

Apparatus for Purification of LiquidsBACKGROUND OF THE INVENTION

This invention relates to apparatus for the purification of aqueous liquids, in particular where the purification treatment requires the liquid for purification to be passed through a plurality of treatment stages, each of which comprises a bed of particulate material.

Such treatment stages include for example beds of particulate material such as sand, garnet, carbon or anthracite for filtration, ion exchange resin for removal of anionic and/or cationic impurities or hardness removal, manganese green sand for iron removal and beds of particulate material for taste, odour, acid or colour correction. The description below is directed to ion exchange processes. However, the present invention may also be used in other purification treatments where liquid is passed through a bed or beds of particulate materials not containing ion exchange resins.

A process of conducting ion exchange on an aqueous liquid consists of a service cycle in which aqueous liquid for purification is passed through a bed, or several sequentially arranged beds of different types of ion exchange materials, to produce a product liquid having the desired characteristics. The service cycle is followed by a regenerating cycle, in which the ion exchange resin is regenerated, prior to the ion exchange material becoming exhausted and thus prior to the ion exchange becoming inadequate. For a deionising apparatus regeneration is by flow through the bed of acid or alkali, for cation or anion exchange resins respectively. A water softener exchanges scale-forming ions such as calcium and magnesium ions with non-scale forming ions, and regeneration is usually by using solutions of salts of such ions.

For many types of apparatus regeneration is carried out by flow of regenerating liquid in the same direction through the bed as the service flow. This is termed co-flow regeneration. Thus, the flow may be upwards or

downwards through the beds of treatment material. Co-flow regeneration is adequate for water-softening.

For some apparatus it is advantageous for regeneration to be conducted counterflow, that is with the regenerant liquid being passed through the bed in the opposite direction to the service flow. This is particularly advantageous for some deionising apparatus, particularly the type of apparatus sold by the applicant company under the name "Scion" (trademark) in which the rate of flow of liquids through the bed is higher than most other apparatus of this type and the cycle frequency is higher. In such apparatus improved regeneration is achieved since the resin at different points in the bed contacts regenerant liquid having a different, optimum composition.

15 PRIOR ART

In various known processes, often the different beds of purification material are carried in separate tanks which employ individual beds. Conventionally, each tank may be operated independently of the other.

20 To reduce apparatus costs and improve efficiency, there have also been various attempts at mixing the various purification materials and inserting them into a single tank. However, apparatuses which contain such mixed treatment material have various disadvantages. In particular some materials need to be replenished more often than others or regenerated more often than others and once mixed, the materials cannot be selectively replaced.

It has also been proposed to separate compartments within a single tank. In ion exchange processes it is known that to achieve the best results the resin beads should remain substantially fixed within the bed. However, the volume of the purification materials used may vary. For example, it is known that some ion exchange resins expand or contract, depending upon their level of ionisation, as they remove impurities from the liquid which is being purified. Likewise, for particulate filters, in order to drive out particulate impurities, such beds need

to be backwashed and this requires sufficient space to allow sufficient expansion of the bed for backwash. Therefore in order to have a satisfactory apparatus having more than one bed in a single vessel some flexibility in the size of the separate compartments is required.

In US 3554377, a movable filter-diaphragm for use as a separator between beds in a single tank multi-layer apparatus for purification of liquids is disclosed. The filter-diaphragms are also intended to effect a pre-filtration of a liquid before entry into the respective bed of treatment material.

The filter diaphragms disclosed in this reference are free to slide along the inner walls of the receptacle in which the materials are held, to permit compaction of the bed in response to pressure of liquid or to permit expansion of the beds during regeneration or backwash, whilst still keeping the beds of different filter materials separate from one another. One filter-diaphragm disclosed in this reference comprises a layer of an inert fabric material such as woven plastic with a sufficiently small pore size to provide a filtering function and having an annular ring or rim of elastomeric material with diverging flanges to engage with the internal sides of the container.

However because these filter-diaphragms also provide a filter function, a higher pressure differential will be formed between sequential beds so that the flow rates of liquid through the bed will be reduced per unit of energy to drive the liquid through the apparatus. In addition, a large pressure drop will occur in the centre of the beds of filtering material and therefore liquid will tend to flow along the inner walls of the column and unless there is a perfect seal at the outer edges of the diaphragm, liquid will flow around the edges of the diaphragm and intermixing of neighbouring beds will occur and tend to block with impurities or particulate purification material. Because of the high pressure differential such separators may tend to deform and therefore, they may be unable to provide

satisfactory separation between two beds in addition to satisfactory slidable movement up and down the internal walls of the column.

One other filter-diaphragm disclosed in this reference
5 comprises a disc of plastic foam. However, the pores of these types of separators tend to block irreversibly with ion exchange or other purification material. In addition, for such foam separators to be effective, cutting must be extremely accurate but even then, such separators are not
10 satisfactory if the internal cross section of the column is irregular. Particulate material may escape around the outer edges of such a separator. This is particularly a problem when plastic columns are to be used as the interiors of plastic vessels tend to be somewhat irregular
15 so that leakage of particulate material may occur.

Also, in deionisation processes, the regenerants used may be strong acid or strong alkali. On exposure to such harsh conditions, foam materials tend to become brittle and may eventually lose their resilience.

