

FILTER FOR REMOVING SOLIDS FROM LIQUIDS

FIELD OF THE INVENTION

THIS INVENTION relates to filters for removing solids from liquids. The filter is particularly, but not exclusively, intended for the purpose of removing solids
5 from water in the purification of the water for drinking and other purposes such as for use as boiler water.

BACKGROUND TO THE INVENTION

Water which is, without treatment, usable for drinking, agricultural or industrial purposes is in extremely short supply. The sea, which constitutes the most
10 abundant source of water, carries a heavy load (30000 to 40000 parts per million) of dissolved solids. Depending on the particular geographic region it also carries a load of silt and/or sand in suspension. It must therefore be filtered and desalinated before it can be used for any purpose whatsoever.

Water from rivers, lakes and underground sources is usually
15 contaminated with dissolved solids and with solid material which is suspended or dispersed in the water. There can in addition be biological material requiring micro or ultra filtration to remove it.

The object of the present invention is to provide a filter which is an

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improvement over known filters.

BRIEF DESCRIPTION OF THE INVENTION

According to one aspect of the present invention there is provided a filter which comprises a casing having an inlet for water to be filtered, a first stage
5 filter within the casing for removing solid material from the water entering the casing and a second stage filter within the casing to which the water flows from the first stage filter, and which second stage filter includes reverse osmosis membranes for performing ultra filtration or micro filtration and/or for removing solids that are dissolved in the water.

10 In the preferred form said casing is of elongate form, said first and second stage filters being adjacent to one another in the direction of the length of said casing.

According to a further aspect of the present invention there is provided a filter comprising an elongate casing bounding an elongate space, an inlet to said
15 space for water to be purified, an outlet from said space for permeate water, an outlet from said space for brine, a first stage filter in said space for removing solids from the water which has entered said space through said inlet, a chamber forming part of said space and a second stage filter, the second stage filter including reverse osmosis membranes for performing ultra filtration or micro filtration and/or for
20 removing solids that are dissolved in the water, the first stage filter, the chamber and

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the membranes being positioned so that water flows in the direction of the length of the casing to pass through said first stage filter to said chamber and through the second stage filter to said outlets from the chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

5 For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a diagrammatic section through a filter in accordance with the present invention, Figure 1 also showing the piping connected to the filter;

10 Figure 2 is a front view of a disc of the filter of Figure 1, Figure 2 being to a larger scale than Figure 1;

Figure 3 is a section through the disc on the line III-III of Figure 2;

Figure 4 is a rear view of the disc;

Figure 5 is a view, to a larger scale than Figures 2 to 4, of a spiral flow guide;

15 Figure 6 is a section, to a greatly exaggerated scale, illustrating the manner in which a part of the filter operates;

Figure 7 is a pictorial view of a reverse osmosis cartridge;

Figure 8 is a section through a further form of filter;

Figure 9 is an end view of the filter of Figure 8;

20 Figure 10 is an "exploded" diagrammatic view of the filter of Figures 8 and 9;

Figure 11 is a pictorial view, to a larger scale, of part of the filter of Figures 8

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to 10;

Figure 12 is a section through another form of filter;

Figure 13 is an end view of the filter of Figure 12; and

Figure 14 is an "exploded" diagrammatic view of the filter of Figures 12 and

5 13.

DETAILED DESCRIPTION OF THE DRAWINGS

The filter shown in Figure 1 is designated 10 and comprises a plurality of porous pipes, the pipes being designated 12. Each pipe 12 has a hairpin bend 14 therein, and the ends of the pipes are attached to a disc 16 which fits in a cylindrical casing 18. Seals (not shown) are provided between the casing 18 and the disc 16, the seals fitting in the grooves 20 (see particularly Figure 3) which are formed in the outer periphery of the disc 16.

