Abstract: A treatment system for a wastewater includes an electrolytic reactor, which has a first chamber. A second chamber and a conduit. The first chamber is configured for accumulating the wastewater entering therein. The second chamber has a pair of electrodes configured to produce an electric field. The conduit is configured to connect the first chamber to the second shamber. The system is configured such that a follow of the wastewater through the electric field is substantially laminar. The treatment system also includes a precious metal recover system as well as various filtration and sedimentation apparatuses including s semi-permeable envelope filter.

Integrated waste water recovery and background of the invention

The present invention relates to a wastewater treatment system and, in particular, it concerns a wastewater treatment system using laminar flow through an electric field. By way of introduction, electrolysis of wastewater is performed as part of a water treatment process to remove metals and remove and/or neutralize organic and other impurities from a wastewater. Electrolysis is a preferred method to remove metals from wastewater, as it does not require the use of hazardous chemicals, unstable bacteria treatment or expensive treatment by catalysts. The electrolysis process normally involves passing the wastewater between at least one pair of electrodes to produce hydroxyl ions that precipitate metal ions from the wastewater as metal hydroxides. The wastewater stream is then filtered to remove the metal ions and other impurities. However, for the electrolysis process to be successful, the electrodes need to pass sufficient energy to the water.

According to the prior art, if wastewater is to be activated electrolytically, the wastewater should be made to flow turbulently past electrodes. Representative prior art patents include U.S. Patent No. 5,928,493 and U.S. Patent No. 6,294,061, both to Morkovsky et al., and U.S. Patent No. 6,346,197, to Stephenson et al. These patents teach electrocoagulation initiated by having the wastewater flow in a serpentine path around interleaved electrode plates. Representative prior art patents also include U.S. Patent No. 6,328,875, to Zappi et al., who teach electropurification in electrolytic cells in which the wastewater flows through and around the electrodes.

Also of relevance to the present invention is U.S. Patent No. 6,358,395 to Schorzman et al. Schorzman et al. teach the conditioning of drinking water by reverse osmosis, followed by electrolysis. The electrolysis is performed in a vertical electrolytic cell in which electrode plates are mounted vertically. After the water leaves the area between the electrode plates, the water enters a dissolving chamber, which is directly above the electrode plates. The dissolving chamber contains water in a quiet zone, undergoing preferably laminar flow. Within this quiet zone, additional room is provided for the oxygen gas to dissolve into the water. First, Schorzman et al. uses the electrolysis to condition the water and not to purify the water.

Second, Schorzman et al. does not teach laminar flow of the water between the electrodes, rather Schorzman et al. teaches laminar flow after the water has left the electrodes.

Also of relevance to the present invention is U.S. Patent No. 6,139,714 to Livshits, which teaches an apparatus for adjusting the pH of an aqueous flowable fluid. The apparatus includes two columns which are interconnected. One column which contains a pair of electrodes has a smaller volume than the other column. Therefore, the addition of water to the column without the electrodes causes an acceleration of the water between the electrodes in the other column. There is also a membrane between the electrodes. U.S. Patent No. 6,139,714 does not refer to whether the water flow is laminar or turbulent. However, it is evident from the square edges of the design of the columns (Fig. 3 and Fig. 4) that maintaining laminar flow was not considered important, as the square edges of the columns will generally set up turbulence within the water.

A shortcoming of the aforementioned systems is due to water flowing turbulently through an electric field to purify water. First, if the water is flowing turbulently, air pockets form in the water, causing parts of the water to remain untreated or subject to different levels of treatment. Second, air pockets create electrical resistance and reduce the effect of the transfer of electrical energy by the electrodes to the water. It should be noted that the success of electrolysis in purifying water depends on the electrical energy transfer to the water during the process. Third, if the water is flowing turbulently, different portions of the water will travel through the electric field at different speeds resulting in different levels of treatment to different portions of the water.

There is therefore a need for a wastewater treatment system which employs laminar flow of wastewater through an electric field while giving a high throughput of wastewater treatment.