20 One other known movable separator is known as a "rolling diaphragm". In a purification column which includes a rolling diaphragm, a sheet of a porous material having a diameter greater than the horizontal cross-sectional area inside the column is arranged between two
25 separate beds. This type of separator is fixed around its perimeter to the internal wall at a fixed height within the column. Such a rolling diaphragm may be subject to a large pressure differential and in addition because the diaphragm rolls upwardly or downwardly past its fixed position in the
30 column it is subject to a large amount of wear and tear and is liable to break.

SUMMARY OF THE PRESENT INVENTION

The present invention aims to overcome the problems of the known devices and in addition to provide a useful
35 separator which can be inserted into the pre-formed plastic columns conventionally used today. These moulded columns have a relatively small entry port having a diameter

considerably less than the internal diameter of the column.

The present invention aims to provide a separator which can effectively separate two beds but in addition can move within a column overcoming the problems of the prior art and which can easily be inserted into a pre-formed column having an entry port smaller than the cross-sectional area of the interior of the column in which it is to be used.

According to a first aspect of the present invention there is provided a movable separator for use in a liquid purification column, the separator comprising a flexible porous container, containing solid particulate separator material which exerts pressure on the container so that in use in the column, slidable contact of the container against the internal walls of the column is effected, the container where it contacts the internal walls of the column, comprising resilient material.

The flexible, porous container comprises an inert fabric material, generally comprising woven or more preferably moulded plastic mesh. This material should be substantially unaffected by contact with the regenerating liquids to be used in a water purification process, and preferably comprises polyethylene, polypropylene, PVC, PVDC or polyamide. The most preferred material is Tygan Cloth or SARAN (trademark of Courtaulds). SARAN comprises PVDC fibres with a 2/2 twill weave, an air space between the fibres of 26.3% and pore size 181/567 μ m. Preferably, the material does not form any filtering function for particulate impurities as this causes too large a pressure drop across the separator which is undesirable. Most preferably, the material provides substantially no resistance to flow therethrough. Thus, the pore size of the pores in the porous material may be any size appropriate to enable the container to contain the solid particulate material i.e. to prevent the particulate material from falling through the pores. Generally the pore size of the material is at least 50 μ m or even at least 100 μ m.

Generally the pore size of the porous material is no greater than 10mm and preferably no greater than 5mm.

In use, the particulate separator material inside the container exerts pressure on the side portions of the container to ensure close contact between the container and the internal walls of the column, and hence effective separation between the beds. The contact is slidable contact such that the separator is free to move upwardly and downwardly within the column.

The container where it contacts the internal walls of the column in use, may be formed from solid flexible material, but it is especially preferred that the portions of the container which are in slidable contact with the internal walls of the purification column are porous. This ensures that in use the pressure drop towards the centre of the column is kept to a minimum and more uniform fluid flow through the column results.

The contact of the movable separator with the internal walls of the purification column should be such that the separator is freely slidable up and down the inside of the column but is sufficiently close to substantially prevent the passage of particulate material from a lower bed below the separator to an upper bed above the separator and/or vice versa. Preferably, in use in the purification column the sliding fit of the movable separator inside the column should also restrict flow of liquid between the movable separator and the internal walls of the column. Thus contact of the container with the internal walls of the column is around at least part of the internal perimeter of the column, preferably with at least 40% of the perimeter, most preferably at least 60% or even at least 90% of the internal perimeter of the column, without resulting in a pressure drop towards the middle of the column. Most preferably contact of the container with the internal walls is around substantially the whole internal perimeter of the column.

The container should be sufficiently large that the desired volume of particulate material can be held within the container.

The container of the movable separator of the present invention comprises a flexible material such that it can be deformed to be inserted into a purification column through a small entry port. Particularly when it is an open container, the container is advantageously substantially resilient such that it substantially regains its shape once inside the column. However, if it is not wholly resilient, the shape of the container can be arranged by inserting a rod through a port of the column. This is particularly important for open containers as these may be placed in the column empty, and the particulate separator material may be introduced subsequently by pouring through the entry port of the column. Thus, particularly if the container is open, preferably it is substantially resilient. However, if necessary after insertion into the column a rod may be introduced through a port in the column to lift the side portions of the container and open the container ready for receiving the particulate separator material.

Alternatively, the container may be a closed container such as a porous bag of any shape, which is partially filled with particulate material prior to insertion into the column. The bag is formed from flexible material and its flexibility and the fact that it is only partially filled and/or formed from elastic material, together enable the bag to be inserted through a port having a smaller diameter than that of the column, even though it already contains the particulate separator material. After insertion through the port the container will then lie on top of a lower bed of particulate purification material already in the column, the particulate separator material inside the bag ensuring that the container of the separator covers substantially the whole horizontal cross-sectional area of the column, and being in slidable contact with the internal sides of the column preferably substantially

wholly around its perimeter. In this embodiment the part of the bag which contacts the surface of the bed of particulate purification material in use forms a base portion for the container and the parts of the bag which
5 contact the internal walls of the column in use, form side portions.

The pressure exerted by the solid particulate separator material in the container enables the flexible container to have slidable contact with the internal walls
10 of the column even though the internal diameter and shape of the column may be irregular.

