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Abstract

A thickener or clarifier is described. The clarifier has a feed line for introducing
a feed slurry to the thickener or clarifier, the feed slurry comprising one or
5 more solid species and a liquid fraction; a sedimentation zone for receiving the
feed slurry from the feed line and allowing the one or more solid species to
settle under gravity towards a lowermost portion of the sedimentation zone
whereupon a semi-clarified liquor is displaced in an upward direction; and a
multi-media filter bed comprising a plurality of filter media particles and
10 arranged at a height above the sedimentation zone for filtering solids from the
upwardly displaced semi-clarified liquor to produce a clarified liquor overflow.

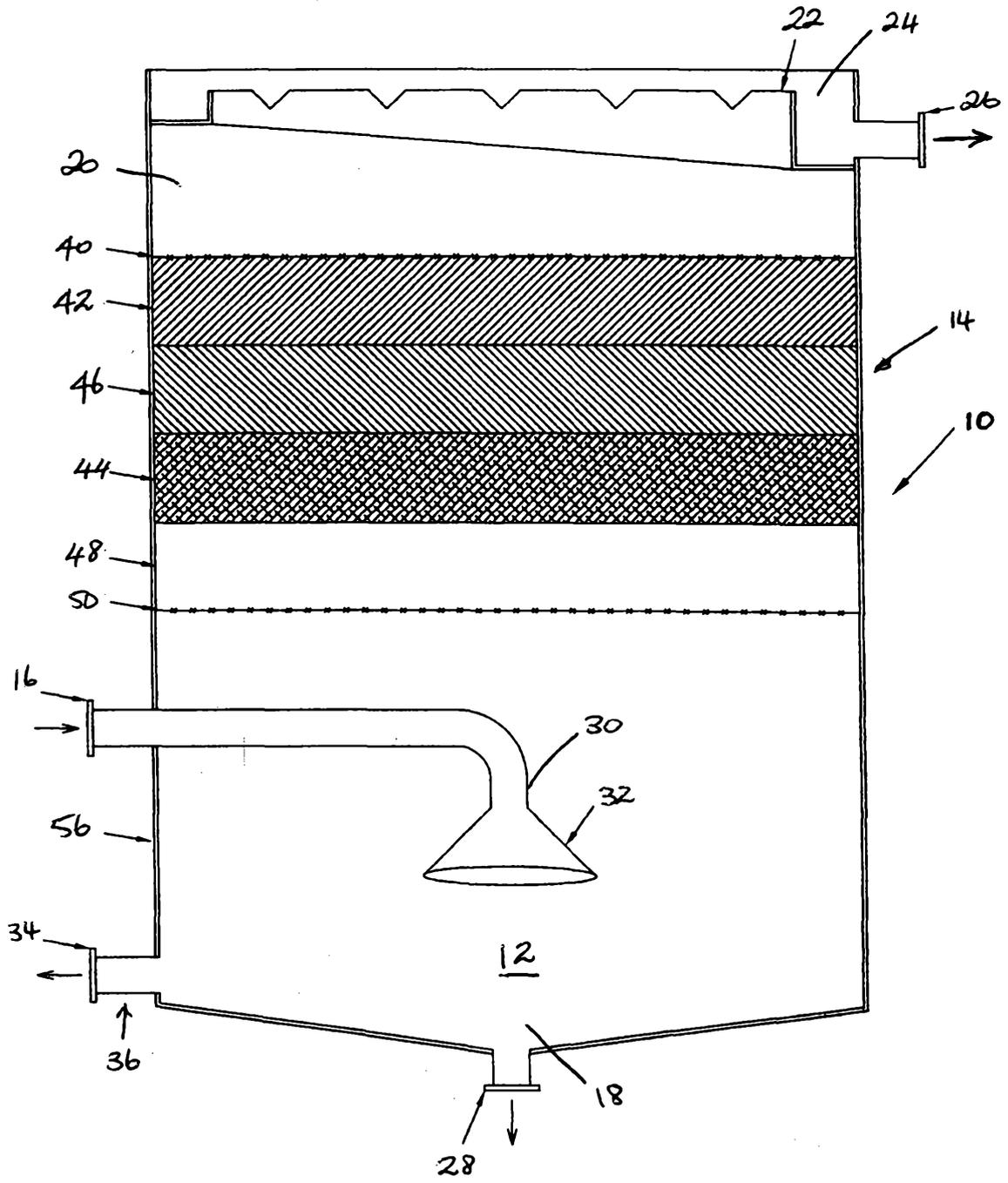


Fig-1

"Multi-media clarifier or thickener"

FIELD OF THE INVENTION

5 The present invention relates generally to a thickener, clarifier or settler and relates particularly to an apparatus which includes a multi-media filter bed in combination with a sedimentation zone to provide improved clarification of a feed slurry.

BACKGROUND TO THE INVENTION

10 It is known to use gravity settling of solids to effect separation of the solid and liquid components of a feed slurry and thereby produce a high density solids fraction referred to as "sludge" and a clear liquid referred to as "clarified liquor". For example, Australian patent No. 667938 describes and illustrates various thickeners relying on gravity settling of solids in a slurry contained
15 within a vessel. The slurry flows via a feed conduit to a feed cylinder or well which is located within an upper free settling region of the vessel. Any flocculant or coagulant agents added to the slurry are allowed to freely disperse through the slurry in the feed cylinder or well. The flocculated slurry then passes into the upper free settling region, in one embodiment via several
20 flocculating cylinders. A clarified liquid fraction moves upwardly through the vessel and is removed as a clarified liquid overflow, and a solids fraction settles under gravity and moves downwardly through the vessel into a lower compaction region. A thickened sludge can then be removed as an underflow from the base of the vessel.

25 In the early 1980's a technology for filtering solids from wastewaters referred to as "buoyant media filtration" was developed. Buoyant media filtration refers to liquid filtration in which a liquid to be filtered is passed up through a bed of granular media that has a specific gravity less than that of the liquid
30 being filtered. Buoyant media filtration has been used in the treatment of wastewaters produced during the manufacture of automobiles, for example wastewater produced from a chrome plating shop or wastewater contaminated with paint. The prior art buoyant media filter relies on a single layer of inert low density ceramic spheres of a particular nominal size range. The media is

less dense than the liquid and is retained from floating to the top of the liquid using a suitably sized perforated plate or screen. Solids become entrained in the filter media which is backwashed by either reversing the flow of the liquid or by simply allowing the liquid to drain under the influence of gravity from the bottom of the filter unit.

This prior art type of buoyant media filter has a number of disadvantages. Due to the nature of the media being used, the suspended solids in the wastewater being filtered tend to accumulate on the surface of the media which greatly limits the solids handling and solids holding capability of the buoyant media filter. As the weight of solids builds up on the surface of the single layer of buoyant media, flakes or chunks of the solids that accumulate on the media tend to slough off and sink within the clarifier, often dragging media with them as they break away.

The apparatus and method of the present invention were developed to provide a clarifier or thickener which produces an overflow liquor of high clarity as an alternative to the devices described above.

It will be clearly understood that, although a number of prior art publications are referred to herein, this reference does not constitute an admission that any of these documents forms part of the common general knowledge in the art, in Australia or in any other country. In the summary of the invention, the description and claims which follow, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a thickener or clarifier comprising:

a feed line for introducing a feed slurry to the thickener or clarifier, the feed slurry comprising one or more solid species and a liquid fraction;

a sedimentation zone for receiving the feed slurry from the feed line and allowing the one or more solid species to settle under gravity towards a lowermost portion of the sedimentation zone whereupon a semi-clarified liquor is displaced in an upward direction;

5 a multi-media filter bed comprising a plurality of filter media particles and arranged at a height above the sedimentation zone for filtering solids from the upwardly displaced semi-clarified liquor to produce a clarified liquor overflow;

10 an underflow outlet for removing a high density solids underflow from a lowermost portion of the sedimentation zone; and,

an overflow outlet for removing clarified liquor from an uppermost portion of the multi-media filter bed.

15 In one embodiment the multi-media filter bed comprises a plurality of sizes of particles of a filter media, the plurality of sizes including a least one coarse fraction and one fine fraction, the mean particle size of the particles in the coarse fraction being greater than the mean particle size in the fine fraction. The plurality of sizes may further include at least one intermediate fraction wherein the mean particle size of the intermediate size fraction is greater than
20 the mean particle size of the fine fraction but less than the mean particle size of the coarse fraction.

25 In another embodiment, the multi-media filter bed comprises a plurality of compositional types of filter media particles, each type of filter media particle having different chemical or physical properties. The plurality of different compositional types of filter media particles may have the same mean particle size or a variety of sizes. When the different chemical property is the specific gravity of the particles, the multi-media filter bed consists of at least one heavy fraction and at least one light fraction. The different chemical property may
30 equally be the surface chemistry of the particles, or the multi-media filter bed may include at least one cationic fraction for attracting anionic solids species from the semi-clarified media or the multi-media filter bed may include at least one anionic fraction for attracting cationic solids from the semi-clarified media. Equally, the different chemical property may be the reactivity of the particles

and the semi-clarified liquor reacts with at least one of types of particles to form precipitates.

5 If the filter media particles are not buoyant, the clarifier or thickener may further comprise a plurality of screens for holding the plurality of different types of media within a corresponding plurality of designated layers within the multi-media filter bed or a plurality of graded screens for holding the plurality of different sizes of media within a corresponding plurality of designated layers within the multi-media filter bed.

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A pre-filtering screen arranged between the sedimentation zone and the multi-media filter bed may be provided to effect pre-filtering of a desired range of sized solids from the semi-clarified liquor as it flows from the sedimentation zone to the multi-media filter bed. Alternatively or additionally the clarifier or thickener may further comprise a pre-conditioning zone arranged between the sedimentation zone and the multi-media filter bed for treating the semi-clarified liquor as it flows from the sedimentation zone to the multi-media filter bed.

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20 To resist downward movement of the filter media particles of the multi-media filter bed, the clarifier or thickener may further comprise a lower filter media retention screen. Similarly, to resist upward movement of the filter media particles of the multi-media filter bed, the clarifier or thickener may further comprise an upper filter media retention screen.

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In a preferred embodiment, the multi-media filter bed comprises particles of a buoyant filter media, the filter media particles having a specific gravity less than the specific gravity of the semi-clarified liquor. In this embodiment, the upper filter media retention screen may be arranged to ensure that the buoyant filter media remains submerged in use in the semi-clarified liquor being filtered.

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The filter media particles may be made from the following materials alone or in combination: plastic, metal, glass, ceramic, or composite and may equally be

hollow or porous. The filter media particles may have a central core of one compositional type with a coating of a second compositional type.

5 The clarifier or thickener may further comprise a feed well baffle for directing the feed slurry into the sedimentation zone, the feed well baffle having an upper end and a lower end, the lower end of the feed well baffle being below the lowermost depth of the multi-media filter bed. In one embodiment, the body of the clarifier is defined by one or more walls and the multi-media filter bed is located within an annulus defined between the outermost surface of the feed well and the innermost surface of the wall(s) of the clarifier or thickener. The feed well baffle may be positioned concentrically within the body of the clarifier or thickener or off to one side. In an alternative embodiment, the feed line delivers feed slurry to an annulus defined between the outermost surface of the feed well baffle and the innermost surface of the wall(s) of the clarifier or thickener and the multi-media filter bed is located within the feed well baffle.