Opposite ends of the casing are closed by end caps 22 and 24 which are held in place by two part locking ring structures 26. The outer ring 28 of each locking ring structure 26 is embedded in the wall of the casing 18 when the casing is manufactured using glass fibre reinforcing and resin. The inner ring 30 is in the form of a removable split ring which is decreased in diameter before being inserted into the ring 28. The inner rings 30 can be removed by reducing their diameters and sliding them out of the casing 18 thereby to release the end caps.

20 O-rings (not shown) seal between the end caps 22 and 24 and the

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casing 18, the O-rings being in grooves 32 and 34 of the end caps 22 and 24.

The end cap 22 and the disc 16 define a chamber 36 which contains the pipes 12. A tube 38 extends through the end cap 22, across the chamber 36 and terminates in communication with a central bore 40 of the disc 16. A bore 42 passes through the end cap 22 and communicates with the chamber 36. A pump 44 is connected to the bore 42 by a pipe 46 and feeds the water to be filtered to the chamber 36 from a source 48. The pump 44 is also connected to a reservoir 50 of clean, filtered water. Valves 52, 54 enable filtered or raw water selectively to be pumped by the pump 44.

The disc 16 has bores 56 therethrough, each end of each pipe 12 communicating with a respective bore 56 and the pipes hanging in U-formation below the disc 16 in the chamber 36. The bores 56 are not arranged axially but at an angle (see Figures 2 to 4) so that water entering the conical vortex chamber designated 58 formed in the upper face of the disc 16 swirls in the chamber 58. As will be seen from Figures 2 and 4 the bores 56 are arranged in a spiral array.

A spiral flow guide 60 is integral with, or secured to, the disc 16 and is within the vortex chamber 58. The guide lies within the peripheral flange 62 that protrudes from the main body of the disc 16.

The chamber 58 constitutes one end portion of the space designated

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64 which is bounded by the disc 16 and the end cap 24.

Within the space 64 there is a hollow envelope 66 comprising two sheets of membrane material through which water can permeate. The two sheets are welded or otherwise secured together around their peripheries. Any type of membrane material can be used. For example ultra filtration membranes, micro
5 filtration membranes or reverse osmosis membranes can be employed. When the sheets are welded together two tubes 68 and 70 are welded in. The tube 68 extends from the envelope 66, through the walling of the casing 18 to a shut-off valve 72. The valve 72 is connected to a source 74 of air or water under pressure.

10 The tube 70 passes through a central bore 76 of the end cap 24, emerges from the casing 18 and is connected to a valve 78. A plurality of side-by-side envelopes 66 forming a pack can be provided. Spacers 80 inside the envelopes 66 and further spacers (not shown) between the envelopes 66 prevent
collapse of the envelopes in normal operation and also prevent excessive expansion
15 of the envelopes 66 when they are internally pressurized.

An outlet bore 82 for water containing any last remaining solids passes through the end cap 24. A pipe 84 leads from the bore 82 to a T-piece 86. The other pipes which connect to the T-piece are designated 88 and 90. The pipe 88 leads to a valve 92 and the pipe 90 to a valve 94.

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Between the valve 94 and the pump 44 there is a T-piece 96. A valve 98 is connected between the pipe 46 and the T-piece 96. A branch pipe 100 leads from the pipe 46 to a valve 102. The tube 38 is connected by a pipe 104 to a valve 106.

5 In use water containing solids that are to be filtered out is withdrawn from the source 48 by the pump 44 and fed under pressure to the chamber 36 via the T-piece 96, the valve 98 and the pipe 46. The pipes 12 filter out the bulk of the solids in the water as will be described hereinafter.

10 The water which penetrates the walls of the pipes 12 through the pores in the pipe walls enters their interiors, flows along the bores of the pipes 12, enters the bores 56 and then flows into the vortex chamber 58.

 The angle at which the bores 56 enter the vortex chamber 58, and the provision of the spiral guide 60, promotes swirling of the water in the vortex chamber 58 and in the part of the space 64 immediately above the vortex chamber 58.

15 The valve 106 is fully open at start-up and the pressure in the space 64 causes an initially strong water outflow through the central bore 40, tube 38 and pipe 104. This results in the creation of the vortex at the centre of the chamber 58.

