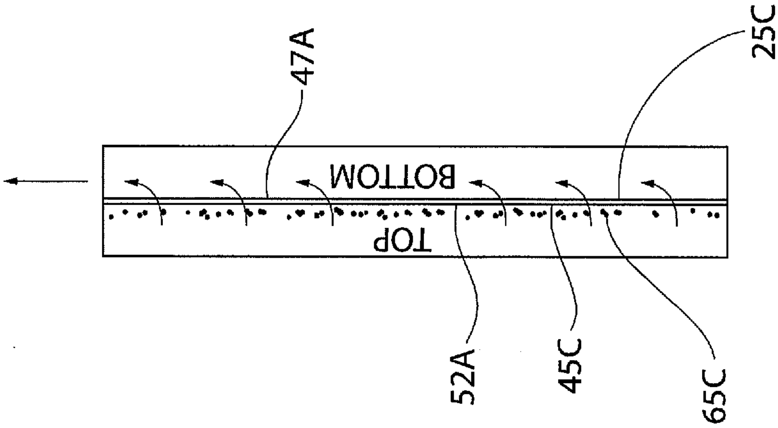


FIG. 12B

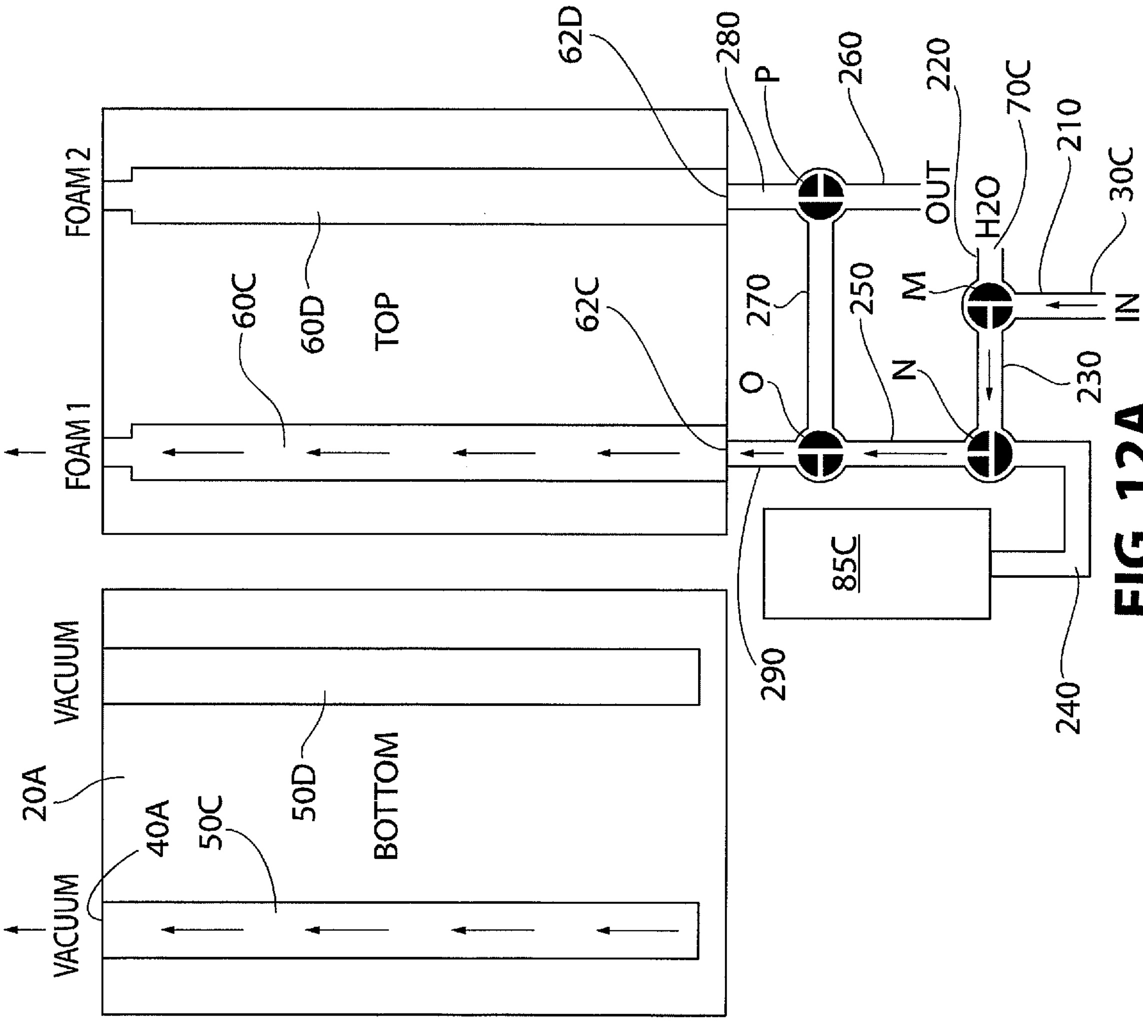


FIG. 12A

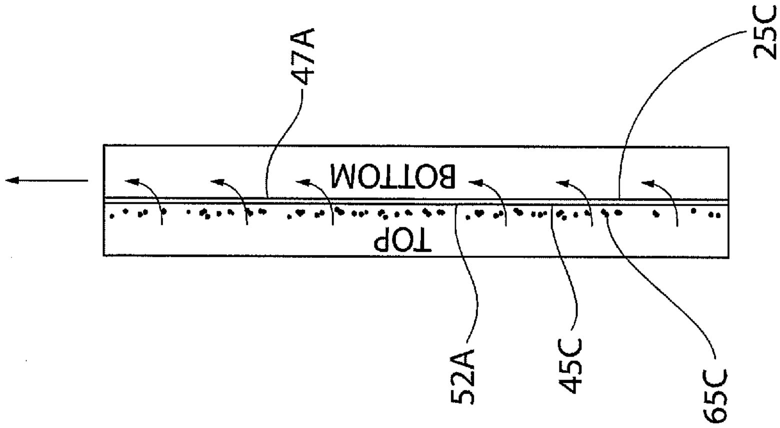


FIG. 13B

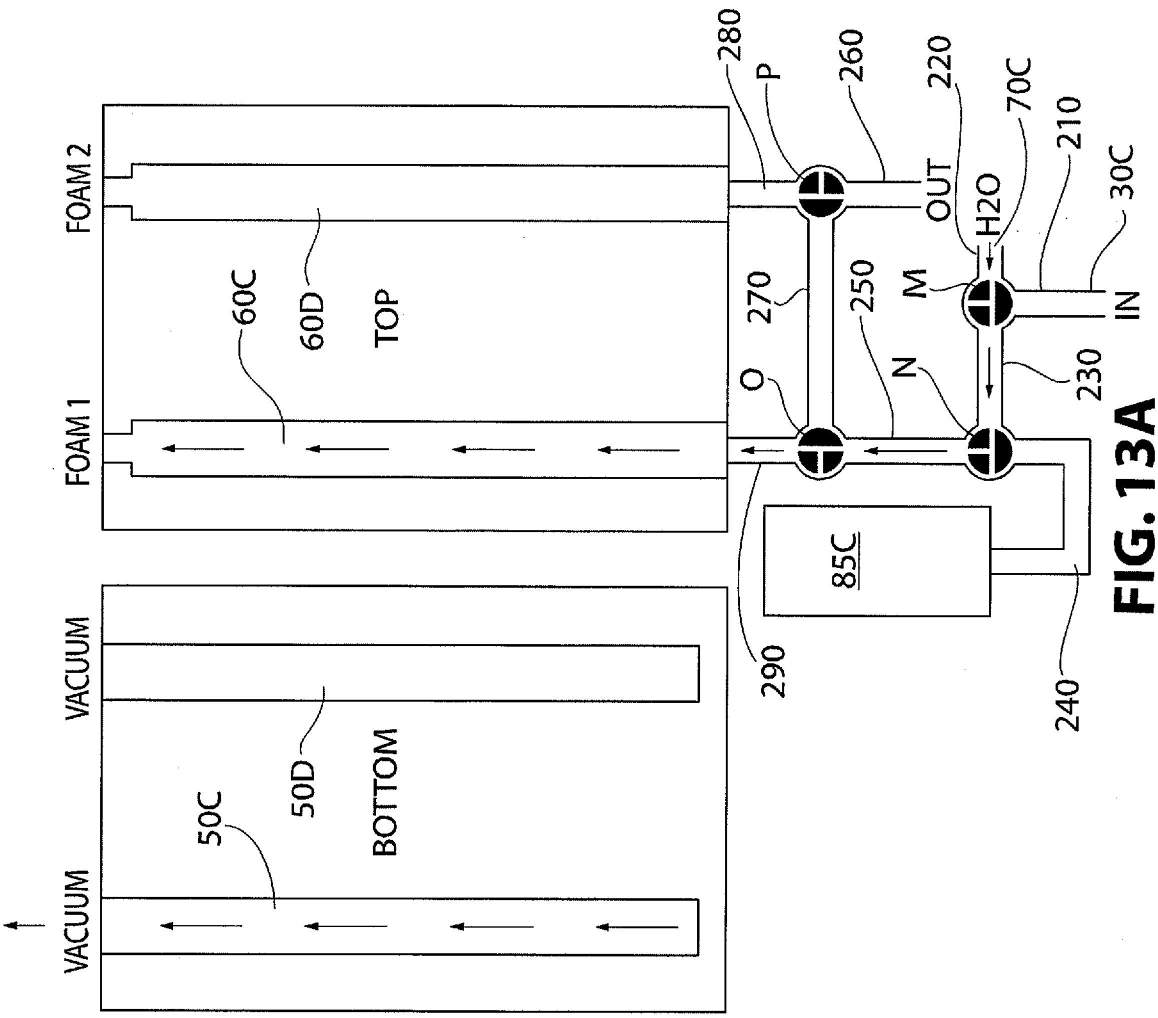


FIG. 13A