15 The clarifier or thickener may further comprise a flow diverter baffle positioned adjacent to and below the lower end of the feed well baffle to direct settling solids from the multi-media filter bed towards the lowermost portion of the sedimentation zone.

20 Preferably, the overflow outlet comprises a weir over which clarified liquor flows into a launder from which clarified liquor is removed through the overflow liquor outlet.

25 To facilitate periodic rinsing of retained solids from the multi-media filter bed, the clarifier or thickener may further comprise a backwashing system including a backwash outlet arranged at a height below the multi-media filter bed. When a lower filter media retention screen is being used, the backwash outlet is preferably arranged at a height below the lower filter media retention screen. The clarifier or thickener may further comprise a rinse liquor outlet arranged at a height above an upper filter media retention screen but below the level of an overflow weir. In one embodiment, the backwash outlet comprises a backwash outlet pipe with a first end which terminates within the sedimentation zone, the

first end of the backwash outlet pipe including a frustoconical flared portion.

5 In one embodiment, the clarifier or thickener further comprises a media scouring system arranged to inject a fluid into the multi-media filter bed so as to cause agitation of the filter media particles. The media scouring system may comprise an arrangement of pipes, headers or manifolds for directing and controlling the injection of the fluid into the multi-bed filter bed. The arrangement of pipes, headers or manifolds may direct the injection of the fluid upwards, horizontally, tangentially or downwards. The fluid may be a gas or
10 liquid, preferably air or liquor.

In one embodiment, the fluid is injected into the media filter bed at a first flow rate to cause vigorous agitation of the filter media particles for a pre-determined first period of time during scouring and a second flow rate to cause
15 gentle agitation for a pre-determined second period of time after scouring to encourage the filter media particles to self-arrange into optimum position after scouring.

20 According to a second aspect of the present invention there is provided a method of thickening or clarifying comprising the steps of adding a feed slurry to the clarifier or thicker according to the first aspect of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

25 In order to achieve a better understanding of the nature of the present invention several preferred embodiments of a thickener or clarifier will now be described in some detail, by way of example only, with reference to the accompanying drawings in which:

30 Figure 1 is a side sectional view of one embodiment of the thickener or clarifier in which the multi-media filter bed extends across the entire cross-sectional area of the clarifier;

Figure 2 is a side sectional view of another embodiment including a feed well baffle which defines an annulus within which the multi-media filter bed is arranged in layers of different types of filter media of the same size;

Figure 3 is a side sectional view of a thickener or clarifier with

graded filter media and a side flush port;

Figure 4 is a side sectional view of a thickener or clarifier with a flow diverter baffle;

5 Figure 5 is a plan view of the thickener or clarifier illustrated in Figure 4;

Figure 6 is a side sectional view of a thickener or clarifier illustrating floating graded media and a flushing pipe with flow diverter cone;

10 Figure 7 is a side sectional view of the thickener or clarifier of Figure 6 using layers of different types of filter media instead of filter media particles of different sizes;

Figure 8 is a side sectional view of a thickener or clarifier using grading screens to maintain separation of the layers of the multi-media filter bed;

15 Figure 9 is a side section view of a thickener or clarifier with the multi-media filter bed positioned within the feed well baffle and the feed line delivering feed slurry into the annulus;

Figure 10 is a side sectional view of the thickener or clarifier illustrated in Figure 9 using grading screens to maintain separation of the layers of the multi-media filter bed;

20 Figure 11 is of a plan view of the thickener or clarifier illustrated in Figure 10; and,

Figure 12 is a side view of an alternative embodiment in which the opening of the frustoconical flared portion is oriented downwardly.

25 **DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS**

Particular embodiments of the present invention are now described. The terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention. Unless defined otherwise, all technical and scientific terms used
30 herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs.

With reference to Figure 1 there is provided a clarifier or thickener 10 comprising a sedimentation zone 12 and a multi-media filter bed 14 arranged

above the sedimentation zone 12. A feed slurry comprising one or more solid species and a liquid fraction is fed to the sedimentation zone 12 of the clarifier 10 through a feed line 16. Within the sedimentation zone 12, the one or more solid species present in the feed slurry settle under gravity towards a lowermost portion 18 of the sedimentation zone 12 forming a high density solids sludge. As the solids settle towards the lowermost portion 18 of the sedimentation zone 12, semi-clarified liquor is displaced upwards. The multi-media filter bed 14 is arranged above the sedimentation zone 12 and is used to facilitate removal of the remaining solids from the semi-clarified liquor so as to produce a clarified liquor overflow with a low solids density. The clarified liquor continues to flow upwardly out of the multi-media filter bed 14 towards an uppermost portion 20 of the clarifier 10 where it flows over a weir 22 into an overflow launder 24. The clarifier 10 is provided with an overflow outlet 26 for removing clarified liquor from the overflow launder 24. A high density solids underflow is removed continuously or periodically from an underflow outlet 28 located adjacent to the lowermost portion 18 of the sedimentation zone 12.

The solids in the semi-clarified liquor are removed by physical and/or chemical filtration as the semi-clarified liquor passes through the multi-media filter bed 14 depending on the nature of the filter media used. Accordingly, the particular mechanism of removal of the solids species present in the semi-clarified liquor depends on the type of media used to form the multi-media filter bed 14 as described in greater detail below. It is to be understood that the solids present in the semi-clarifier liquor will also continue to settle under the influence of gravity and this mechanism of separation is encouraged by collision of the solids species in the semi-clarified liquor during filtration of the semi-clarified liquor in the multi-media filter bed 14.

The feed line 16 terminates within the clarifier 10 at a feed line outlet 30 which is arranged to deliver the feed slurry into the sedimentation zone 12. The action of delivering the feed slurry into the sedimentation zone 12 causes a degree of turbulent mixing. This turbulent mixing encourages the solids species to collide and coalesce to form larger particles or "flocs". This phenomenon encourages sedimentation. In the embodiment illustrated in

Figure 1, the feed line outlet 30 includes a frustoconical flaring portion 32 to assist in distributing the feed slurry into the sedimentation zone 12 and reduce the velocity of the feed slurry as it enters the sedimentation zone 12. It will be appreciated that due to the higher percentage of solids present in the feed slurry compared with the percentage of solids present in the semi-clarified liquor, and due to the proximity of the sedimentation zone 12 to the feed line outlet 30, the operating conditions within the multi-media filter bed 14 will be more quiescent than the operating conditions within the sedimentation zone 12. Just as the high shear flow rate within the sedimentation zone 12 is highly conducive to the settling of solids from the feed slurry, the more quiescent conditions within the multi-media filter bed 14 are more conducive to the filtration of solids from the more dilute semi-clarified liquor.

In the embodiment illustrated in Figure 1, the multi-media filter bed 14 consists of three types of buoyant filter media particles with each of the three types of buoyant filter media particles having different chemical or physical properties, in this example, different specific gravities. Advantageously, all of the three types of filter media particles have a specific gravity lower than the semi-clarified liquor to be filtered, such that if left to their own devices the filter media particles would float to the top of the liquor. To retain the buoyant filter media particles in a submerged state within the semi-clarified liquor, the clarifier 10 is provided with an upper filter media retention screen 40 in the form of a perforated plate, nozzle plate, mesh, grid or screen. The upper filter media retention screen 40 includes a plurality of apertures (not shown). The size of the apertures of the upper filter media retention screen 40 may vary provided only that the apertures are small enough to block movement of the buoyant filter media particles through the upper filter media retention screen 40.

The buoyant filter media particles may be of equal size or a plurality of sizes graded from a coarse fraction at the bottom of the multi-media filter bed 14 to a fine fraction at the top. When the buoyant filter media particles are of equal size but different density, the heaviest fraction will sink to the bottom of the multi-media filter bed with the lightest fraction rising to the top. The buoyant

filter media particles self-arrange into at least an upper layer 42 which comprises the lightest fraction of the particles and at least a lower layer 44 which comprises the heaviest fraction of the particles. Any number of intermediate layers 46 may also form between the upper layer 42 and the lower layer 44, depending on the specific number of different compositional types of buoyant filter media used and the specific gravity of each of the different types. In Figure 1, three layers of buoyant filter media of equal depth are shown. In Figure 2, the multi-media filter bed 14 comprises four layers of buoyant filter media of different types, each layer comprising particles of different density. The number of layers and the depth of each layer may vary depending on the quantity and type of buoyant filter media particles used. There is also no requirement that distinct layers be formed, it being equally possible for the multi-media filter bed 14 to comprise a continuous grading of buoyant filter media particles of different types and/or different sizes.

Filtration of the semi-clarified liquor could equally be achieved using particles with a specific gravity equal to or greater than the specific gravity of the semi-clarified liquor using a plurality of suitably sized retention screens (not shown) to maintain separation of the various layers of media of different sizes or compositional types. Similarly, other chemical or physical properties of the different types of filter media can be varied other than specific gravity. For example, different types of filter media may be provided with differing ionic characteristics to attract specific solid species from the semi-clarified liquor as it rises through the multi-media filter bed. The filter media may equally be hollow or be provided with different surface chemistry or coated or comprise particles of different porosity to entrain solids species of different sizes and/or ionic characteristics. Precipitation of solids may be caused to occur upon contact of the solids species in the semi-clarified liquor with particular types of filter media used in the multi-media filter bed. The precipitated solids may settle under gravity or be flushed from the multi-media filter bed during backwashing operations. The filter media particles may be made from any suitable material, for example plastic, metal, glass, ceramic, or composite alone or in combination. The particular type of material selected will depend in part on the type of feed slurry being clarified or thickened.

Returning to the embodiment illustrated in Figure 1, the clarifier 10 also includes a lower filter media retention screen 50 for maintaining the filter media of the multi-media filter bed 14 at a predetermined height above the sedimentation zone 12. The predetermined height of the lower filter media retention screen need not be immediately below the lower layer. In Figure 1, a space 48 is formed between the lower layer 44 of the buoyant filter media particles and the lower filter media retention screen 50 when the buoyant filter media particles float upward in use. If desired, the lower filter media retention screen may be sized to effect pre-filtering of solids from the semi-clarified liquor as the semi-clarified liquor flows upward from the sedimentation zone 12 to the multi-media filter bed 14.

In Figure 2 for which like reference numerals refer to like parts, the clarifier of Figure 1 is modified to include a feed well baffle 54 of generally cylindrical shape arranged concentrically within the wall or walls 56 of the clarifier 10. The feed line 16 is arranged to discharge the feed slurry into the interior of the feed well baffle 54. The feed slurry flows downwardly under the influence of gravity towards the lowermost portion 18 of the sedimentation zone 12. Sedimentation of the solids species in the feed slurry may commence within the feed well baffle 54 as the feed slurry flows downwardly and the solids species within the feed slurry collide and form flocs. The feed well baffle 54 may be of variable length, provided only that the lower peripheral edge 58 of the feed well baffle 54 is below the level of the lower layer 44 of the multi-media filter bed 14 or below the predetermined height of the lower filter retention means 50 if a lower filter retention means is being used.