When the container is an open container, it may comprise a base portion and side portions, the side portions extending upwardly from the base portion to form
15 a container. In this case, in use the side portions contact the internal walls of the column. The side portions may extend above the desired bed depth of particulate material to no detrimental affect. Generally the side portions will extend upwardly from the base
20 portion at least 5 cm and no greater than 40 cm.

The side portions may provide a larger circumference to the container than the internal circumference of the column or may extend upwardly and outwardly from the base portion to enable the container to have adaptable
25 circumference depending on the internal surface of the column, or the side portions may be elastic.

It is particularly preferred that the material of the side portions should be substantially deformable so that the container may expand slightly (in particular where it
30 contacts the internal walls of the column) due to the pressure of the particulate material if the internal walls of the purification columns are slightly irregular. For example, Tygan Cloth and SARAN, each as mentioned above have a degree of deformability in the diagonal direction
35 but the original shape can be regained. Thus where Tygan Cloth or SARAN is used to form an open container having a base portion and side portions, preferably the side

portions are formed so that the Tygan Cloth or SARAN is cross-cut, the upwardly extending walls having the plastic strands of Tygan Cloth positioned diagonally, enabling outward expansion and inward contraction of the side portions of the container. When the container is open, the shape and dimensions of the base portion of the porous material preferably tend towards substantially the shape and dimensions of the internal horizontal cross-section of the column in which it is to be used. However, the shape may vary, for example, if the side portions extending upwardly from the base portion have sufficient elasticity to enable them to have slidable contact with the internal side walls of the purification column, or if they extend upwardly and outwardly from the base portion as described above. Preferably however, the shape and dimensions of the base portion of the porous material are substantially the same as the internal horizontal cross-sectional shape and dimensions of the purification column in use. Generally such columns are cylindrical and therefore the base portion will be substantially circular.

In this case a similarly shaped top portion may be provided to form a closed container.

The container may also comprise a reinforcing material to promote its resilience. In particular where the container is open and comprises a base portion and side portions, it may have a reinforcing rim for example at the periphery of the base portion and/or the upper (open) end of side portions. Alternatively, reinforcing strips may be substantially horizontal on a container in use. Such reinforcement may comprise for example a rubbery or similar elastomeric material.

The particulate separator material held in the container may be any particulate material optionally comprising mixtures of different particulate materials and in any amount which will exert sufficient pressure to enable slidable contact of the side portions of the porous container with the internal walls of the purification

column. Generally the average diameter of the particulate material will be at least 0.5mm, preferably at least 1mm or even 1.5mm. Generally the average diameter of the particulate material will be no greater than 50mm, preferably no greater than 25mm and most preferably no greater than 10mm. If it is desired to increase the weight of the separator, weights may be added to the container.

Preferably the distribution of the particle size of the particulate material will be as low as possible so that the particles are relatively uniformly sized to ensure substantially consistent resistance to flow of liquid through the bed of particulate material. Preferably at least 50% of the particles have a diameter with up to 30% or most preferably no greater than 10% variance. Suitable materials are for example gravel or metal particles such as ball bearings. Mixtures of different particulate materials may be used. The particle size of the particulate material may be arranged substantially graded (for example in layers) such that in use the particulate material closest to the liquid purification material has a smaller particle size than that in a layer in the centre of the container. This helps to prevent passage of purification material into the movable separator.

Gravel or pebbles are a particularly preferred suitable particulate material for use in the separator of the invention. However, if the aqueous liquid purification process requires strong alkali to be passed through the movable separator, it is preferred that the pebbles or gravel should be coated for example with polymeric coating to increase their chemical resistance.

Preferably the particulate material in the container has a density greater than the density of the particulate purification material generally ion exchange material in the bed below the separator container. Preferably the density will be greater than 1 g/cm^3 , more preferably 2 g/cm^3 and most preferably 5 g/cm^3 , or even above 10 g/cm^3 .

The amount and density of the particulate separator material are also dependent upon the pressure required to be exerted on the lower bed in the column.

5 The depth of the particulate separator material is such as to form a bed of particulate material in the container. The bed depth of particulate material will generally be at least 3 cm, preferably at least 5 cm. Any depth of particulate material may be provided, depending upon the height of the purification column and the bed
10 depth of active purification material, generally ion exchange resin, which is required. For example the particulate material in the container may be up to 20cm or even 30 cm deep.

The invention is particularly advantageous because the
15 density and amount of particulate material in the container of porous material can be selected to form a heavy layer. Thus when positioned above a bed of ion exchange resin in a column, a movable separator of the invention can enable free space to be provided in the column but in addition can
20 effectively fix the bed so that it must remain substantially stable and cannot mix. It has been found that during a service cycle, improved performance can be obtained using ion exchange resin when the resin is held substantially stable and movement is limited.

25 The invention is particularly useful in a counterflow regeneration apparatus and process. It is well known that for optimum performance when using counterflow regeneration techniques, there should be no mixing of the resin beads during any stages of the operational cycle. The advantages
30 of counterflow deionisation processes are also well known and the success of such processes is highly dependent on the presence of an efficient regeneration step. Therefore, the separators of the present invention can be used to give enhanced stability to a bed during the regeneration and
35 service steps and increase the efficiency of the bed, whilst permitting expansion and contraction of the bed during the operational cycle.