Summary of the invention

The present invention is a wastewater treatment system and method of operation thereof.

According to the teachings of the present invention there is provided, a treatment system for wastewater, comprising: (a) a first chamber; (b) a second chamber having a pair of electrodes configured to produce a first electric field; and (c) a conduit configured to connect the first chamber to the second chamber, wherein at least one of the first chamber, the second chamber and the conduit are formed such that a flow of the wastewater through the first electric field is substantially laminar.

According to a further feature of the present invention, there is also provided: (d) a semi-permeable membrane which is disposed between the pair of electrodes.

According to a further feature of the present invention, the semi-permeable membrane substantially separates at least a part of the wastewater which is in the second chamber into a first flow and a second flow; and wherein the second chamber includes a first outlet and a second outlet such that the first flow exits from the second chamber via the first outlet and the second flow exits from the second chamber via the second outlet.

According to a further feature of the present invention, the wastewater is configured to flow first substantially parallel and then substantially perpendicular to the first electric field.

According to a further feature of the present invention, the wastewater is configured to flow first substantially perpendicular and then substantially parallel to the first electric field.

According to a further feature of the present invention, at least one of the pair of electrodes is configured so that upon at least one of entering and exiting the second chamber, the wastewater flows substantially parallel to the first electric field.

According to a further feature of the present invention, at least one of the pair of electrodes has two major surfaces and a hole extending between the two major surfaces so that upon at least one of entering and exiting the second chamber, at least part of the wastewater flows through the hole.

According to a further feature of the present invention, there is also included: (d) an edge protector having a length perpendicular to the major surfaces; the length being longer than a depth of the one electrode measured perpendicular to the major surfaces, the edge protector being configured to enhance an energy transfer between the one electrode and the wastewater which is flowing through the hole.

According to a further feature of the present invention, at least one of the first chamber, the second chamber and the conduit are formed such that separate flows of the wastewater through the first electric field are treated substantially identically.

According to a further feature of the present invention, there is also included: (d) a third chamber; and (e) a second conduit configured to connect the third chamber to the second chamber, wherein at least one of the first chamber, the second chamber, the third chamber, the conduit and the second conduit are formed such that a flow of the wastewater through the first electric field is substantially laminar and separate flows of the wastewater through the first electric field are treated substantially identically.

According to a further feature of the present invention, there is also included: (f) a fourth chamber having a second pair of electrodes configured to produce a second electric field; wherein the system is configured such that the wastewater is treated substantially identically by the first electric field and the second electric field.

According to a further feature of the present invention, there is also included a filtration apparatus which includes: (a) a plurality of filtration elements configured to cooperate to filter the wastewater of an impurity; and (b) an air pump configured to clean the filtration elements of at least a part of the impurity during a normal operation of the filtration apparatus.

According to a further feature of the present invention, each of the filtration elements includes a member having a plurality of grooves thereon.

According to a further feature of the present invention, there is also included a precious metal recovery apparatus which includes: (a) a first electrode formed from a material having a high surface area to volume ratio; and (b) a second electrode, the first electrode and the second electrode being configured for connection to a power supply to enable recovery of the precious metal from the wastewater by electroplating of the first electrode with at least part of the precious metal.

According to a further feature of the present invention, the material is an absorbent conducting material.

According to a further feature of the present invention, the material is a carbographite material.

According to a further feature of the present invention, there is also included a semi- permeable envelope for filtering an impurity from the wastewater, the envelope including: (a) an inlet configured to allow the wastewater to enter the envelope; and (b) a plurality of holes configured to: (i) allow exit of the wastewater from the envelope; (ii) trap at least part of the impurity inside the envelope; wherein the envelope is configured to stretch to maintain a substantially constant filtering throughput of the envelope when the at least part of the impurity adheres near the holes.

According to a further feature of the present invention, the envelope is substantially formed of a knitted fabric.

According to a further feature of the present invention, the knitted fabric includes a polyamide thread.