When the feed well baffle 54 is arranged concentrically with the walls 56 of the clarifier 10 as illustrated in Figure 1, an annulus 64 is defined between the outermost surface 66 of the feed well baffle 54 and the innermost surface 68 of the wall(s) 56 of the clarifier 10. In the embodiment illustrated in Figure 1, the feed line 16 discharges the feed slurry into the interior of the feed well baffle 54 and the multi-media filter bed 14 is positioned within the annulus 64. The flow conditions within the annulus 64 are quiescent relative to the flow

conditions within the sedimentation zone 12. In alternative embodiments illustrated in Figures 9, 10 and 11, the feed line 16 discharges the feed slurry into the annulus 64 and the multi-media filter bed 14 is positioned within the feed well baffle 54.

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In the embodiment illustrated in Figure 3 for which like reference numerals refer to like parts, the multi-media filter bed 14 comprises a plurality of sizes of particles of one compositional type of filter media, the plurality of sizes including a least one coarse fraction 80 and one fine fraction 82. The mean particle size of the particles in the coarse fraction 80 is greater than the mean particle size of the particles in the fine fraction 82. Any number of intermediate fractions 84 may be included in the multi-media filter bed. The mean particle size of each intermediate size fraction 84 is greater than the mean particle size of the fine fraction 82 but less than the mean particle size of the coarse fraction 80.

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In this embodiment, the particles are all of the same compositional type with varying specific gravities based on porosity. When the specific gravity of the particles is less than the specific gravity of the semi-clarified liquor, the particles will float and self-arrange whereby the fine fraction rises to the top of the multi-media filter bed 14 with the coarse fraction being positioned towards the bottom of the multi-media filter bed 14. An upper filter media retention screen 40 is used to ensure that the fine fraction 82 remains submerged within the semi-clarified liquor as described above. A lower media retention screen 50 may also be used as described above provided only that the size of the apertures (not shown) of the lower media retention screen 50 are small enough to block passage of the coarse fraction of particles 80 from passing through if the liquor is drained from the clarifier 10. The finer the mesh of the lower media retention screen 50, the more likely it is that the lower media retention screen may be blocked with fine suspended solids which would mean that the screen would need to be cleaned more frequently. One advantage of this embodiment of the present invention is that the coarse fraction 80 self-arranges towards the bottom of the multi-media filter bed 14 which means that the mesh size of the lower media retention screen 50 can be relatively large. A

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flow-on advantage of being able to use a relatively coarse mesh for the lower media retention screen 50 is that any flocculants or coagulants present in the semi-clarified liquor can readily pass through the lower media retention screen without significant impediment.

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As the semi-clarified liquor rises upwardly through the multi-media filter bed 14, any remaining solids present in the upwardly displaced semi-clarifier liquor encounter ever decreasing interstices between the buoyant filter media particles. This graded, or multi layered approach enables the coarsest suspended solids to be trapped by the coarse fraction 80 which the semi-clarified liquor encounters first as it rises through the multi-media filter bed 14.

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As the semi-clarified liquor passes through the coarse fraction 80 it reaches an intermediate sized fraction 86, wherein intermediate sized solids present in the semi-clarified liquor are removed. Similarly, finer solids present in the semi-clarified liquor are removed as the liquor rises up and through the particles which make up the fine fraction 82.

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Without wishing to be bound by theory, the reduction in the interstitial gaps between the buoyant filter media particles as the liquor flows upwards through the multi-media filter bed 14 means that the frequency of orthokinetic flocculation between the suspended solid particles is increased, which in turn promotes larger flocs to form resulting in more effective removal of the suspended solids as the filtrate penetrates further through the multi-media filter bed 14. Balanced against this, the pressure required to achieve flow through the filter increases with the depth of the multi-media filter bed 14. Thus, using layers that are graded from coarse to fine as the semi-clarified liquor rises upwardly through the multi-media filter bed 14, the solids holding capacity of the bed increases as it becomes possible for solids of different sizes to become retained across the full depth of the bed. This ensures longer run cycles between backwash cycles.

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The multi-media filter bed 14 is expected to become less efficient over time due to a build up of filtered solids being retained in the bed. Backwashing may be conducted periodically to rinse the multi-media filter bed 14 of these

retained solids as required. Advantageously, the buoyant filter media particles will self-arrange into the fractions or layers described above in use after backwashing has been completed. To effect backwashing operations, the clarifier 10 is provided with a backwashing system 34 for rinsing retained solids from the multi-media filter bed 14.

In the embodiments illustrated in Figures 1, 2 and 3, the backwashing system 34 consists of a backwash outlet 36 arranged at a height below the multi-media filter bed 14 or below the level of the lower media retention screen 50 when a lower media retention screen 50 is being used. In the embodiments illustrated in Figures 4 to 12, the backwashing system 34 further comprises a rinse liquor outlet 38 arranged at a height above the upper filter media retention screen 40 but below the level of the overflow weir 22. The backwash outlet 36 comprises a backwash outlet pipe 70 with a first end 72 which terminates within the sedimentation zone 12.

In the embodiment illustrated in Figure 4, the first end 72 of the backwashing outlet pipe 70 includes a frustoconical flared portion 74, the opening of which is oriented upwardly. To protect against direct discharge of the feed slurry into the upwardly oriented flared portion 74, the clarifier 10 is fitted with a flow diverter baffle 76. In an alternative embodiment illustrated in Figure 12, the opening of the frustoconical flared portion 74 is oriented downwardly to reduce the percentage of solids in the semi-clarified liquor that is removed through the backwash outlet pipe 70 during backwashing.

When backwashing is required, a first control valve (not shown) is actuated to allow liquor and solids from the sedimentation zone 12 to flow out of the clarifier 10 through the backwash outlet 36. There is no requirement to stop the addition of the feed slurry during this backwashing operation provided only that the rate of addition of the feed slurry is less than the rate of removal of liquor and solids through the backwash outlet 36. Provided that this requirement is met, the flow of liquor through the multi-media filter bed 14 is reversed and the overall liquor level in the clarifier 10 will drop. As a result, the clarified liquor from the uppermost portion 20 of the clarifier 10 drains back

downwardly through the multi-media filter bed 14. The clarified liquor in the uppermost portion 20 of the clarifier has already been filtered and thus represents a ready made source of clean liquid with which to rinse retained solids from the multi-media filter bed 14 during backwashing.

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Draining of the liquor and solids through the backwash outlet 36 is allowed to continue until the clarified liquor level has dropped to the level of the upper filter media retention screen 40 at which time the first control valve is shut. When this occurs, the liquor level will start to rise again due to the ongoing addition of feed slurry to the clarifier 10. Inevitably, the multi-media filter bed 14 will still have some retained solids within the bed, in particular, solids that were dislodged from within the bed itself during backwashing. Moreover, if the layers within the multi-media filter bed have been disturbed during the backwashing operation, some time is required to allow the filter media particles to settle back into optimum position. It is thus expected that the semi-clarified liquor that rises through the multi-media filter bed 14 immediately after backwashing (herein referred to as rinse liquor) will have lower clarity than the clarity achieved during steady-state operation. The rinse liquor is removed from the clarifier 10 by opening a second valve (not shown) to allow the rinse liquor to be removed through the rinse liquor outlet 38. The clarity of the rinse liquor is monitored and the second valve is closed when it is determined that the clarity of the rinse liquor is of sufficient quality.

Whilst it is preferred that the filter media particles are buoyant, this is not required for the working of the present invention. In the embodiments illustrated in Figures 8 and 10, the specific gravity of some or all of the various types of filter media is greater than the specific gravity of the semi-clarified liquor. In these embodiments, the clarifier 10 is provided with a plurality of screens 88 to hold the plurality of different types of media within a corresponding plurality of designated layers denoted 89, 91, 93 and 95 within the multi-media filter bed 14. It is equally possible to use a lower media retention screen 50 instead of or in combination with the plurality of screens 88 to resist downward movement of non-buoyant filter media particles below a pre-determined height.

Figure 9 illustrates an alternative embodiment of the clarifier illustrated in Figure 8, for which like reference numerals refer to like parts, in which the feed line 16 discharges the feed slurry into the annulus 64. In this embodiment, the multi-media filter bed 14, the upper media retention means 40 and the optional lower media retention means 50 are positioned within the feed well baffle 54. The operation of the clarifier 10 remains otherwise unchanged except that the position of the weir 22 and overflow launder 24 has also changed to facilitate removal of clarified liquor from the centre of the clarifier rather than the periphery. An alternative arrangement for effecting removal of the clarified liquor from above the multi-media filter bed 14 is illustrated in Figures 10 and 11 for which like reference numerals refer to like parts. In this embodiment, the overflow outlet 26 is provided at a first end 102 of an overflow liquor pipe 104. The second end 106 of the overflow liquor pipe 104 terminates within the feed well baffle 54 at a height above the multi-media filter bed 14. As best seen in Figure 10, the second end 106 includes a frustoconical flared portion 108 to assist in guiding the flow of the clarified liquor into the overflow liquor pipe 104.

Now that several preferred embodiments of the present invention have been described in some detail, it will be apparent to those skilled in the art that the thickener or clarifier has at least the following advantages over the admitted prior art:

- a) the thickener or clarifier is effective in filtering solids from a variety of semi-clarified liquors after subjecting a feed slurry to an initial sedimentation stage to reduce the percentage of solids present;
- b) sedimentation and filtration are achieved in a single compact unit;
- c) the thickener or clarifier can be designed such that the filter media layers are graded from fine to coarse or self-arrange into discrete layers according to different relative specific gravities;
- d) the thickener or clarifier can be designed such that the coarsest fraction of particles assist in retention of the filter media on a lower media retention screen whilst ensuring that the finer fraction of filter particles are retained within the clarifier at all times;

e) the filter media can be provided with different material properties such that different substances suspended within the liquor are preferentially attracted to one or other media layers as the semi-clarified liquor percolates upwards through the multi-media filter bed;

5 f) filtration efficiency is improved because finer solids from the semi-clarified liquor are removed using the fine fraction of filter media particles after the coarse solids have been removed from the semi-clarified liquor by the coarse fraction of filter media particles before the liquor reaches the finer zones;

10 g) the potential for the filtrate or feed liquor to channel through the graded filter media is reduced because the nature of the multi-media filter bed is such that it provides a high degree of uniformity of overall cross-section due to the ability of the multiple layers to self-arrange to smooth out any partial channelling that may start to occur;

15 h) the reduction in the interstitial gaps of the media as the liquor flows upwards through the filter bed means that the frequency of orthokinetic flocculation between the suspended solid particles is increased, which in turn promotes larger flocs resulting in more effective removal of the suspended solids as the filtrate penetrates further through the bed; and,

20 i) when compared against a single media filter bed, the dirt holding capacity is greatly increased as a single media filter bed is only able to filter on the surface, while filtration is able to occur through the full depth of the multi-media filter bed of the present invention.