The density and amount of particulate material in the movable separator can easily be adapted to suit the particular application. Thus for example where the regeneration step comprises upward flow, for a higher flow rate of regenerant, the container can be arranged to contain a heavier or more dense bed of particulate material or a greater volume of particulate separator material, to ensure stability of the bed and still allow a degree of expansion of the ion exchange resin bed.

According to a second aspect of the invention, a movable separator is provided for use in a liquid purification column, the separator comprising a flexible porous container, containing solid particulate separator material which exerts pressure on the container, beneath which is positioned a layer of substantially inert material having a density below 1g/cm^3 and in use, in the column, slidable contact of the separator against the internal walls of the column is effected.

It is not essential that the container, where it contacts the internal walls of the column is porous. Thus, for example the container may comprise a base and side portions as described above, but in which the side portions are formed from non-porous, flexible and/or elastic material such as a rubbery plastic. The use of a layer of inert material beneath the container ensures that in use, the pressure of liquid flowing through the movable separator does not become so great at the internal walls of the column that purification material is carried past the sides of the separator. Mixing of neighbouring beds of liquid purification material is therefore prevented.

The present invention also includes an apparatus for purification of liquid, the apparatus comprising a liquid purification column, the column comprising in sequence a lower bed of liquid purification material, a movable separator and above the movable separator, an upper bed of liquid purification material. The movable separator is as described above. A plurality of beds of liquid

purification material may also be provided in the column, optionally, each being separated from the neighbouring bed by a movable separator as defined above. Preferably the apparatus is an aqueous liquid purification apparatus.

5 Preferably the liquid purification materials comprise ion exchange resin.

In accordance with a further aspect of the present invention, there is provided an apparatus for purification of liquid, the apparatus comprising a liquid purification

10 column, the column comprising in sequence a lower bed of liquid purification material, a movable separator and an upper bed of liquid purification material, the movable separator comprising a flexible, porous container containing solid particulate separator material which

15 exerts pressure on the porous container, beneath which is positioned a layer of substantially inert material having a density lower than the liquid purification material of the lower bed and lower than 1g/cm^3 and in use in the column, slidable contact of the container against the

20 internal walls of the column is effected.

The invention also includes a process in which water for purification is passed through the apparatus described above, in a service cycle, and in a regenerating cycle, regenerant liquid is passed through the apparatus.

25 In this case, the amount and density of the particulate separator material may be sufficient to substantially hold down the inert beads to result in a substantially floating separator, when liquid for purification is passed through the column.

30 The density of the substantially inert material must be lower than the density of the particulate liquid purification material in the lower bed and is generally less than that of water, for example below 1g/cm^3 and preferably below 0.9g/cm^3 or even 0.8g/cm^3 . The use of a

35 combination of low density particulate material beneath the movable separator ensures ease of adjusting the loading of pressure exerted by the movable separator as not only can



the amount and density of the particulate separator material be adjusted, but in addition the amount and density of the low density particulate material can also be adjusted. Generally, the low density material comprises
5 inert resin beads but any particulate material having a density below that of the water purification material in the lower bed (that is, below the movable separator) may be used such as hollow spheres or chopped low density plastic. The low density material may be arranged loose as a bed or
10 inside a porous divider such as a further porous container as described above.

Where the particulate separator material is large and the pores in the container do not prevent carry-through of ion exchange resin from the ion exchange resin beds above
15 and below the separator, when positioned in the column, the apparatus may be used in conjunction with a bed of inert exchange resin material on one or both sides of the container. This ensures that any carrythrough of resin is inert so that the ion exchange beds remain substantially
20 stable and immobile.

The separator of the invention may optionally be provided with a honeycomb layer on one or both sides of the container, especially where inert resin is provided. The honeycomb layer extends across substantially the whole
25 cross-sectional area of the column. This substantially fixes the inert resin and further reduces mobility of the ion exchange resins and therefore improves the performance of the separator.

The honeycomb layer may be provided by a layer of foam
30 which is preferably substantially chemically resistant to the regenerating liquids which are to be passed through the ion exchange column.

Generally at least 60% or even 80% or 90% of the low density particulate material will have a particle size such
35 that it will not pass through a mesh having apertures with a width 0.5mm, preferably it will not pass through a mesh having apertures with a width 1mm. Generally at least 60%

or even 80% or 90% of the low density particulate material will pass through a mesh having apertures with width 20mm and preferably with width 10mm. The use of inert material having a particle size greater than that of the particulate liquid purification material of the lower bed is advantageous.

It is particularly advantageous for the movable separator to include a layer of inert material beneath the container, as it enables the use of up-flow service liquid purification systems in which in the service flow, liquid for purification is passed upwardly through the column, passing firstly through the lower bed of liquid purification material, then through the low density inert material and upwardly through the container and upper bed before leaving the column through an exit port at the top of the column without intermixing of the beds of purification material. This is particularly advantageous as the low density, inert material and amount and density of the particulate material in the container can be adjusted so that the apparatus will retain the lower bed in a substantially fixed position whilst still being allowed room for expansion. In addition, the inert bed not only ensures good separation but also contributes to good distribution of the liquid for purification or regenerant liquid through subsequent beds irrespective of flow rate.

The regeneration step can be either up-flow or down-flow, preferably it will be a counter flow, down-flow regeneration.