 The bulk of the solids not filtered out by the pipes 12 enters the bore

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40. It will be understood that all the water that enters the bore 40 is flowing to waste. The flow rate through the valve 106 is thus adjusted after start up until the minimum outflow of water is obtained consistent with the continued existence of the vortex. By adjustment of this flow rate it is possible to achieve a flow pattern in which the so-called overflow vortex which normally exists co-axially with the main vortex is suppressed. Experimental work has shown that the main vortex extends a distance above the disc 16, steadily diminishing in strength and eventually becoming undetectable. Above the main vortex there is an upward flow of water but little or no overflow vortex capable of carrying particles upwardly with it.

The final stage in the filtering process takes place when the water permeates through the membrane material constituting the envelopes 66. Solid particles remain on the outside of the envelopes 66 and water which is substantially devoid of solid particles flows through the tube 70 to the valve 78 and then to a storage reservoir, water main or point of use.

The pressure at the outlet bore 76 of the filter 10 is monitored and, when a pressure loss of sufficient magnitude is detected, an automatic cleaning sequence is initiated.

The main part of the cleaning sequence involves closure of the valves 52, 98, 92 and 106 for a brief period and opening of the valves 54, 94 and 102 for a brief period. This results in clean water being drawn from the reservoir 50 and

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pumped by the pump 44 through the valve 94 to the space 64. The increase in pressure in the space 64 results in a commensurate increase in pressure in the pipes 12. The reverse flow through the pores of the pipes 12 cleans the pipes as will be described hereinafter. Cleaning of the pipes 12 is thus effected by temporarily
5 increasing their internal pressure above their external pressure.

The material dislodged from the outside of the pipes 12 exits from the chamber 36 via the bore 42, pipe 100 and valve 102.

The reverse flow of water causes the vortex in the chamber 58 to collapse. When the valves 52, 98, 92 and 106 re-open, and valves 54, 94 and 102
10 re-close, the valve 106 must be fully opened and then subsequently adjusted to re-establish the vortex.

Because clean water is being fed to the space 64, flow of water through the envelopes 66 is not interrupted during the cleaning procedure for the pipes 12.

15 To clean the envelopes 66, the valve 72 is opened briefly, typically for a second or less, and hence the envelopes 66 are inflated by air or water under pressure. Simultaneously the valve 78 is closed briefly. The external spacers between the envelopes 66 prevent them over inflating and bursting. The sudden expansion of the envelopes dislodges solid material which has adhered to the

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outside thereof and the general flow from the space 64 to the bore 82 carries away the dislodged solid material which exits through the valve 92.

It will be understood that there is a tube 68 and a tube 70 for each envelope 66. The tubes 68 and 70 lead to common manifolds.

5 The pipes 12 are of rubber, a rubber compound or a synthetic plastics material which has a surface to which the solid material will not adhere strongly. The type of surface required can be compared to that of a motor vehicle tyre. Whilst mud will adhere to the tyre, the bond is not strong and the mud can, if dry, easily be knocked off or, if wet, can easily be washed off.

10 Each pipe 12 has therein a plurality of pores which extend from the outer surface of the pipe to the inner surface of the pipe. One such pore, designated 108, is shown in Figure 6. The pore 108 is, at the external surface of the pipe, wider than at the internal surface of the pipe. Preferably the diameter at the outer end of the pore is in the region of five microns and at the inner end of the pore is of the
15 order of one micron or two microns. The pipe wall thickness is about 15mm.

Grains of solid material, designated 110 in Figure 3, lodge in the pores 108 and, within a short period of time after start up (from a few seconds to a few minutes), each pore 108 has therein a mass of grains which act as a filter allowing water to permeate into the hollow interior of the pipe 12 but preventing other solid

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material from passing through. It will be understood that as the water passes through the filter constituted by the grains in each pore 108, the solid material that was entrained therein is deposited onto the outer surface of the pipe 12. This accumulation of solid material is designated 112 in Figure 6. When flow in the reverse direction through the pores 108 occurs as described the accumulations of solid material are swept away.