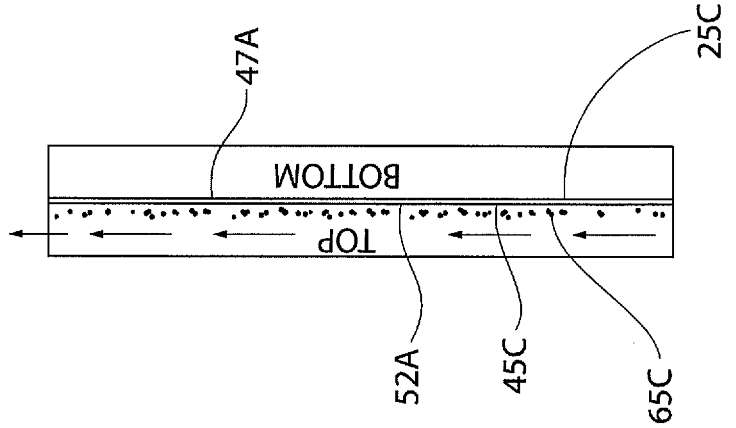


FIG. 14B

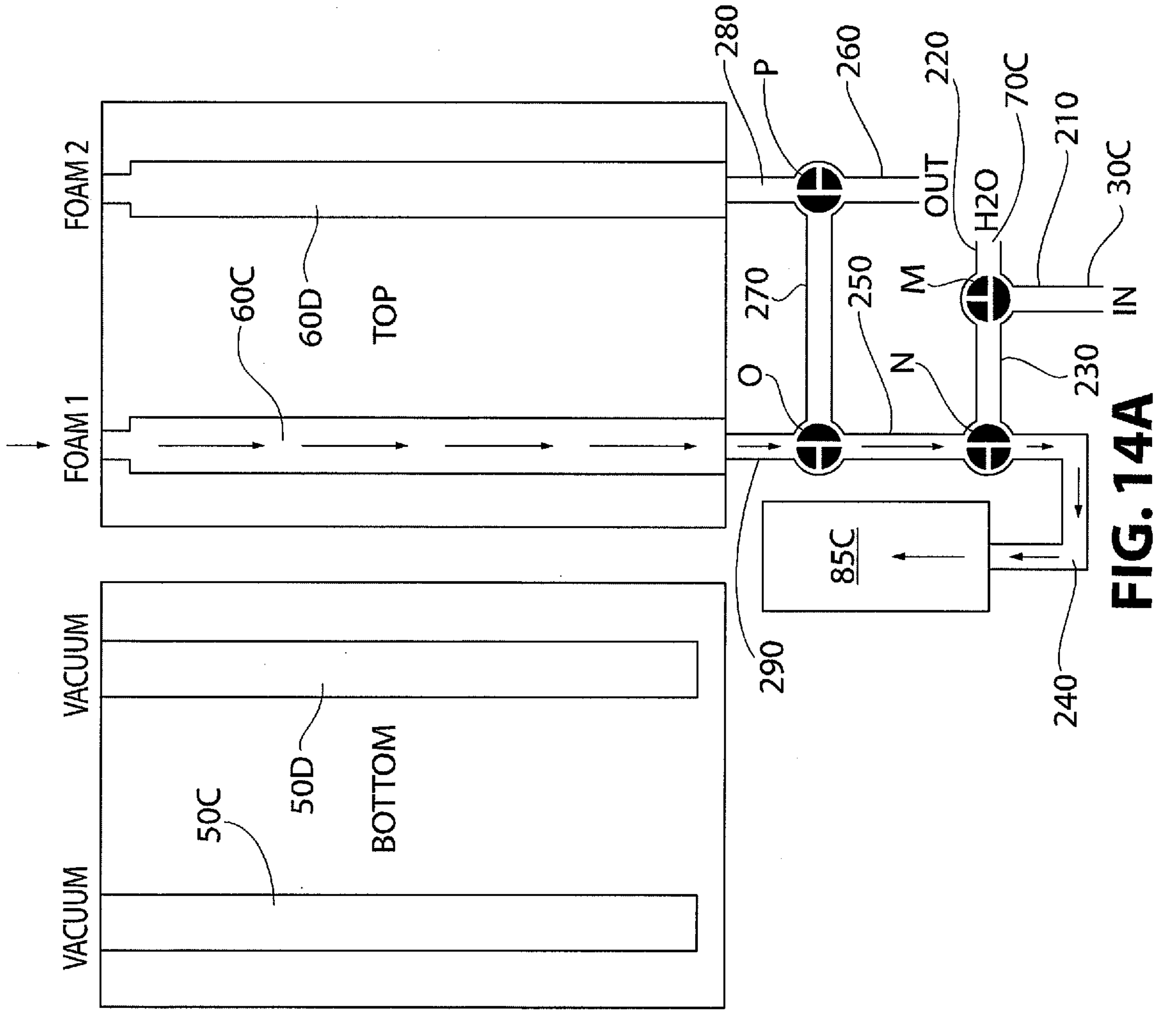


FIG. 14A

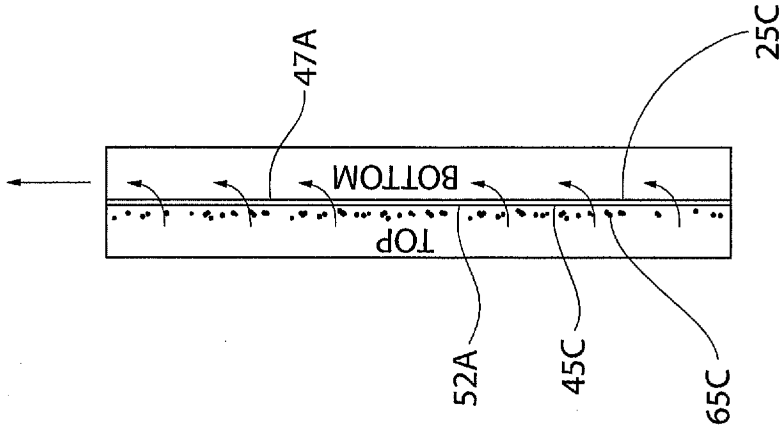


FIG. 15B

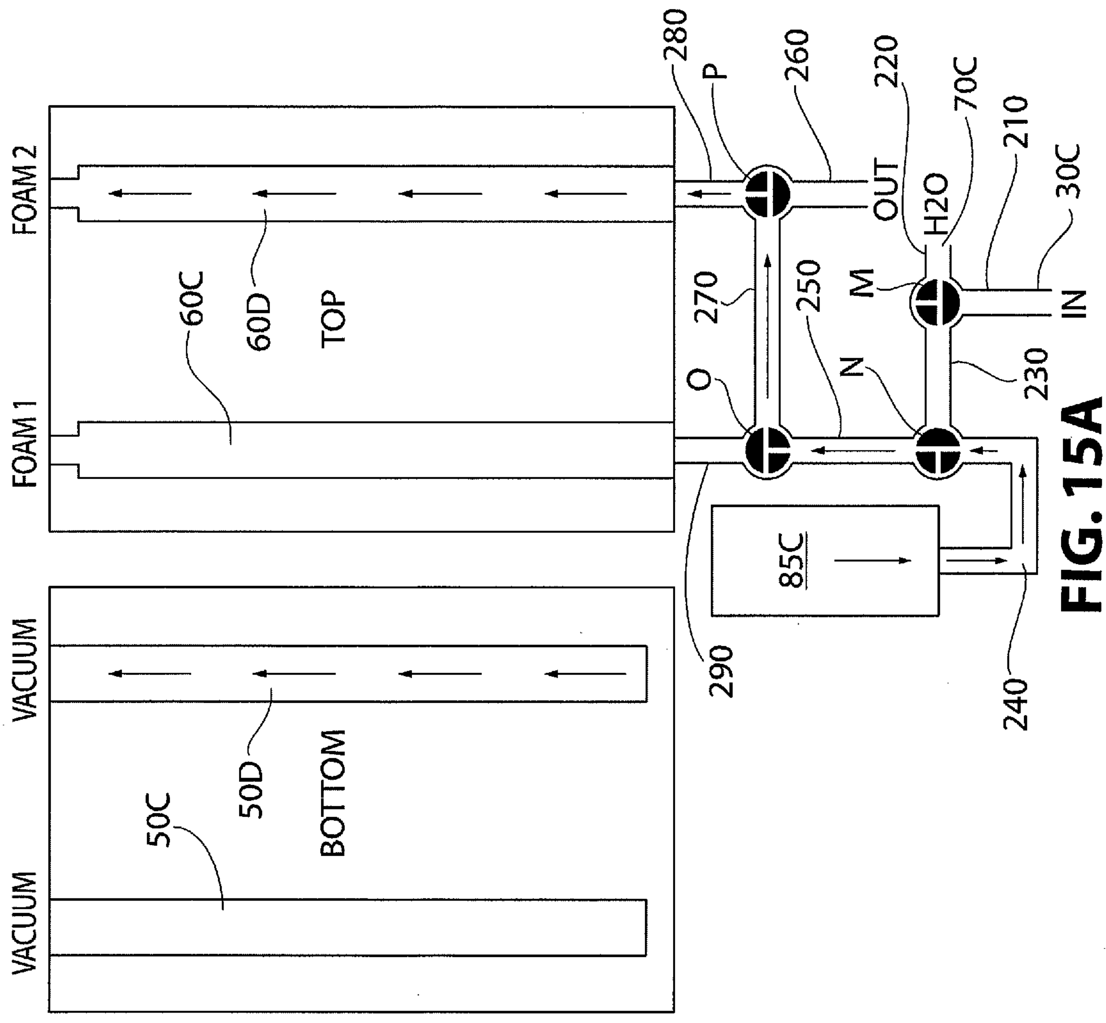


FIG. 15A

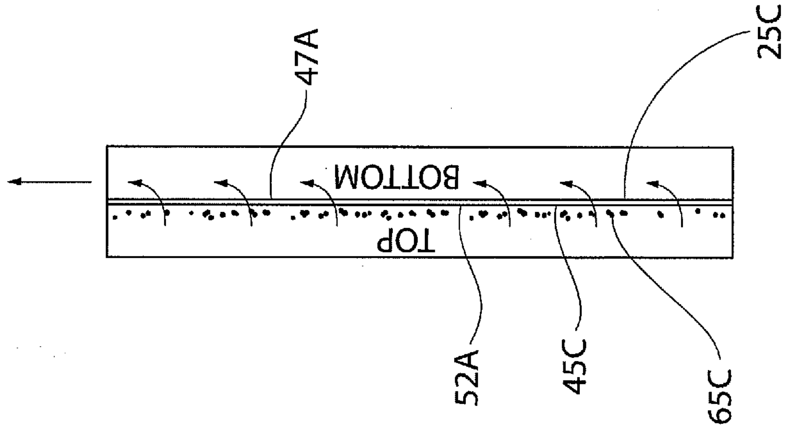