25 Now that several embodiments of the invention have been described in detail, it will be apparent to persons skilled in the relevant art that numerous variations and modifications can be made without departing from the basic inventive concepts. For example, the clarifier or thickener may be provided with a pre-filtering screen arranged between the sedimentation zone and the
30 multi-media filter bed for pre-filtering a desired range of sized solids from the semi-clarified liquor as it is flows from the sedimentation zone to the multi-media filter bed.

As another example, the clarifier may include a pre-conditioning zone arranged between the sedimentation zone and the multi-media filter bed for treating the semi-clarified liquor as it flows from the sedimentation zone to the multi-media filter bed. Pre-conditioning may be achieved in a variety of ways, including
5 chemical injection and/or adjusting the temperature of the semi-clarified liquor stream using an injection of steam. Pre-conditioning may include the addition of a chemical, for example a pH modifying agent which causes precipitation of solids from the semi-clarified liquor. Pre-conditioning of the slurry may equally
10 be achieved through the addition of a flocculating or coagulating agent or polymer to encourage the formation of flocs. The space 48 above the lower media retention screen 50 is an ideal location for pre-conditioning the semi-clarified liquor.

To facilitate cleaning of suspended solids from the multi-media filter bed 14,
15 the clarifier 10 may be fitted with a media scouring system (not shown). In one embodiment, the media scouring system relies on the injection of a fluid, through an arrangement of pipes, headers or manifolds into the multi-media filter bed 14 so as to cause agitation of the filter media particles. In one
20 embodiment the fluid is a gas, for example air. The fluid could equally be a liquid, for example liquor. Without wishing to be bound by theory, agitation of the filter media particles causes collisions between the particles with the result that suspended solids that are otherwise attached to the media particles become dislodged as individual particles collide or rub together.

25 The fluid may be injected into the multi-media filter bed 14 either upwards, horizontally, tangentially or downwards, depending on the cleaning requirements of the particular type of multi-media filter bed 14.

Injection of the fluid is allowed to continue for a pre-determined interval of
30 time before the media scouring system is switched off. The filter media particles may then be rinsed using the backwashing system 34 described above. It is equally possible to run the media scouring system and the backwashing system simultaneously. The overall objective of the media scouring and backwashing operations is to improve media cleaning and

maintenance, so that efficient filtration can be realized over a sustained period of time.

5 Reassembly of the various layers of the multi-media filter bed 14 into the desired sequence of size and density order after scouring can be facilitated by gently lowering the level of the liquor in the clarifier 10, then raising the level slowly again. This allows the various layers of the multi-media filter bed 14 to self-arrange in the manner described above.

10 The media scouring system may be arranged to inject the fluid under pressure between particular target layers in the multi-media filter bed 14 or be arranged to cause agitation of all of the layers in the multi-media filter bed 14. One suitable location for the media cleaning system is between intermediate layer(s) 46 and the lower layer 44 of Figure 1. In order to ensure that
15 effective cleaning of the multi-media filter bed 14 occurs, the fluid is introduced when the liquor level has been lowered to just below lower media retention screen 40.

The multi-media cleaning system may equally be mounted within the space 48
20 which is formed between the lower layer 44 of the buoyant filter media particles and the lower filter media retention screen 50, as shown on Figure 1 so that all the layers of the of the multi-media filter bed 14 will be subject to the cleaning operation.

25 In yet another embodiment, the multi-media cleaning system comprises an arrangement of pipes arranged to distribute air or another suitable fluid into the multi-media filter bed 14 and the arrangement of pipes forms a portion of the lower media retention screen 50.

30 Where the media scouring system has been set to cause vigorous agitation, it can be beneficial, towards the end of the scouring operation, to reduce the rate of injection of the fluid into the media filter bed 14 for a period of time sufficient to enable the filter media particles to self-arrange into optimum position. In this embodiment, the fluid is injected into the media filter bed 14

at a first flow rate to cause vigorous agitation of the filter media particles for a pre-determined first period of time during scouring, and a second flow rate to cause gentle agitation for a pre-determined second period of time after scouring to encourage the filter media particles to self-arrange into optimum position after scouring. Alternatively or additionally, the liquor may be pulse drained or subjected to other hydraulic action such as will facilitate the return to the desired media layers in the optimum position.

All such modifications and variations are considered to be within the scope of the present invention, the nature of which is to be determined from the foregoing description and the appended claims.

Claims defining the Invention:

1. A thickener or clarifier comprising:
 - a feed line for introducing a feed slurry to the thickener or clarifier, the feed slurry comprising one or more solid species and a liquid fraction,
 - a sedimentation zone for receiving the feed slurry from the feed line and allowing the one or more solid species to settle under gravity towards a lowermost portion of the sedimentation zone whereupon a semi-clarified liquor is displaced in an upward direction;
 - a multi-media filter bed comprising a plurality of filter media particles and arranged at a height above the sedimentation zone for filtering solids from the upwardly displaced semi-clarified liquor to produce a clarified liquor overflow;
 - an underflow outlet for removing a high density solids underflow from a lowermost portion of the sedimentation zone; and,
 - an overflow outlet for removing clarified liquor from an uppermost portion of the multi-media filter bed.

2. The clarifier or thickener of claim 1 wherein the multi-media filter bed comprises a plurality of sizes of particles of a filter media, the plurality of sizes including a least one coarse fraction and one fine fraction, the mean particle size of the particles in the coarse fraction being greater than the mean particle size in the fine fraction.

3. The clarifier or thickener of claim 2 wherein the plurality of sizes further includes at least one intermediate fraction wherein the mean particle size of the intermediate size fraction is greater than the mean particle size of the fine fraction but less than the mean particle size of the coarse fraction.

4. The clarifier or thickener of claim 1 wherein the multi-media filter bed comprises a plurality of compositional types of filter media particles, each type of filter media particle having different chemical or physical properties.

5. The clarifier or thickener of claim 4 wherein the plurality of different compositional types of filter media particles have the same mean particle size.
6. The clarifier or thickener of claim 4 or 5 wherein the different physical property is the specific gravity of the particles such that the multi-media filter bed consists of at least one heavy fraction and at least one light fraction.
7. The clarifier or thickener of claim 4 or 5 wherein the different chemical property is the surface chemistry of the particles
8. The clarifier or thickener of claim 4 or 5 wherein the multi-media filter bed includes at least one cationic fraction for attracting anionic solids species from the semi-clarified media or the multi-media filter bed includes at least one anionic fraction for attracting cationic solids from the semi-clarified media.
9. The clarifier or thickener of any one of claims 4 to 8 further comprising a plurality of screens or a plurality of graded screens for holding the plurality of different types of media within a corresponding plurality of designated layers within the multi-media filter bed.
10. The clarifier or thickener of any one of the preceding claims further comprising a lower filter media retention screen to resist downward movement of the filter media particles of the multi-media filter bed.
11. The clarifier or thickener of any one of the preceding claims further comprising an upper filter media retention screen to resist upward movement of the filter media particles of the multi-media filter bed.
12. The clarifier or thickener of any one of the preceding claims wherein the multi-media filter bed comprises particles of a buoyant filter media, the filter media particles having a specific gravity less than the specific gravity of the semi-clarified liquor.

13. The clarifier or thickener of claim 12 wherein the upper filter media retention screen is arranged to ensure that the buoyant filter media remains submerged in use in the semi-clarified liquor being filtered.

14. The clarifier or thickener of any one of the preceding claims wherein the filter particles are made from the following materials alone or in combination: plastic, metal, glass, ceramic, or composite.

15. The clarifier or thickener of any one of the preceding claims wherein the filter media particles are hollow or porous

16. The clarifier or thickener of any one of the preceding claims wherein the filter media particles have a central core of one compositional type with a coating of a second compositional type.

17. The clarifier or thickener of any one of claims 1 to 16 wherein the feed line delivers feed slurry to an annulus defined between the outermost surface of a feed well baffle and the innermost surface of the wall(s) of the clarifier or thickener and the multi-media filter bed is located within the feed well baffle.

18. The clarifier or thickener of any one of the preceding claims further comprising a backwash system including a backwash outlet for periodically rinsing retained solids from the multi-media filter bed, the backwash outlet arranged at a height below the multi-media filter bed.

19. The clarifier or thickener of claim 18 wherein the backwash outlet is arranged at a height below a lower filter media retention screen.

20. The clarifier or thickener of claim 18 or 19 further comprising a rinse liquor outlet arranged at a height above an upper filter media retention screen but below the level of an overflow weir.

21. The clarifier or thickener of any one of claims 18 to 20 wherein the backwash outlet comprises a backwash outlet pipe with a first end which terminates within the sedimentation zone, the first end of the backwash outlet pipe including a frustoconical flared portion.

22. The clarifier or thickener of any one of the preceding claims further comprising a media scouring system arranged to inject a fluid into the multi-media filter bed so as to cause agitation of the filter media particles.

23. The clarifier or thicker of claim 22 wherein the media scouring system comprises an arrangement of pipes, headers or manifolds for directing and controlling the injection of the fluid into the multi-bed filter bed.

24. The clarifier or thickener of claim 23 wherein the arrangement of pipes, headers or manifolds directs the injection of the fluid upwards, horizontally, tangentially or downwards.

25. The clarifier or thickener of any one of claims 22 to 24 wherein the fluid is injected into the media filter bed at a first flow rate to cause vigorous agitation of the filter media particles for a pre-determined first period of time during scouring and a second flow rate to cause gentle agitation for a pre-determined second period of time after scouring to encourage the filter media particles to self-arrange into optimum position after scouring.

26. The clarifier or thickener of any one of claims 22 to 25 wherein the fluid is one or both of air or liquor.

27. A method of thickening or clarifying comprising the steps of adding a feed slurry to the clarifier or thicker of any one of claims 1 to 26 and removing a clarified liquor therefrom.

28. A plurality of filter media particles for use in the clarifier or thickener of any one of claims 1 to 26.

29. A thickener or clarifier substantially as herein described with reference to and as illustrated in the accompanying drawings.

30. A method of thickening or clarifying substantially as herein described with reference to and as illustrated in the accompanying drawings.

31. A method of backwashing a thickener or clarifier substantially as herein described with reference to and as illustrated in the accompanying drawings.