According to a further feature of the present invention, there is also included a wastewater sedimentation apparatus which includes: (a) a plurality of deflecting elements configured to cooperate to enhance sedimentation of impurities from the wastewater: and (b) a distribution member configured to distribute the wastewater among the deflecting elements.

According to a further feature of the present invention, each of the deflecting elements is shaped substantially as a truncated cone.

According to a further feature of the present invention, the truncated cone has at least one projection.

According to a further. feature of the present invention, the projection is substantially radial.

According to a further feature of the present invention, the distribution member is a perforated pipe.

According to a further feature of the present invention, the deflecting elements and the distribution member are co-axially arranged.

According to a further feature of the present invention, there is also provided a plurality of spacer members, each of the spacer members being disposed between the distribution member and two of the deflecting elements, the spacer members configured to maintain a laminar flow of the wastewater in order to enhance sedimentation of impurities from the wastewater.

According to a further feature of the present invention, there is also included a filtration apparatus to filter an impurity from the wastewater, the filtration apparatus including: (a) a first surface having a plurality of ridges and grooves; and (b) a second surface having a plurality of ridges and grooves wherein the first surface is disposed facing the second surface such that, the grooves of the first surface are nonparallel to the grooves of the second surface in order to cause at least part of the wastewater to take a non-linear path between the first surface and the second surface thereby filtering at least part of the impurity.

According to a further feature of the present invention, the grooves of the first surface are substantially cross-aligned with the grooves of the second surface.

According to a further feature of the present invention, there is also included a filtration apparatus for filtering an impurity from wastewater, the filtration apparatus including: (a) a granular catalyst configured to remove at least part of the impurity from the wastewater; and (b) a semi-permeable envelope having a plurality of holes, the envelope being configured to contain the granular catalyst, the plurality of holes being configured to allow exit of the wastewater from the envelope, wherein the envelope is configured to stretch to maintain a substantially constant filtering throughput of the envelope when at least part of the impurity adheres near the holes.

According to a further feature of the present invention, the envelope has an upper surface, the filtration apparatus further including: (c) a tank configured to hold the envelope; and (d) a water disperser configured to distribute the wastewater entering the tank over the upper surface of the envelope in order to maximize contact of the wastewater with the granular catalyst.

According to a further feature of the present invention, the water disperser includes an element having a plurality of holes therein, wherethrough the wastewater flows.

According to a further feature of the present invention, the filtration apparatus further includes: (c) a tank configured to hold the envelope, the tank having an outlet configured to allow a drainage of the wastewater from the tank; and (d) a water integrator configured to prevent the envelope from obstructing the drainage of the wastewater via the outlet.

According to a further feature of the present invention, the water integrator is an element having a plurality of holes therein, wherethrough the wastewater flows.

According to a further feature of the present invention, the envelope is substantially formed of a knitted fabric.

According to a further feature of the present invention, the knitted fabric includes a polyamide thread.

According to a further feature of the present invention, there is also included an apparatus for aerating the wastewater, the apparatus including: (a) a pipe configured for connection to a fluid supply; and (b) a discharge head operationally connected to the pipe, the discharge head including at least one channel having a cross-sectional area, at least part of the channel being configured for insertion into the wastewater, the cross-sectional area being small enough that when a flow of a fluid from the fluid supply is activated, a low pressure region is set up in the wastewater, thereby producing a plurality of micro-bubbles which aerate the wastewater.

According to a further feature of the present invention, the fluid is air.

According to a further feature of the present invention, the fluid is recycled water.

According to a further feature of the present invention, there is also included an apparatus for aerating wastewater, the apparatus including: (a) a first pipe configured to introduce the wastewater to the apparatus; (b) a second pipe configured for connection to a fluid supply; and (c) a discharge head having at least one channel, the channel being configured to operationally connect the second pipe to the first pipe, the channel having a cross-sectional area that is small enough that when a flow of a fluid from the fluid supply is activated, a low pressure region is set up in the first pipe that: (i) produces a plurality of micro- bubbles which aerate the wastewater; and (ii) quickens a flow of the wastewater into the apparatus.