FIG. 16B

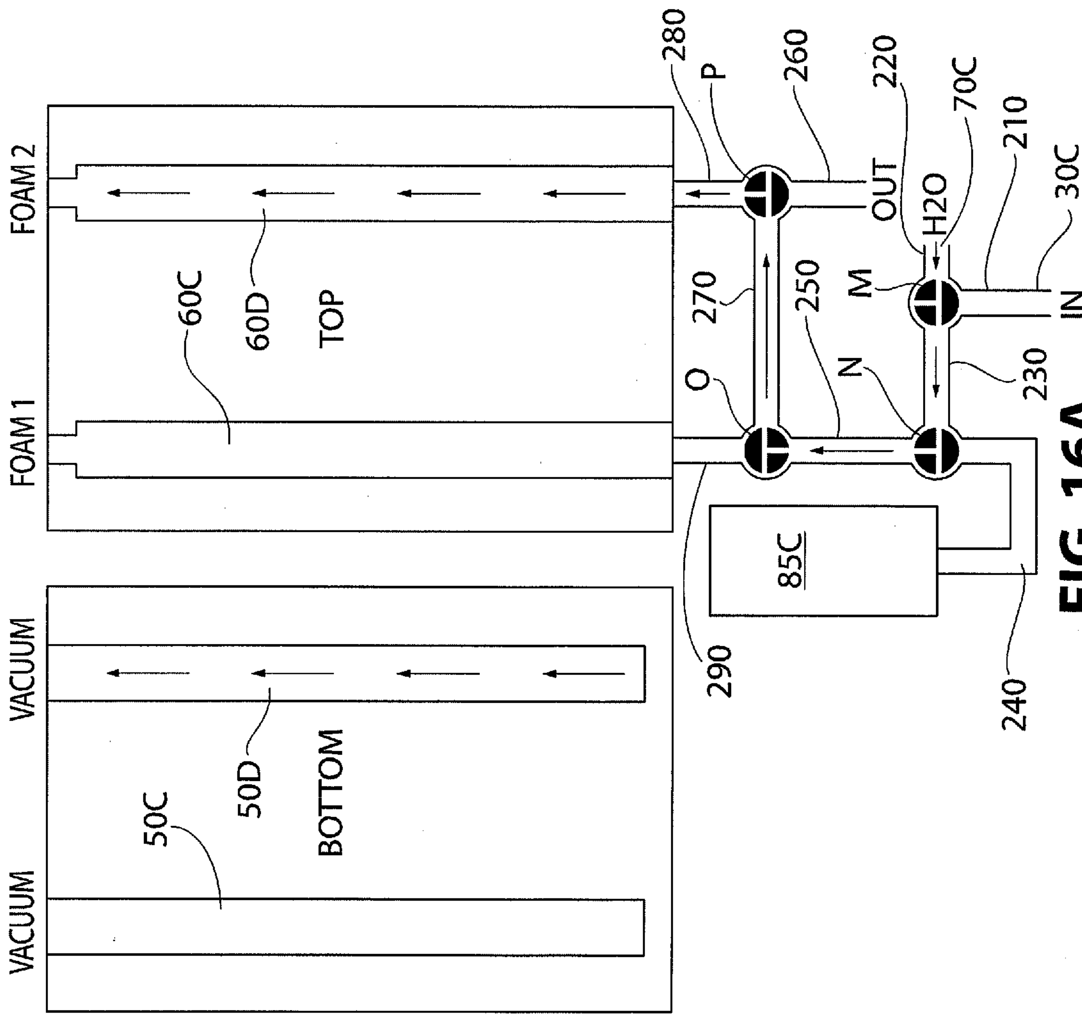


FIG. 16A

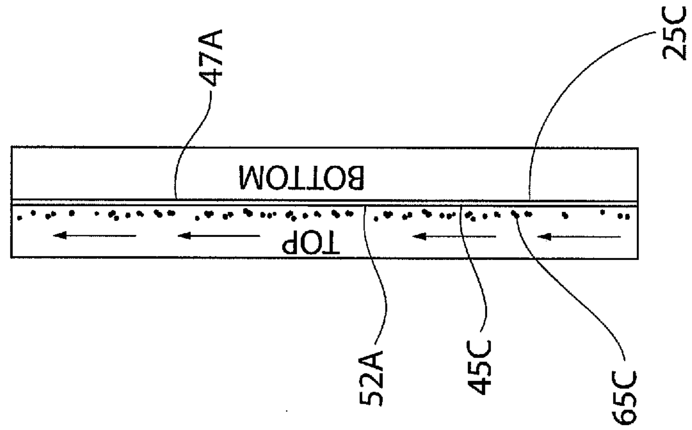


FIG. 17B

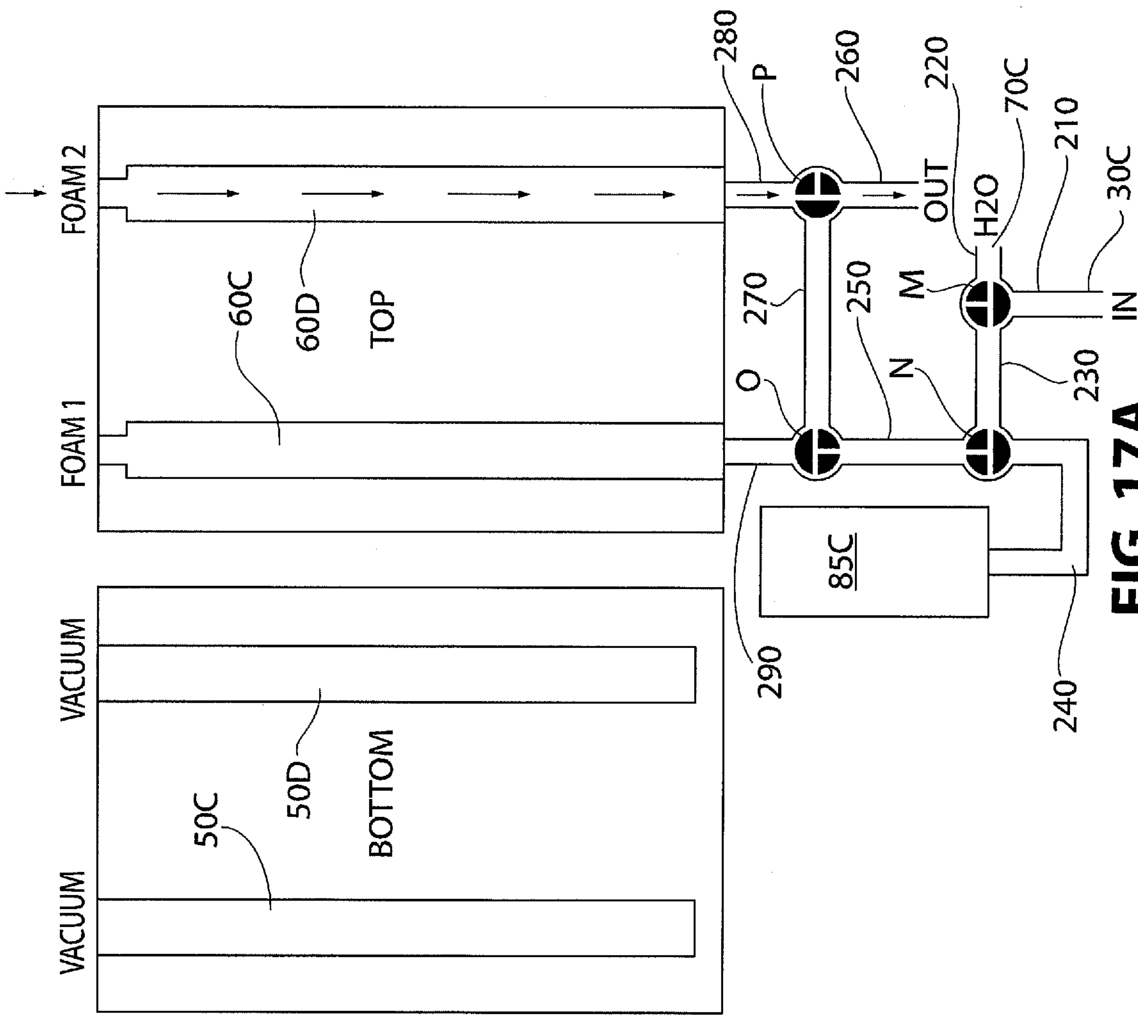


FIG. 17A

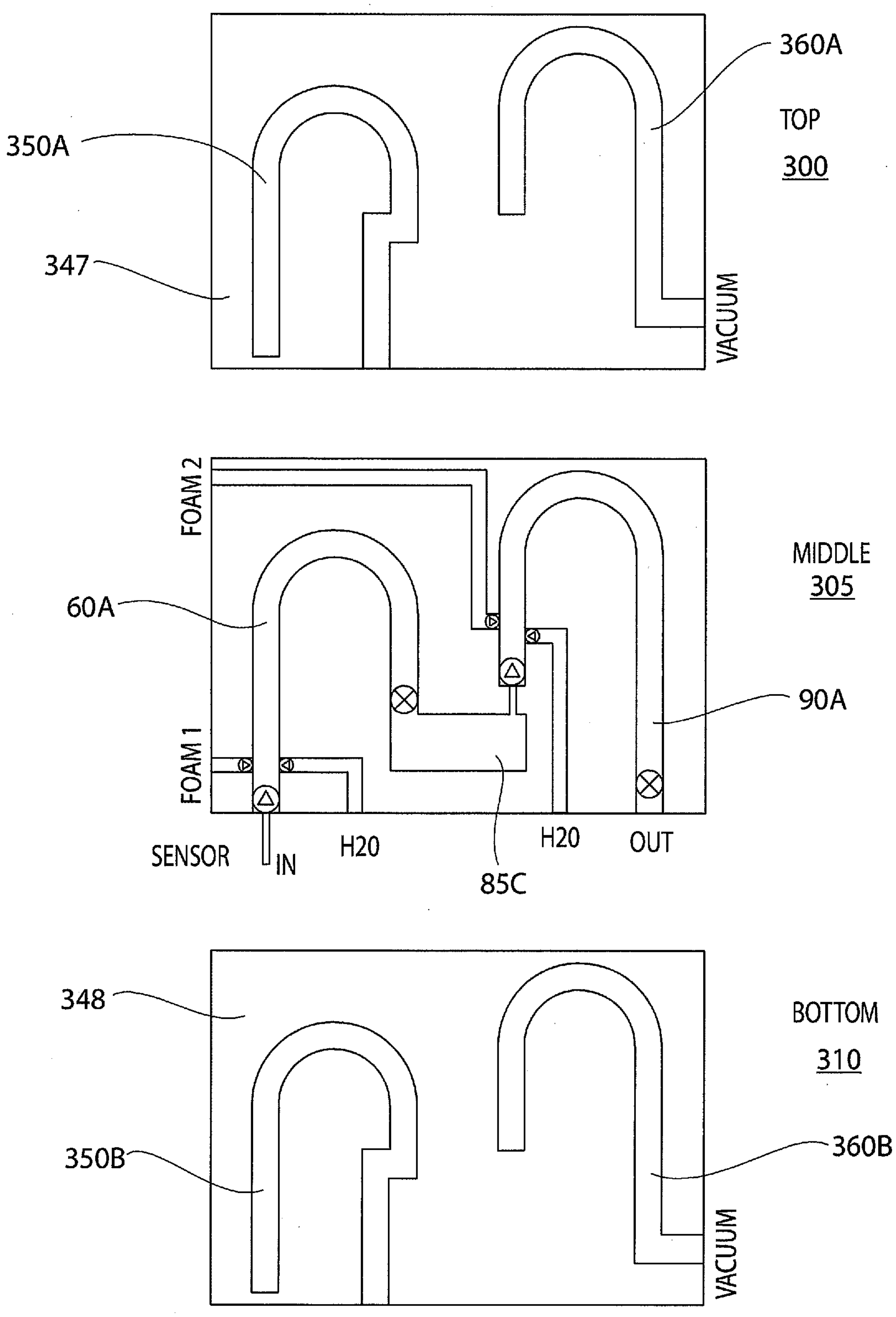