It has also been found that the pressure drop across each pore 108 should not be excessive. If the pressure drop is excessive the grains 110 in the pores 108 and the solids accumulation 112 are sucked into the pores 108 with such force that it becomes difficult to dislodge the accumulation 112 of material. The pores 108 are thus blocked and flow through the filter from the pipe 46, through the pores 108 in the pipes 12 to the hollow interiors of the pipes and thence to the vortex chamber 58 drops significantly.

The envelopes 66 can be replaced by a spirally wound membrane, for example, a reverse osmosis membrane in the form of a cartridge 114 as shown in Figure 7. Such a filter will be described in more detail with reference to Figures 12, 13 and 14.

The cartridge 114 comprises a central pipe 116 around which reverse osmosis packages 118 each comprising two sheets 120, 122 of complex polymer and an intervening spacer 124 are wound. The pipe 116 has holes 126 in it, the

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holes being in rows extending along the pipe. Water in the permeate passages designated 128 enters the pipe 116 through these holes. The salt retention passages are designated 130.

Two sheets 120 and 122 are welded together around three of their
5 edges to form each package 118. The fourth edges are not welded together but secured by adhesive to the pipe 116 on opposite sides of a row of holes 126 in the pipe 116. Thus each row of holes 126 is in communication with the permeate passage 128 of a respective package.

In Figure 7, simply for illustrative purposes, the membrane sheets 120
10 and 122 of the top package 118 are shown separated so that the spacer 124 can be seen. The other packages 118 are shown as having the edges of the sheets 120 and 122 welded together so that the spacer 124 is concealed.

The number of packages 118 used depends on the number of rows of
holes 126 because each package must be positioned so that its permeate passage
15 128 communicates with a respective row of holes.

Once wound onto the pipe 116, the membrane sheets 120 and 122 of each package 118 are in face-to-face contact with the sheets 120 and 122 of the adjacent packages 118.

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Once all the packages 118 have had the inner edges of their sheets 120 and 122 adhered to the pipe 116, the packages are wound tightly around the pipe 116 and then taped to prevent them unwinding. An outer sleeve (not shown) is then provided to prevent the packages 118 bursting when pressure is applied to the sheets 120 and 122 upon feed water being introduced into the cartridge 114. The outer sleeve fits into the casing 18.

It will be understood that the passages 130 are open at both axial ends of the wound cartridge.

The cartridge is used in conjunction with two end caps designated 132 and 134. The end cap 132 comprises a disc 136 and a flange 138 which extends around the periphery of the disc 136. The cap 132 is at the end of the cartridge from which the brine stream emerges. The disc 136 has in it a central hole 140 which registers with the pipe 116 and a plurality of holes 142 through which the brine stream flows. There is a gap of, for example, two to four centimetres between the end of the cartridge and the disc 136. The function of the end cap 132 is to cause a back pressure immediately adjacent the exit ends of the brine passages. The axes of the holes 140, 142 are parallel to the axis of the pipe 116.

The end cap 134 is at the inlet end of the cartridge. It comprises a disc 144 having a central hole 146 which registers with the pipe 116 and a plurality of holes 148 between the hole 146 and a peripheral flange 150 that extends around

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the periphery of the disc 144. The disc 144 can be against the end of the cartridge or up to four centimetres from the cartridge.

The axes of the holes 148 are not parallel to the axis of the pipe 116

but are at an angle to it. This results in the discrete streams of water which pass
5 through the holes 148 and impinge on the end of the cartridge 114 doing so at an angle and not along paths parallel to the pipe 116. The orientation of the holes is such that the streams swirl in the same direction as the packages are wound.

It will be understood that the cartridge 114 is positioned with the end
cap 134 adjacent the disc 16 and the end cap 132 at the other end of the casing 18
10 adjacent the end cap 24.