The low density material may be for example a cellular structure in which air is trapped or may be a structure comprising low density particulate material such as a foam material in which the low density particulate material is trapped.

The present invention also comprises a process for purification of liquids comprising passing liquid for purification through at least two beds of liquid

purification material in a purification column, separated from one another by a movable separator as described above.

The liquid purification material may comprise for example, particulate filter material such as carbon, manganese green sand, garnet, anthracite or sand, or ion exchange resin which may be weak, strong or mixed anion, weak or strong cation or a mixed bed resin. Preferably the liquid purification material is ion exchange resin.

The present invention has been found to be particularly useful for separating two (or more) beds of anion exchange resin in particular where one comprises either weak or mixed base anion resin and a second comprises strong base anion resin.

Often in a deionisation treatment, beds of both anion and cation exchange resins are required. There may be one ion exchange column for anion resins and a separate column for cation exchange resins or, beds of both anion or cation may be in the same column. The present invention is particularly useful for separating two beds of anion exchange resin because in practice, it is advantageous to use in a demineralisation apparatus for aqueous liquids both a weak or mixed base anion resin and strong anion resin. Weak resins are more easily regenerated requiring less chemical regenerant than strong resins and will remove at least some of the impurities in the liquid for purification. However weak resins will not remove all of the impurities and so in particular for a deionisation process, it is necessary to include a bed of strong resin to ensure removal of all the ionic impurities. It is less efficient to use only strong resin because regeneration requires more regenerant and will take longer than for an equivalent amount of weak resin.

However, conventionally it is difficult to use both strong and weak or mixed anion resins in the same column because their densities are too similar to enable operation of the two beds without intermixing. Furthermore, fixed partitions are undesirable due to expansion and contraction

of the anion exchange resin depending upon whether it is in the ionised or de-ionised form. The present invention enables the use of an anion exchange resins comprising weak or mixed base anion resin in addition to strong base anion resin in the same column. In use, liquid for purification will flow through the weak anion resin, then through the movable separator and then through the strong base anionic resin.

The present invention is also useful for separating two types of cation resin. Cation units often use only one ion exchange resin type for example a strong cation exchange resin. However as for the anion exchange resins discussed above, it is also desirable to use a combination of weak acid cation exchange resin with strong resin. As explained for the anion resin, since weak resin is more easily regenerated it is preferable to remove at least some of the cations using a weak cation resin rather than to remove all of the cation impurities using strong acid cationic exchange resin. This ensures more efficient regeneration and an overall increase in efficiency of the water purification process.

The invention is also particularly useful for use in processes which have to be run at high temperatures. Some ion exchange resins tend to be unsuitable for use at high temperatures. In addition, since a combination of weak or mixed resin with strong resin has to be selected with the resins having relative densities such that the two will substantially not mix during use. The choice of suitable resins which can be used in conventional processes therefore is limited and it may be impossible to select the resins most appropriate for the purification of the particular liquid for purification. The present invention overcomes this problem as the separator prevents intermixing and enables the resin choice to be determined by the technical consideration of the resin and particular aqueous liquid source, thus producing increased efficiency.

Expansion and contraction of the beds is still permitted.

The invention is particularly useful for separating a mixed or weak anion exchange resin from a strong anion exchange resin where the resin is one which is suitable for use at high temperatures for example above 30°C or even above 35°C or 40°C. Thus for a downflow service apparatus, a cation resin containing column may comprise strong cation resin positioned beneath mixed or weak cation exchange resin and separated by a movable separator of the invention and liquid for purification passes downwardly firstly through the mixed or weak cation resin and subsequently through the strong cation resin. Alternatively, the service flow can be upwardly and the beds of ion exchange resin in the opposite arrangement. Prior to the present invention this problem could be overcome by incorporating a fixed connector. However such a connector does not operate as a separator and intermixing between the beds still occurs. Alternatively a stationary separator could be incorporated in the column and regenerate using a split flow which reduces operating efficiency. The present invention overcomes all of these prior art problems.

The present invention enables efficient separation of two beds of ion exchange material irrespective of their densities, whilst still enabling sufficient expansion of the beds throughout the deionisation and regeneration steps. Thus, the invention enables use of the preferred ion exchange resin for purification of a particular aqueous liquid: the most appropriate resins can be selected on their merits appropriate to a liquid for purification and irrespective of their respective densities. This results in considerable benefits to process efficiency.

In addition, because there is no risk of considerable intermixing of the beds which are separated by the movable separator, ion exchange columns can be packed more fully, and therefore greater process efficiency results for a given column size. In conventional processes, sufficient free space must be left in an ion exchange column to enable

backwashing so that after use and resultant mixing of two beds of purification material, back-washing could be effected in order to reform two separate beds.

There is no need to provide a separate back-wash facility to the apparatus of this invention. The free space in a column should therefore be sufficient to allow expansion and contraction of the ion exchange resin at various stages of the service and regeneration cycles, depending on the chemical form of the resin but does not have to be so great as to enable backwash. The free space may therefore be lower than 20%, or even 15% or 10% of the internal volume of the column.

Although the present invention is particularly directed to deionisation processes, such a movable separator may also be incorporated into water softening units (for exchange of hardness ions such as calcium and magnesium and chloride).