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EDITORIAL NOTE

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**The following amended Claims do not contain
page number 26.**

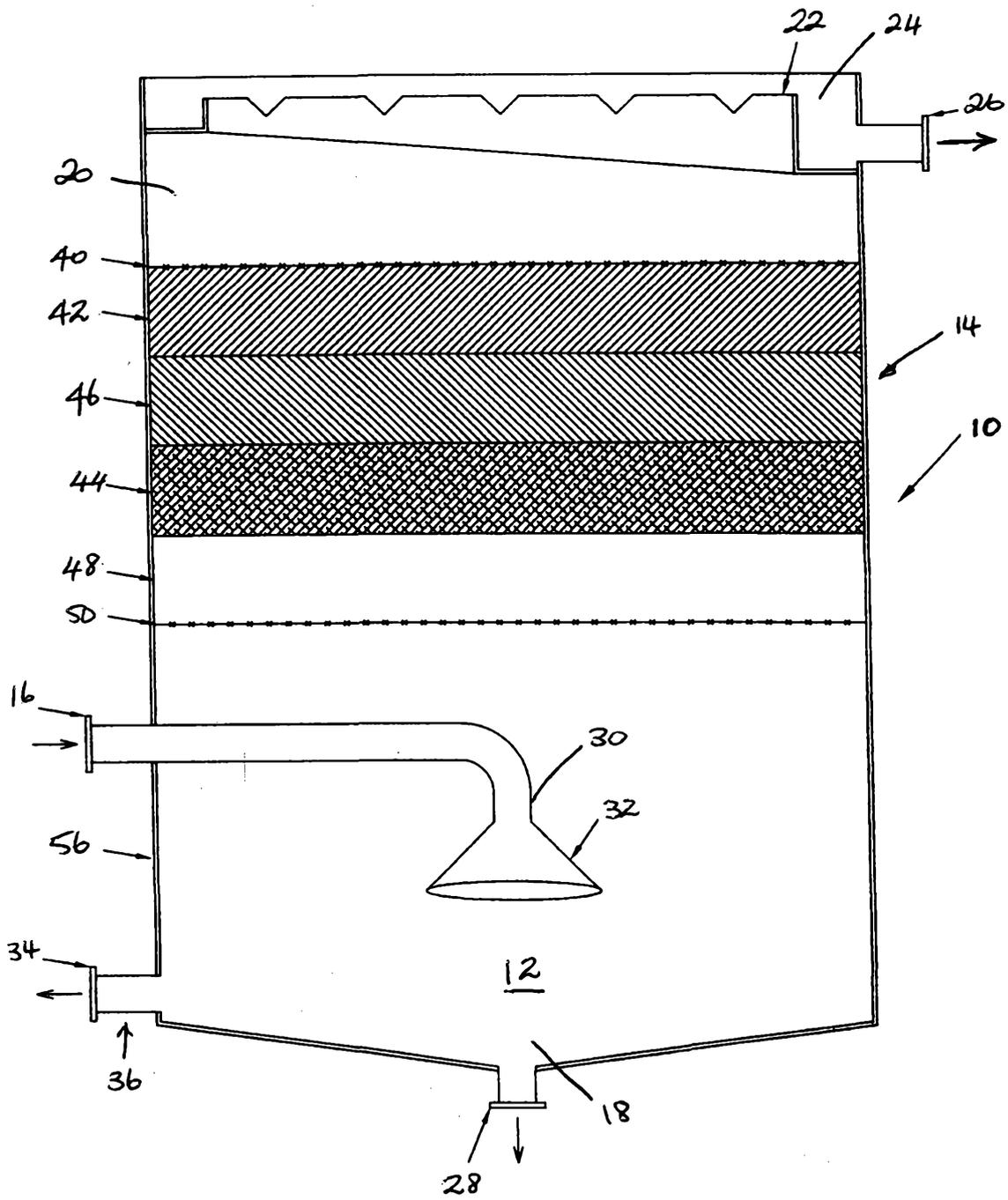


Fig-1

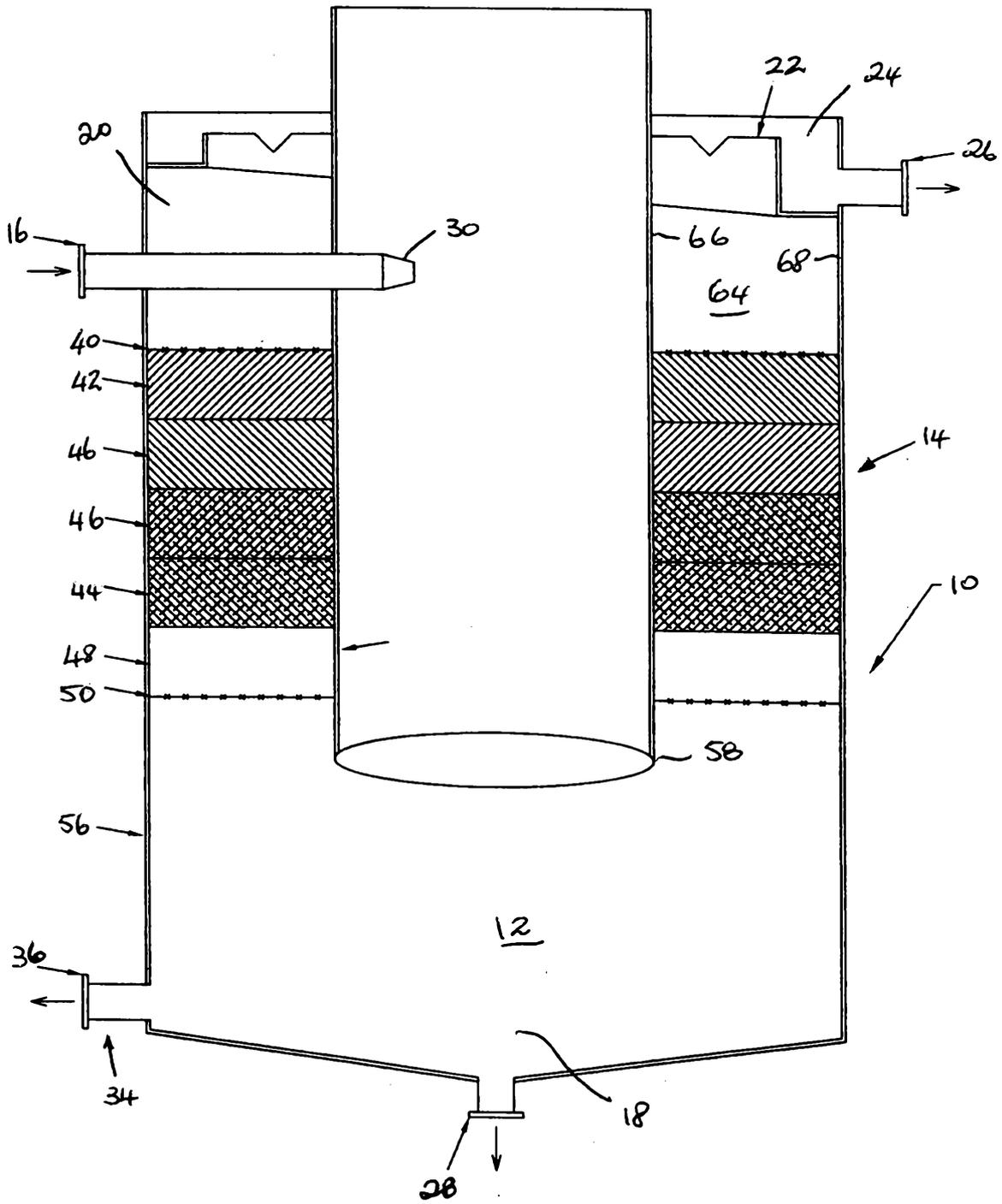


Fig-2

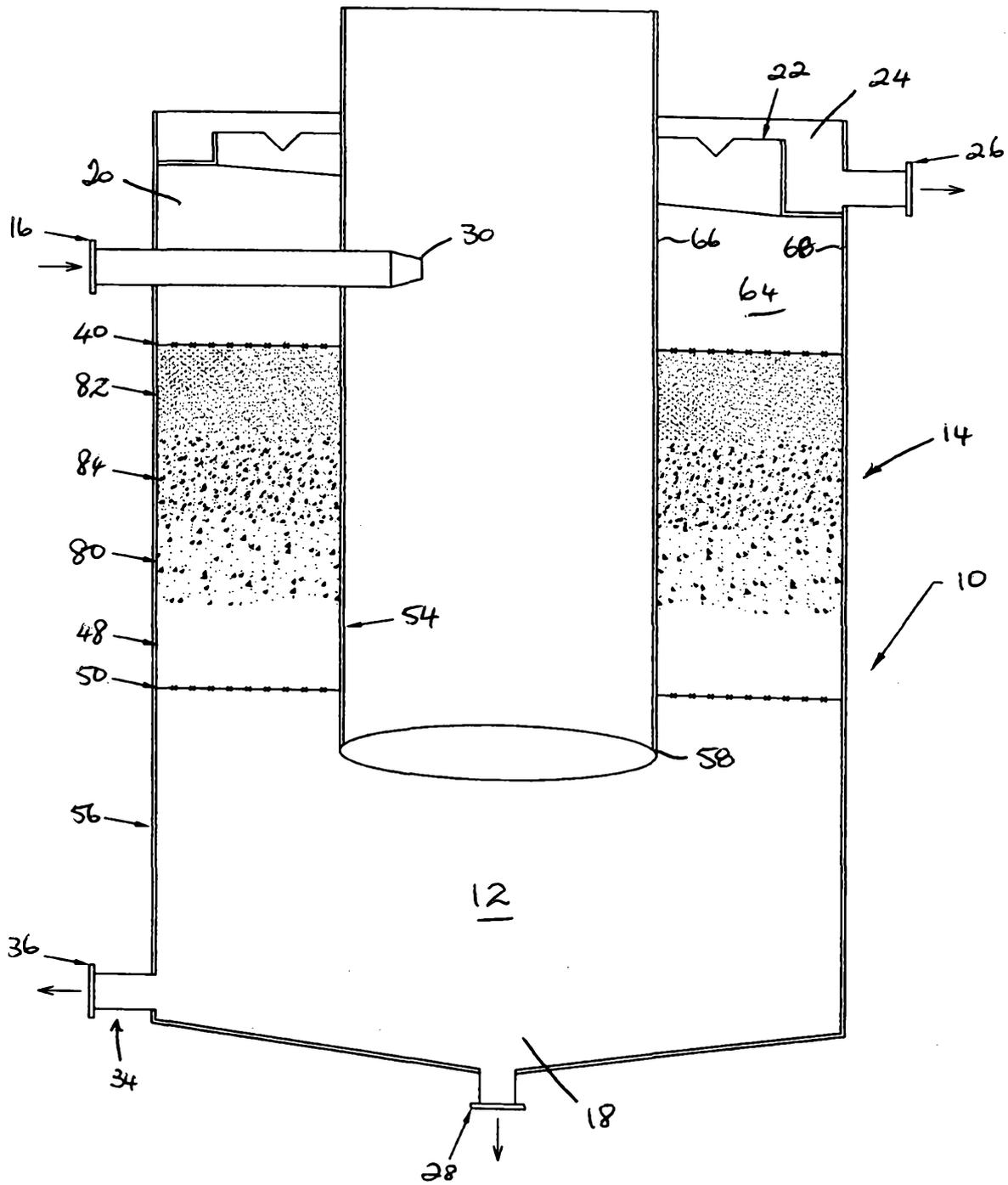


Fig-3

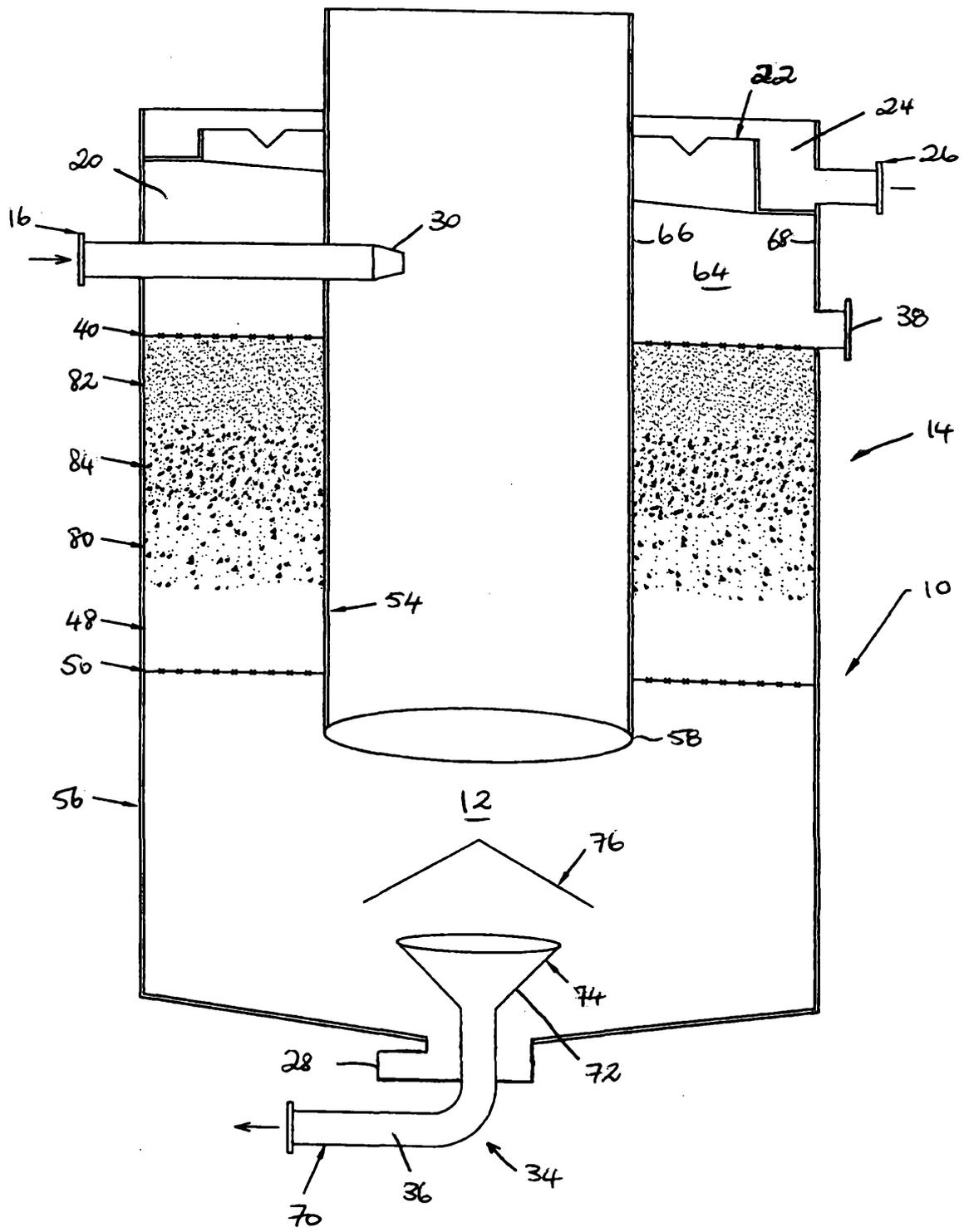


Fig-4