Turning now to Figures 8 to 11 this illustrates a filter 152 which
comprises a casing 154 in which there is a membrane cartridge 114 of the type
described with reference to Figure 7 and a pre-filter designated 156. The prefilter
156 comprises three cylinders 158 including walls of mesh screening material. The
15 cylinders 158 are in a chamber 160. The inlet to the chamber 160 is designated
162. The water flows through the walls of the mesh cylinders 158 into the interiors
of the cylinders and from the interiors of the cylinders 158 to a further chamber 164
via bores 166. The chamber 164 is bounded on one side by a disc 168 on which the

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cylinders 158 are mounted and in which the bores 166 are formed and on the other side by the end cap 134 of the cartridge 114.

The brine outlet from the cartridge 114 is designated 170 and the permeated water outlet is designated 172, these being in an end cap 174.

5 The cartridge 114 and disc 168 are held in place by spacers designated 176, 178 and 180. The inlet 162 is in an end cap 182, there being ring structures 184 and 186 for holding the end cap 182 and the end cap 174 in place.

Piping generally designated 188 connects the interiors of the cylinders 158 to an outlet 190 in the end cap 182. A waste pipe 192 leads from the chamber
10 164 through the end cap 182 to waste.

During normal operation water with solids entrained in it enters the filter through the inlet 162, flows through the mesh cylinders 158, through the bores 166, across the chamber 164 and thence into the salt retention passages of the cartridge 114. Permeate emerges through the outlet 172 and brine emerges
15 through the outlet 170.

To clean the filter, water under pressure is supplied to the outlet 172, the water flowing from the permeate passages through the membranes to the salt retention passages. On emerging from the salt retention passages into the chamber

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164, some of the water can flow to waste through the pipe 192.

The remainder of the water flows through the bores 166 into the cylinders 158. A portion of the water entering the cylinders 158 flows through the mesh to clean the outside surfaces of the cylinders. The remainder of the water
5 flows through the piping 188 to the outlet 190 carrying with it solid material which had previously passed through the mesh of the cylinders 158.

The piping shown in Figure 1 is modified to enable a cartridge to be cleaned by removing the tube 68 and connecting the valve 72 and water source 74 directly to the bore 76. The valve 78 is closed whilst membrane cleaning takes
10 place.

Turning finally to Figures 12, 13 and 14 this illustrates a filter similar to that shown in Figure 1 but which has a cartridge 114 in place of the envelopes 66. Furthermore it is similar in construction to the filter of Figures 8 to 11 but in place of the mesh cylinders 158 it has pipes 12 as described with reference to Figure 1.

15 The end cap 134 of Figure 14 is shown as having a pattern of holes that differs from that shown in Figure 10. Otherwise, where applicable, like reference numerals have been used in Figures 12, 13 and 14 on the one hand and 8 to 11 on the other hand.

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The filter of Figures 12 to 14 is cleaned in the same way as described above in relation to the filter of Figures 8 to 11.

Filters which include the vortex chamber 58 are operated in a vertical position as shown in Figures 1 and 12. The filter of Figures 12 to 14 hence has to
5 be operated in a vertical position. The filter of Figures 8 to 11 can be operated horizontally.

The pipes 12 can remove all solids above twelve microns in size. The filter cylinders 158, depending on the mesh used, remove all solids above about 20
10 micron. The type of prefilter selected depends on the solids load of the feed water and the desired final water quality.

It is possible, in place of the hoses 12 and the cylinders 158, to use a disc filter, preferably a self cleaning disc filter, or any other type of filter which will
remove solid material down to the requisite size before the water flows to the
cartridge 114 or envelopes 66 for ultra or micro filtration or for the removal of
15 dissolved solids.

If small balls of a rubber-like material are placed in the chamber 160, these are displaced by the flowing water and tend to "bounce" around in the chamber keeping the solids in suspension and thus assisting in preventing clogging
of the filter.

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It is also possible to clean membranes by suddenly closing a valve in the permeated water pipe. The shock wave passing in the reverse direction shakes loose solids in the salt retention passages. A similar effect can be obtained by feeding air under pressure into the permeate water pipe.