According to a further feature of the present invention, the second pipe is at least partially disposed within the first pipe.

According to a further feature of the present invention, the discharge head has a conical surface having an apex that points opposite to a direction of flow of the wastewater in the first pipe.

According to the teachings of the present invention there is also provided a filtration apparatus, comprising: (a) a plurality of filtration elements configured to cooperate to filter wastewater of an impurity; and (b) an air pump configured to clean the filtration elements of at least a part of the impurity during a normal operation of the filtration apparatus.

According to a further feature of the present invention, each of the filtration elements includes a member having a plurality of grooves thereon.

According to the teachings of the present invention there is also provided a precious metal recovery system, comprising: (a) a first electrode formed from a material having a high surface area to volume ratio; and (b) a second electrode, the first electrode and the second electrode being configured for connection to a power supply to enable recovery of the precious metal from wastewater by electroplating of the first electrode with at least part of the precious metal.

According to a further feature of the present invention, the material is an absorbent conducting material.

According to a further feature of the present invention, the material is a carbographite material.

According to the teachings of the present invention there is also provided a semi- permeable envelope for filtering an impurity from wastewater, comprising: (a) an inlet configured to allow the wastewater to enter the envelope; and (b) a plurality of holes configured to: (i) allow exit of the wastewater from the envelope; and (ii) trap at least part of the impurity inside the envelope; wherein the envelope is configured to stretch to maintain a substantially constant filtering throughput of the envelope when the at least part of the impurity adheres near the holes.

According to a further feature of the present invention, the envelope is substantially formed of a knitted fabric.

According to a further feature of the present invention, the knitted fabric includes a polyamide thread.

According'to the teachings of the present invention there is also provided a wastewater sedimentation apparatus, comprising: (a) a plurality of deflecting elements configured to cooperate to enhance sedimentation of impurities from the wastewater; the deflecting elements being shaped substantially as a truncated cone; the truncated cone having at least one projection; and (b) a distribution member configured to distribute the wastewater among the deflecting elements; the distribution member being a perforated pipe, wherein the deflecting elements and the distribution member are co-axially arranged.

According to a further feature of the present invention, the projection is substantially
radial.

According to a further feature of the present invention, there is also included a plurality of spacer members, each of the spacer members being disposed between the distribution member and two of the deflecting elements, the spacer members configured to maintain a laminar flow of the wastewater in order to enhance sedimentation of impurities from the wastewater.

According to the teachings of the present invention there is also provided a filtration apparatus to filter an impurity from wastewater, comprising: (a) a first surface having a plurality of ridges and grooves; and (b) a second surface having a plurality of ridges and grooves wherein the first surface is disposed facing the second surface such that, the grooves of the first surface are nonparallel to the grooves of the second surface in order to cause at least part of the wastewater to take a non-linear path between the first surface and the second surface thereby filtering at least part of the impurity.

According to a further feature of the present invention, the grooves of the first surface are substantially cross-aligned with the grooves of the second surface.

According to the teachings of the present invention there is also provided a filtration apparatus for filtering an impurity from wastewater, comprising: (a) a granular catalyst configured to remove at least part of the impurity from the wastewater; and (b) a semi-permeable envelope having a plurality of holes, the envelope being configured to contain the granular catalyst, the plurality of holes being configured to allow exit of the wastewater from the envelope, wherein the envelope is configured to stretch to maintain a substantially constant filtering throughput of the envelope when at least part of the impurity adheres near the holes.

According to a further feature of the present invention, the envelope has an upper surface, the apparatus further comprising: (c) a tank configured to hold the envelope; and (d) a water disperser configured to distribute the wastewater entering the tank over the upper surface of the envelope in order to maximize contact of the wastewater with the granular catalyst.

According to a further feature of the present invention, the water disperser includes an element having a plurality of holes therein, where through the wastewater flows.