If it is decided to incorporate a filter bed comprising particulate filter bed material in addition to an ion exchange resin bed or beds, the apparatus will be arranged such that in use in a service flow, aqueous liquids for purification will pass first through the filter bed and subsequently through ion exchange resin. It is desirable to leave sufficient space so that the filter can be backwashed in situ, without having to remove all of the ion exchange material. Thus for example the separator can be used to separate an ion exchange resin from a filter bed comprising for example sand. Generally, in the service flow, liquid for purification flows downwardly through the beds of purification material. Therefore, where both a particulate filter material and ion exchange material are provided, in a purification column, preferably the ion exchange resin will be at the bottom of the column and the filter bed will be arranged above the ion exchange resin. Thus, the density and weight of the separator can be adjusted so it exerts sufficient pressure on the bed below to substantially pack the lower bed comprising ion exchange

resin and permit the upper bed to settle so that there is free space above the bed and on backwashing, the density of the separator is sufficient to substantially retain packing of the lower bed so that the filter bed has sufficient free space to be effectively backwashed. Similar adjustments can be made depending upon the required degree of the bed beneath the separator and the free space or expansion space required by the beds either side of the separator.

Generally, in use, in the service flow, liquid for purification passes downwardly through beds of particulate purification material. Thus, in a purification column or other vessel, the beds of different particulate material will be arranged such that the material which the liquid is intended to pass through first is at the top of the apparatus, the beds for subsequent treatment being beneath it in sequence, preferably each sequential bed being separated from a neighbouring bed by a movable separator of the present invention. A column, or other purification apparatus may therefore contain a plurality of movable separators. The apparatus and processes of the present invention are particularly directed to counterflow ion exchange processes where in the service flow liquid for purification flows downwardly through the beds and in the regeneration and/or cleaning cycle, regenerant and/or backwash liquid flows upwardly through the beds.

In accordance with a further embodiment of the invention, a collector/distributor may be incorporated in the movable separator and if desired, this permits split flow processes and also enables the use and regeneration of both anion or cation exchange resins to be used in the same vessel. In this case, the collector will be provided with a grommet or other means to allow the collector/distributor to move with the movable separator. Therefore the present invention is particularly advantageous because it enables the use of a single purification column to fulfil all of the requirements of a water purification system and it may therefore include beds of anion exchange resin,

cation exchange resin, filter beds etc in the same vessel. Thus, very tall columns may be used which require less floor space. For example, the height of the vessels may be above two metres, even above 2.5 or 3 metres. The floor space required can therefore be reduced considerably to around 1m^2 or even 0.5m^2 or 0.25m^2 or below for an ion exchange system comprising a volume of ion exchange resin and other filter material of from 1 or even 2m^3 .

The invention also has the additional advantage that a fast flow rate in both service flow and in particular also regeneration flow rate can be permitted without undue mixing of a bed positioned beneath a separator of the present invention. In particular in counter flow processes, regeneration rate can be increased without undue mixing of a bed as the movable separator can provide a stabilising weight above the bed whilst still enabling expansion/contraction of the bed depending upon its stage of ionisation. The invention is particularly useful for flow rates in the service flow of the order of $80\text{m}^3/\text{m}^2/\text{hour}$ although rates in the range 20 to $80\text{m}^3/\text{m}^2/\text{hour}$ may be used.

The regenerating flow is preferably at a rate of 20- $24\text{m}^3/\text{m}^2/\text{hour}$ through the ion exchange resin beds although the rate may be as low as 4 or $5\text{m}^3/\text{m}^2/\text{hour}$.

The lifting of conventional constraints on the purification of liquids has a significant effect on the cost efficiency of a purification process.

The present invention enables processes to be carried out at higher flow rates but also increases efficiency of the process in particular of the regeneration step. Therefore, the overall time required for removal of unit concentration of impurities from a unit volume of liquid for purification and regeneration of the system is reduced. The overall time required for an effective cycle is therefore reduced. In the current climate of water shortages and the high environmental cost of the use of large quantities of water, any saving to be made on use of recycled water is therefore highly advantageous.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 to 4 illustrate liquid purification columns in which different arrangements of different purification materials are shown.

- 5 Figure 5 illustrates a deionisation process incorporating movable separator according to the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

- 10 In each of Figures 1 to 4, 1 represents the purification column, 2 represents the porous material of the movable separator and 3 represents the particulate material of the movable separator. In Figure 1, 4 indicates weak acid cationic exchange resin and 5 represents strong acid cationic exchange resin. In the service flow, aqueous liquid for purification enters the column through port 6 and flows downwardly through the weak acid cationic exchange resin, the movable separator and subsequently through the strong acid cationic exchange resin to exit the column through port 7. During the regeneration, regeneration liquid enters port 7 and flows upwardly through the column through strong acid cation resin, through the movable separator, through the weak acid cation resin and exits the apparatus through port 6. 8 indicates free space within the vessel enabling expansion and contraction of the beds depending upon their degree of ionisation. If desired, a further movable separator may be incorporated upon bed 4 to help prevent mixing of the bed on rapid regeneration flows. Figure 2 represents the regeneration and backwash flow of a column in which 9 represents a sand filter bed during regeneration and backwash and 10 represents strong acid cation exchange resin which is expanding on regeneration. The movable separator might move very slowly upwards to allow freeing of the bed but does not enable significant mixing in the bed whilst allowing sufficient free space in 9 that effective backwash of the filter bed can be attained. The regenerant is flowing through entry port 11 upwardly
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through the bed 10 and through filter bed 9 to exit from port 12.