- 5 It is also possible to provide electrical coils around the cartridge 114 as described in the specification of PCT application PCT/GB98/0054 (WO 98/30501) for the purpose of enhancing the performance of the cartridge. In Figures 8 and 12 the coils are designated 194, 196 and 198. They are embedded in the walls of the casing as the casing is fabricated.

**CLAIMS:**

1. A filter which comprises a casing having an inlet for water to be filtered, a first stage filter within the casing for removing solid material from the water entering the casing and a second stage filter within the casing to which the water
5 flows from the first stage filter, and which second stage filter includes reverse osmosis membranes for performing ultra filtration or micro filtration and/or for removing solids that are dissolved in the water.

2. A filter according to claim 1, wherein said casing is of elongate form, said first and second stage filters being adjacent to one another in the direction of
10 the length of said casing.

3. A filter according to claim 1, wherein said casing is vertical and there is an inlet at the lower end of the casing for feeding water to be purified into an inlet chamber with the casing, a disc forming part of said first stage filter and constituting the upper end of said chamber, a plurality of bores in said disc, a vortex chamber in
15 the upper face of said disc, the vortex chamber having the shape of an inverted cone, the plurality of bores passing through said disc and entering said vortex chamber, the bores being so orientated that water flowing into said vortex chamber from the bores swirls in said chamber, an exit from said vortex chamber passing downwardly through said disc from the apex of said vortex chamber, and a plurality
20 of pipes with porous walls in said chamber, the interiors of said pipes being in



communication with said bores.

4. A filter according to claim 3, wherein said bores open into said vortex chamber in a spiral array.
5. A filter according to claim 3 or 4, and including a spiral guide in said vortex chamber for promoting spiral flow of water in said vortex chamber.
6. A filter according to claim 3 or 4, wherein each pipe has each of its ends in communication with a respective one of said bores, each pipe hanging in said inlet chamber in a U-shape.
7. A filter according to claim 1, 2, 3 or 4, wherein said first stage filter is constituted by a filter comprising a plurality of filter elements which are pressed together and which define filter passages therebetween.
8. A filter according to claim 1, 2, 3 or 4, wherein said first stage filter comprises a plurality of screens through which the water flows, the screens retaining the solid material thereon.
9. A filter according to claim 1, wherein said second stage filter comprises a plurality of closed envelopes of reverse osmosis membrane in a second stage chamber to which water flows from the first stage filter, a permeated water outlet



from the interior of each envelope, means for feeding fluid under pressure to said envelopes thereby temporarily to inflate the envelopes, and an outlet from said second stage chamber for water with solids therein which have been separated out from the permeate water.

- 5 10. A filter according to claim 1, wherein said second stage filter comprises reverse osmosis membranes wound around a permeate water pipe, the wound membranes being in a second stage chamber to which the water flows from the first stage filter, there being means for feeding clean water under pressure into said permeate pipe for backwashing the membranes.
- 10 11. A filter according to claim 1, wherein said first stage filter comprises a plurality of compartments having walls of screening material, said compartments being in an inlet chamber of the filter, a first outlet from each compartment leading to said second stage filter, a second outlet from each compartment, there being a normally closed valve in said second outlet and means for feeding water through
- 15 said screening material from inside the compartment to said inlet chamber thereby to clean said screening material and for feeding water through said compartments to said second outlet whilst said normally closed valve is open.
12. A filter comprising an elongate casing bounding an elongate space, an inlet to said space for water to be purified, an outlet from said space for permeate
- 20 water, an outlet from said space for brine, a first stage filter in said space for



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removing solids from the water which has entered said space through said inlet, a chamber forming part of said space and a second stage filter, the second stage filter including reverse osmosis membranes for performing ultra filtration or micro filtration and/or for removing solids that are dissolved in the water, the first stage filter, the

5 chamber and the membranes being positioned so that water flows in the direction of the length of the casing to pass through said first stage filter to said chamber and through the second stage filter to said outlets from the chamber.