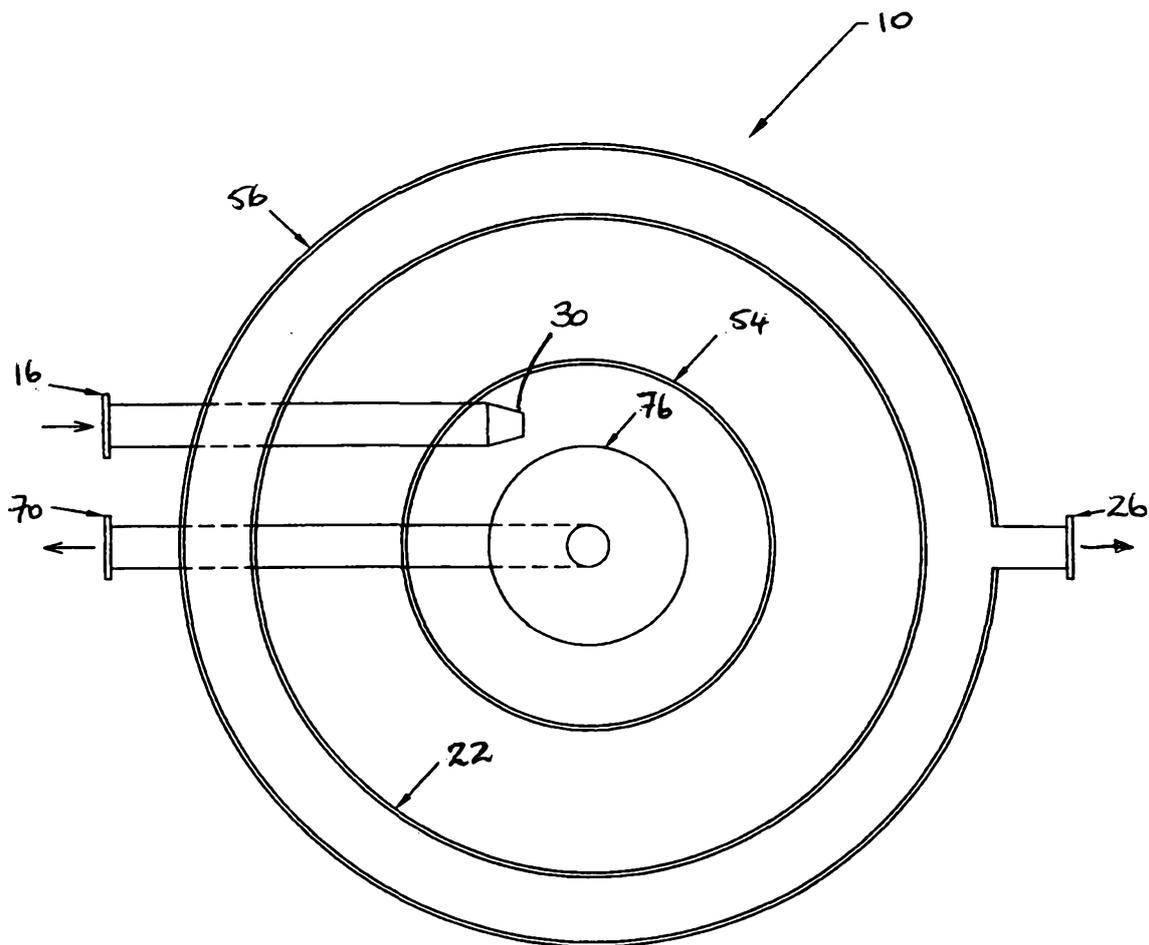


Fig- 5

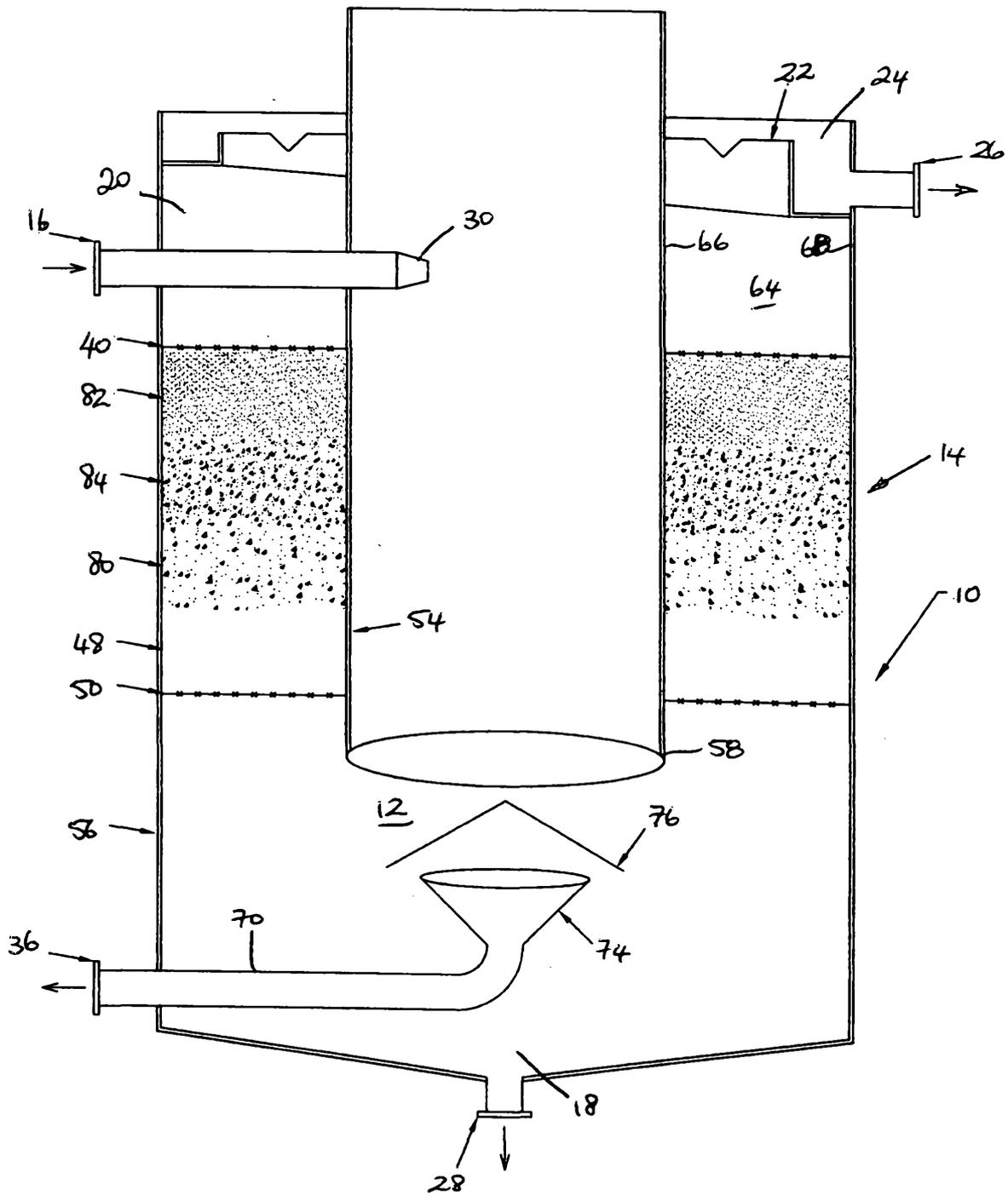


Fig-6

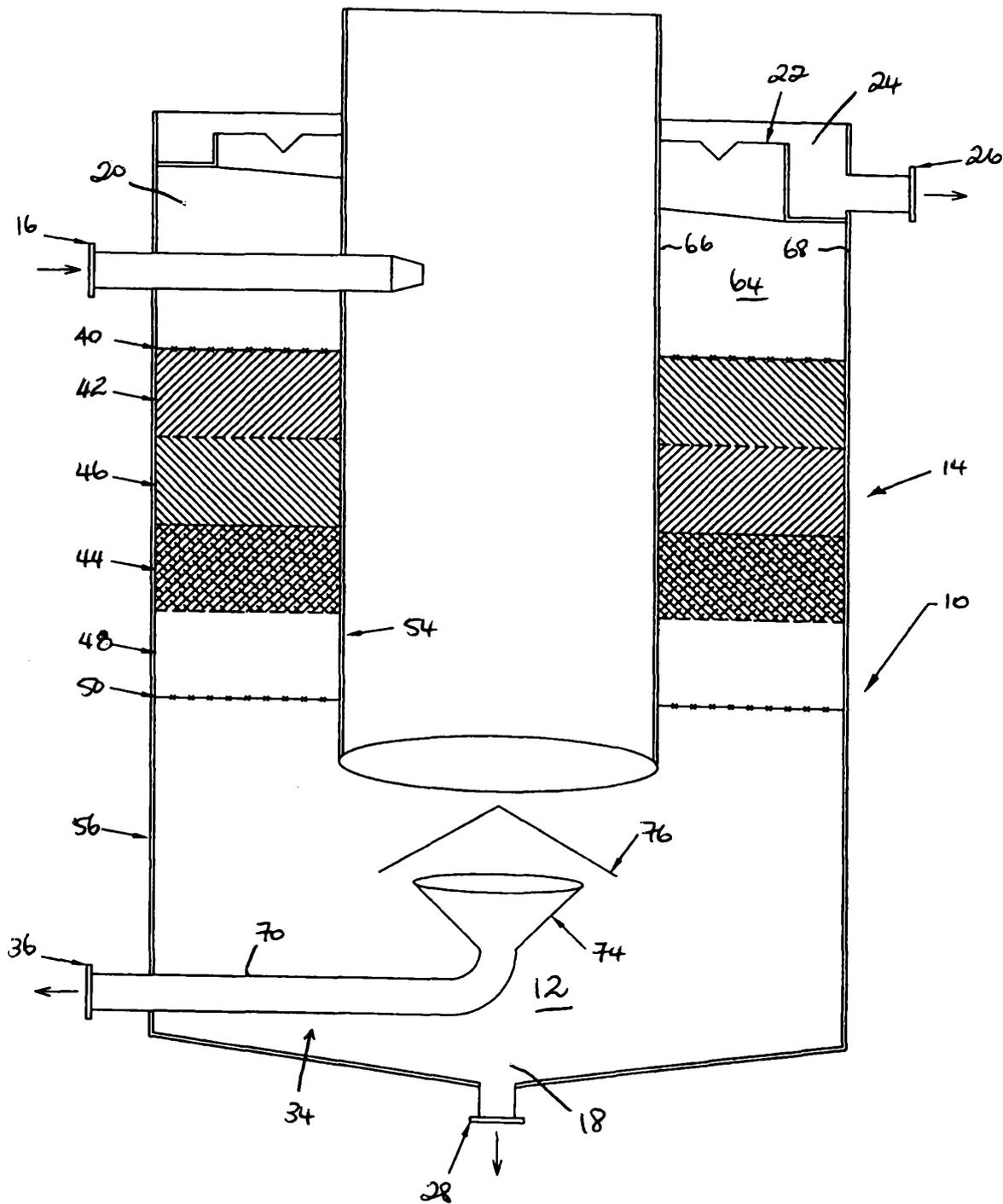


Fig. 7

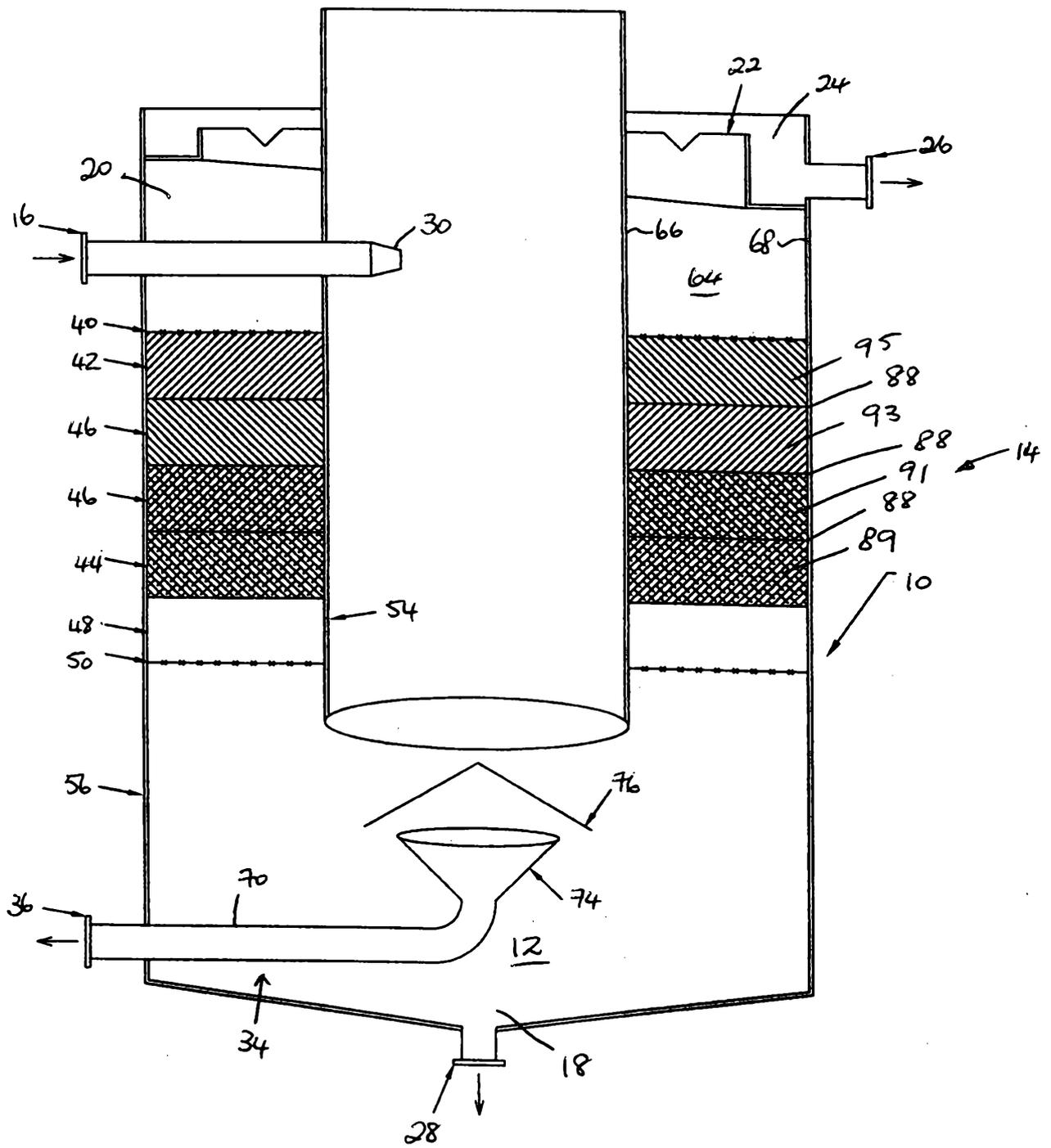


Fig- 8