In Figure 3, 13 represents a bed of anionic exchange resin and 14 represents a strong acid cation exchange resin bed for a water softener apparatus. Aqueous liquid for softening flows inwardly through port 15, upwardly through the bed 14, through movable separator and subsequently through the anion trap 13 before exiting the column through port 16. On regeneration, acid regenerant for the strong acid cation bed enters the column through port 15 and flows upwardly until it reaches the collector/distributor 17 positioned in the particulate material 3 of the movable separator. Likewise, salt solution for regenerating the ionic resin flows downwardly through port 16 through the ion exchange bed 13 until it reaches the distributor/separator 17 in the particulate material of the movable separator. Both regenerating liquids having regenerated the anionic and cationic resins, respectively then flow through the collector distributor 17 to exit the column via line 18.

In Figure 4, 19 represents a bed of anionic exchange resin and 20 represents a bed of cationic exchange resin. During service flow, liquid for purification enters port 21 and flows upwardly through bed 20, through the movable separator and through bed 19 to exit the column through port 22. During regeneration, acid for regenerating the cationic exchange bed enters the column through port 21 and fills upwardly through bed 20 and is removed via collector 23 to exit the column along line 24 and base for regenerating the anion resin enters the apparatus through port 22, flows downwardly through bed 19 and is removed by collector 25 to exit the apparatus along line 26.

Figure 5 shows a cation column 27 and an anion column 28. In column 27, a bed of sand filter material 29 is provided. A basket 30 formed from SARAN mesh contains gravel 31 (Grading 2-3). A bed 32 of inert resin having a specific gravity 0.535 and particle size 1.3-1.7mm, a bed

33 of cation exchange resin, and a bed 34 of crushed granite (grading 2-3) and is provided in the column 27. The crushed granite bed 34 is provided so that the ion exchange resin in bed 33 (which has smaller particle size) is substantially prevented from escaping from the column through the port 35. A sand and resin trap 36 prevents any particulate material which escapes from vessel 27 from being passed into vessel 28. In vessel 28, bed 37 presents a bed of weak base anion exchange resin. As before, 30 represents the cross section of a basket formed from SARAN. Stainless steel ball bearings 38 which are substantially spherical and having an average diameter of 3mm are provided above a bed of inert resin having a density lower than that of water and lower than that of the water purification material (strong base anion resin) in bed 39 below.

In use, in a service cycle, water for purification passes along line 40 enters column 27 through port 41 and passes downwardly through the free space in 42, through sand filter bed 29, the movable separator comprising container 30 and inert bed 32 and subsequently through the bed of cation resin 33 prior to passing through inert bed 34 to exit the column through port 35. Liquid for purification having passed through this column, it proceeds along line 43, through the sand and resin trap 36 and subsequently a long line 34 prior to entering column 28 through port 45. It then passes through free space 46, through the bed of weak base anionic exchange resin, 37 and subsequent through the movable separator comprising the bed of stainless steel particles in container 30 and bed of inert low density material 32. It then passes through bed 39 strong base anion resin prior to leaving column 28 through port 47, along line 48.

In the regeneration cycle, regenerant enters column 28 through port 47 and passes upwardly through the column where it is passed out of the column through port 45 and then a valve 49 is lead away along line 50. Either

simultaneously, or sequentially, regenerant is passed along line 51 and via valve 52, passes into column 27 through port 35. It passes upwardly through the cation exchange column past the movable separator and sand filter and then
5 leaves the vessel through port 41 and is lead away along line 40.

During the service cycle as the beds of ion exchange material become exhausted, their volume changes and the movable separator comprising the container and inert resin
10 bed moves inside the respective columns so that in each case, the change in volume of bed beneath the separator can be accomodated, whilst still being held substantially fixed and without placing undue pressure on the resin as its volume changes. During regeneration, as the volume of the
15 lower beds changes, the movable separator moves again inside the column. An effective separation of the beds either side of the movable separator is provided, even though the internal surfaces of the plastic columns 27 and 28 have irregularities.



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26

CLAIMS

1. A movable separator (2, 30) for use in a liquid purification column (1, 27, 28), the separator (2, 30) comprising a flexible, porous container containing solid
5 particulate separator material (3, 38) which exerts pressure on the porous container so that in use in the column (1, 27, 28) slidable contact of the container against the internal walls of the column is effected and the container, where it contacts the internal walls of the
10 column, comprising resilient material.
2. A movable separator (2, 30) for use in a liquid purification column (1, 27, 28), the separator (2, 30) comprising a flexible porous container, containing solid particulate separator material (3, 38) which exerts
15 pressure on the container beneath which is positioned a layer of substantially inert material having a density below 1g/cm^3 and in use, in the column, slidable contact of the container against the internal walls of the column is effected.
- 20 3. A movable separator according to claim 2 in which the container, where it contacts the internal walls of the column, in use, comprises non-porous flexible material.
4. A movable separator according to claim 1 in which the porous container (2, 30) comprises a closed bag, preferably
25 having cross-sectional area greater than the horizontal cross-sectional area of the column (1, 27, 28).
5. A movable separator according to any of claims 1 to 3 in which the container (2,30) comprises a base portion and side portions extending upwardly from the base portion in
30 the form of an open container, the container being wholly or partially formed from substantially resilient porous material.
6. A movable separator according to claim 5 in which the base portion has substantially the shape and dimensions of
35 the internal horizontal cross-section of the column in which it is for use and the side portions extend upwardly from the periphery of the base portion.