350A
360A
TOP
300
347
VACUUM
FOAM 2
MIDDLE
305
60A
90A
FOAM 1
SENSOR
IN
H20
85C
H20
OUT
348
BOTTOM
310
350B
360B
VACUUM

FIG. 18A

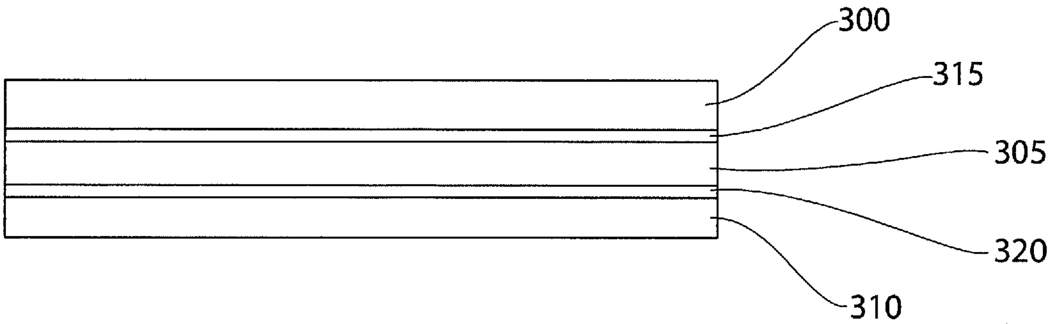


FIG. 18B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/014658

A. CLASSIFICATION OF SUBJECT MATTER

B01D 37/00(2006.01)i, B01D 29/01(2006.01)i, B01D 27/08(2006.01)i, B01D 35/30(2006.01)i, B01D 29/62(2006.01)i, B01D 29/88(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D 37/00; B01D 33/00; B01D 29/68; B01D 61/18; B01D 29/00; C02F 1/44; B01D 61/20; B01D 15/08; C02F 1/00; B01D 29/01; B01D 27/08; B01D 35/30; B01D 29/62; B01D 29/88

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords:filter element, fluid/particle mixture, separation, elution fluid

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 7695627 B2 (BOSCH, M. L. et al.) 13 April 2010 See abstract; column 12, line 44-column 13, line 64; claims 1, 35; and figure 1A.	1-12 13-37
A	US 2002-0030015 A1 (STIPANOVIC, B. et al.) 14 March 2002 See abstract; paragraphs [0039]-[0042]; claims 1, 19; and figure 2.	1-37
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