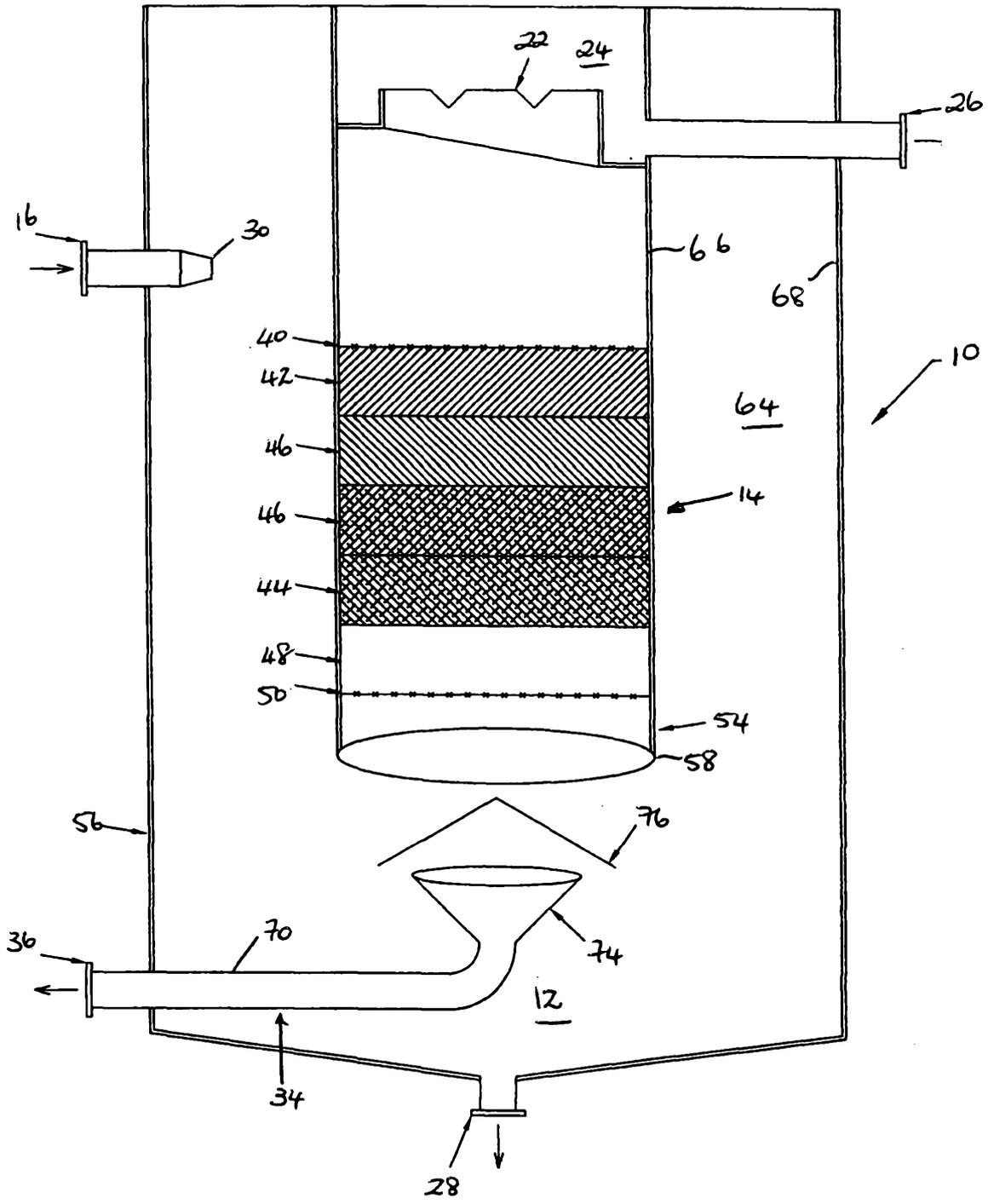


Fig-9

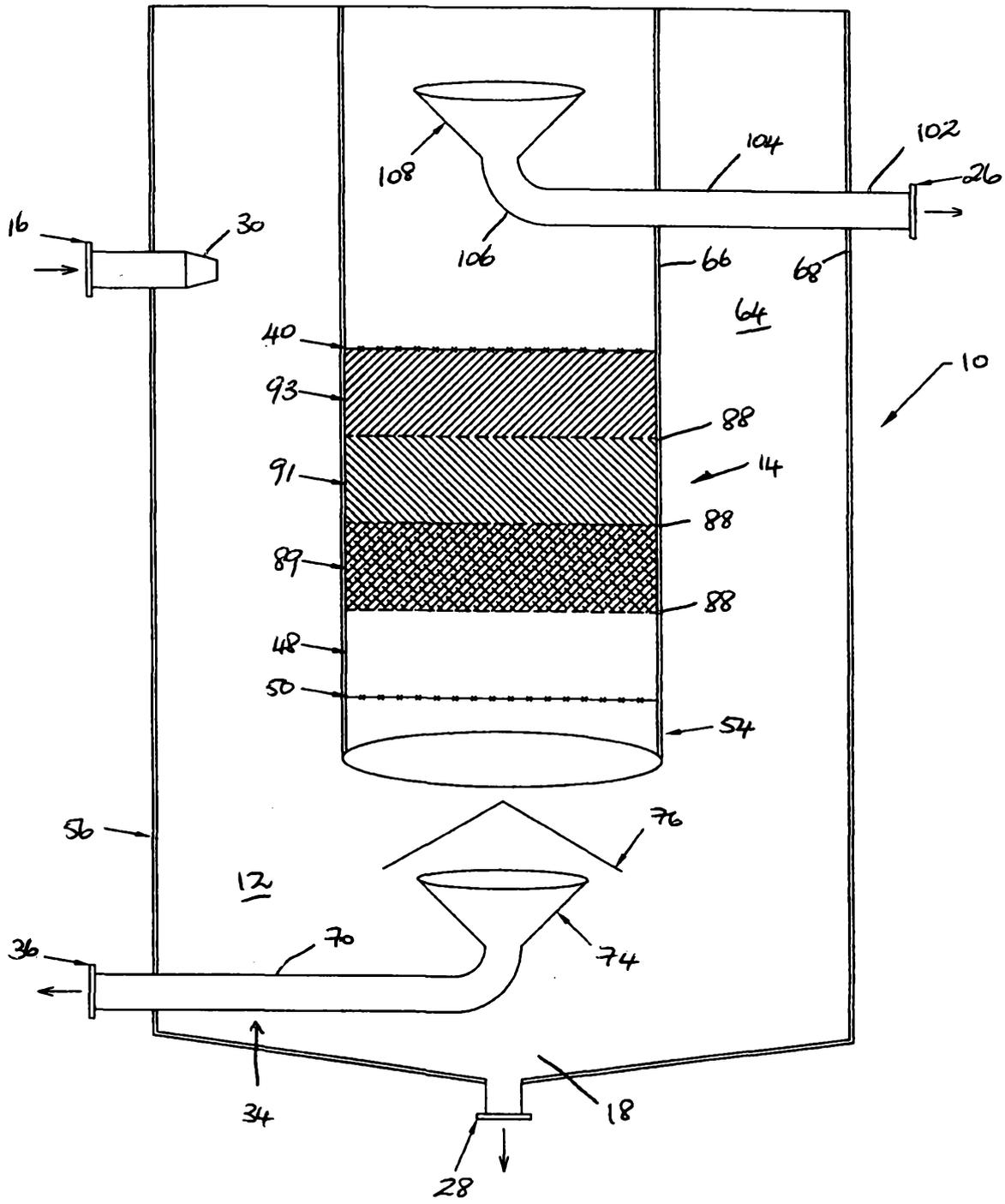


Fig-10

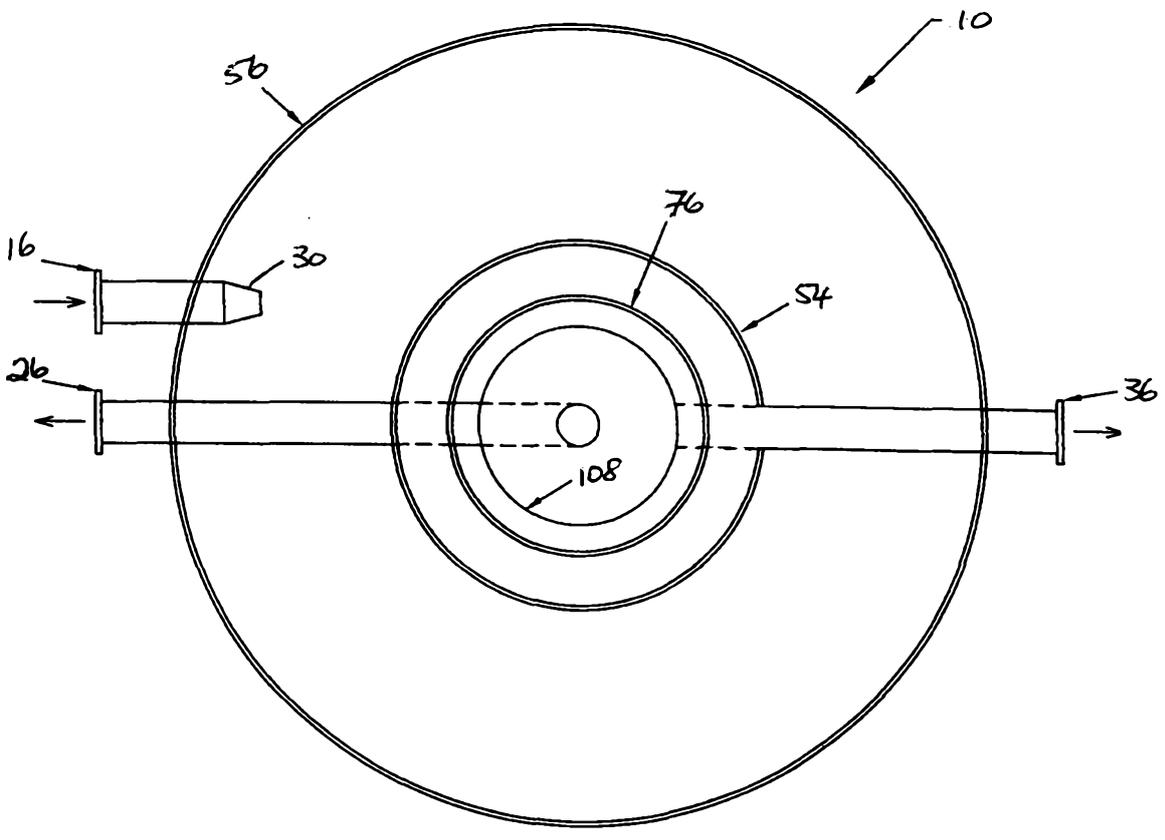


Fig. 11

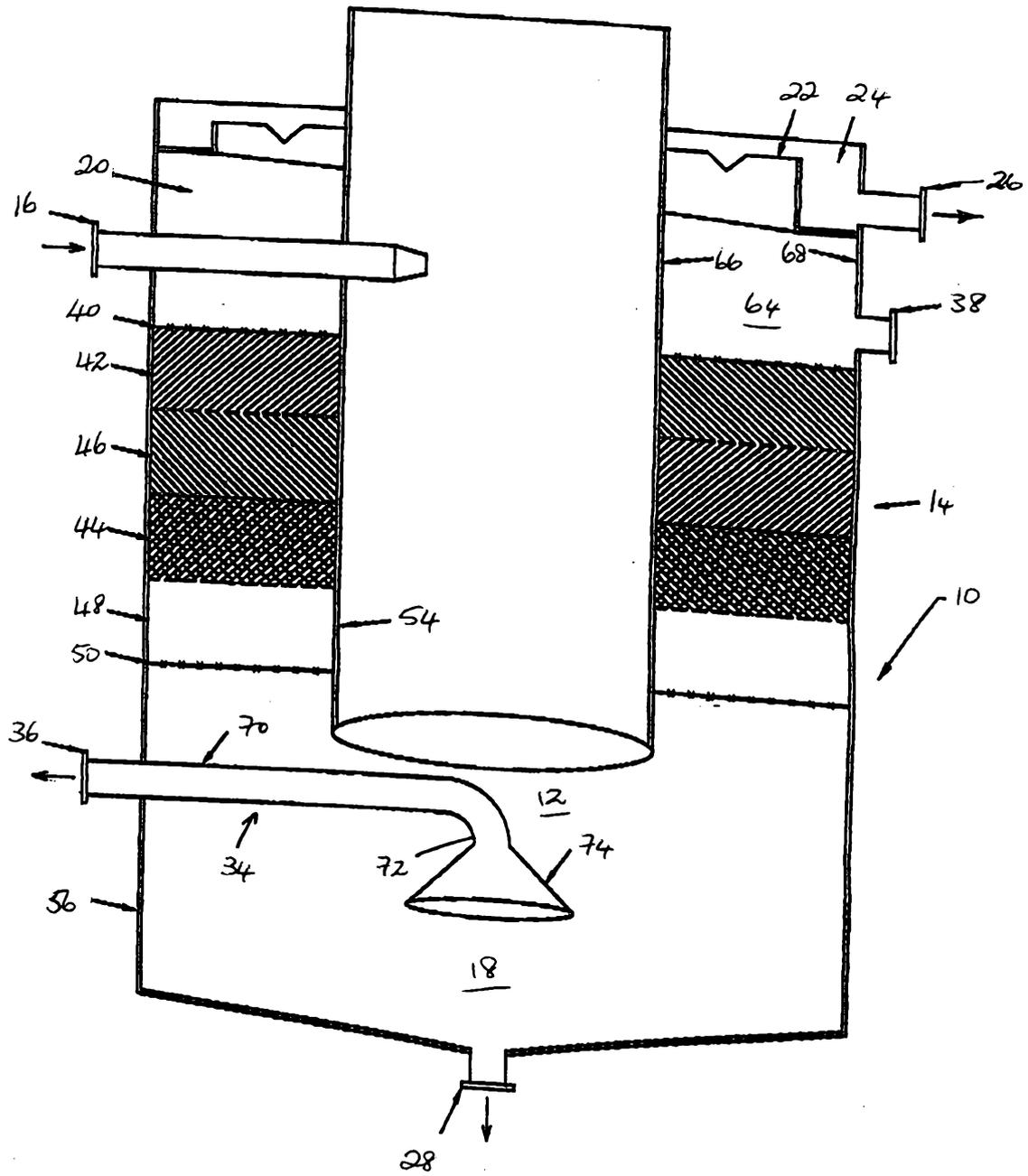


Fig-12