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WO 96/28252

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27

7. A movable separator according to any preceding claim in which the particulate material is substantially inert.
8. A movable separator according to any preceding claim in which the particulate material (3, 38) comprises gravel
- 5 or metallic particles preferably ball bearings.
9. A movable separator according to any preceding claim in which the particulate material (3, 38) was an average diameter to from 2mm to 20mm.
10. A movable separator according to any preceding claim in which in use, the separator (2, 30) is placed immediately above a bed of a particulate purification material, preferably ion exchange material and the density of the solid particulate material in the container is at least 1.5 times greater than that of the purification
- 15 material.
11. A movable separator according to any preceding claim in which a collector/distributor (17, 23, 25) is provided in the bed of particulate material (3, 38).
12. An apparatus for purification of liquids comprising a liquid purification column (1, 27, 28), in use the column comprising at least a bed of particulate liquid purification material (4, 5, 9, 10, 13, 14, 19, 20) and a movable separator (2, 30) according to any of claims 1 to 11.
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13. An apparatus for purification of a liquid comprising a liquid purification column (1, 27, 28), in use, the column comprising at least two beds of loose, particulate liquid purification material (4, 5, 9, 10, 13, 14, 19, 20) and a movable separator (2, 30) being positioned between
- 25 the beds (4, 5, 9, 10, 13, 14, 19, 20) comprising a lower bed beneath the separator and an upper bed above the separator, the movable separator (2, 30) being in direct contact with each of the lower beds and the upper bed and the movable separator comprising a flexible, porous
- 30 container (2, 30) containing solid particulate separator material (3, 38) which exerts pressure on the porous container so that in use, in the column slidable contact of
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28

the container against the internal walls of the column (1, 27, 28) is effected, the container where it contacts the internal walls of the column comprising resilient material.

14. An apparatus according to claim 13 in which beneath the container (2, 30) and above the lower bed there is positioned a layer comprising low density material having a density lower than the liquid purification material in the lower bed.

15. An apparatus according to claim 13 or 14 in which the movable separator is according to any of claims 1 or 4 to 11.

16. An apparatus for purification of a liquid comprising a liquid purification column (1, 27, 28), in use, the column comprising at least two beds of liquid purification material (4, 5, 9, 10, 13, 14, 19, 20) and a movable separator (2, 30) being positioned between the beds, a lower bed beneath the separator and an upper bed above the separator, the movable separator comprising a flexible porous container, containing solid particulate separator material (3, 38) which exerts pressure on the container, and a layer of substantially inert material having a density below 1g/cm^3 which is positioned beneath the container, and in use, in the column, slidable contact of the separator against the internal walls of the column is effected.

17. A process for purification of liquids comprising in a service flow passing liquid for purification through at least a first bed of liquid purification material, and subsequently through a movable separator and then through a second bed comprising a liquid purification material, the movable separator comprising a flexible, porous container containing solid particulate separator material which exerts pressure on the porous container so that in use, in the column slidable contact of the container against the internal walls of the column is effected, the container where it contacts the internal walls of the column comprising porous material.

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29

18. A process according to claim 17 in which the movable separator is as defined in any of claims 1 or 4 to 11.

19. A process for purification of liquids comprising in a service flow passing liquid for purification through at least a first bed of liquid purification material, and subsequently through a movable separator and then through a second bed comprising a liquid purification material, the movable separator comprising a flexible porous container, containing solid particulate separator material which exerts pressure on the container, and a layer of substantially inert material having a density below 1g/cm^3 which is positioned beneath the container, and in use, in the column, slidable contact of the separator against the internal walls of the column is effected.

20. A process according to claim 19 in which the movable separator is as defined in any of claims 1 to 11.

21. A process according to any of claims 17 to 20 in which liquid for purification is passed downwardly through the column in a service cycle and in a regeneration cycle, regenerating liquid is passed upwardly through the column.

22. A process according to any of claims 17 to 21 in which the purification column is a de-ionisation column and each of the first and second beds comprises an ion exchange column, preferably each of the first and second beds comprising ion exchange resin.

23. A process according any of claims 17 to 22 which the first bed comprises strong acid cation resin and the second bed comprises weak or mixed cation resin.

24. A process according to any of claims 15 to 19 in which the first bed comprises strong base anion resin and the second bed comprises weak or mixed base anion resin.

25. A process for purification of liquids comprising in a service flow passing liquid for purification through a liquid purification column, the liquid for purification entering the bottom of the column and passing through a lower bed of liquid purification material, then upwardly through a layer of low density material, subsequently

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through a movable separator and then upwardly through an upper bed of liquid purification material to exit from the top of the column, the density of the lower density layer being lower than the density of the lower layer of liquid

5 purification material.

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