According to a further feature of the present invention, there is also included: (c) a tank configured to hold the envelope, the tank having an outlet configured to allow a drainage of the wastewater from the tank; and (d) a water integrator configured to prevent the envelope from obstructing the drainage of the wastewater via the outlet.

According to a further feature of the present invention, the water integrator is an element having a plurality of holes therein, where through the wastewater flows.

According to a further feature of the present invention, the envelope is substantially formed of a knitted fabric.

According to a further feature of the present invention, the knitted fabric includes a polyamide thread.

According to the teachings of the present invention there is also provided a apparatus for aerating wastewater, comprising: (a) a pipe configured for connection to a fluid supply; and (b) a discharge head operationally connected to the pipe, the discharge head including at least one channel having a cross-sectional area, at least part of the channel being configured for insertion into the wastewater, the cross-sectional area being small enough that when a flow of a fluid from the fluid supply is activated, a low pressure region is set up in the wastewater, thereby producing a plurality of micro-bubbles which aerate the wastewater.

According to a further feature of the present invention, the fluid is air. According to a further feature of the present invention, the fluid is recycled water.

According to the teachings of the present invention there is also provided an apparatus for aerating wastewater, comprising: (a) a first pipe configured to introduce the wastewater to the apparatus; (b) a second pipe configured for connection to a fluid supply; and (c) a discharge head having at least one channel, the channel being configured to operationally connect the second pipe to the first pipe, the channel having a cross-sectional area that is small enough that when a flow of a fluid from the fluid supply is activated, a low pressure region is set up in the first pipe that: (i) produces a plurality of micro-bubbles which aerate the wastewater; and (ii) quickens a flow of the wastewater into the apparatus.

According to a further feature of the present invention, the second pipe is at least partially disposed within the first pipe.

According to a further feature of the present invention, the discharge head has a conical surface having an apex that points opposite to a direction of flow of the wastewater in the first pipe.

According to the teachings of the present invention there is also provided a method for treating wastew^{T}ater, comprising the steps of: (a) providing an electric field; and (b) causing a substantially laminar flow of the wastewater through the electric field in order to precipitate a plurality of metal ions from the wastewater.

According to a further feature of the present invention, there is also included the step of: (c) ensuring that separate flows of the wastewater through the electric field are treated substantially identically.

According to a further feature of the present invention, there is also included the . step of: (c) performing at least one operation selected from the group consisting of filtering of the wastewater and causing sedimentation from the wastewater.

According to a further feature of the present invention, there is also included the step of: (c) substantially separating at least part of the wastewater prior to leaving the electric field into a first flow which includes the metal ions and a second flow.

According to a further feature of the present invention, the step of causing the laminar flow of the wastewater includes causing the substantially laminar flow of the wastewater first substantially parallel and then substantially perpendicular to the electric field.

According to a further feature of the present invention, the step of causing the laminar flow of the wastewater includes causing the substantially laminar flow of the wastewater first substantially perpendicular and then substantially parallel to the electric field.

According to the teachings of the present invention there is also provided a method to filter an impurity from wastewater, comprising the steps of: (a) filtering the wastewater of an impurity using a filter; and (b) cleaning at least part of the filter of the impurity using air pressure.

According to the teachings of the present invention there is also provided a method to recover a precious metal from wastewater, comprising the steps of: (a) electroplating an electrode with at least part of the precious metal; and (b) destroying the electrode in a manner that leaves behind the precious metal that is electroplated thereon.

According to a further feature of the present invention, there is also provided the step of: (c) forming the electrode from a material having a high surface area to volume ratio.

According to a further feature of the present invention, the material is a absorbent conducting material.

According to a further feature of the present invention, the material is a carbographite material.

According to the teachings of the present invention there is also provided a method to aerate wastewater comprising the steps of: (a) providing a fluid; and (b) injecting the fluid into the wastewater such that a low-pressure region is set up. in the wastewater producing a plurality of micro-bubbles which aerate the wastewater.

According to the teachings of the present invention there is also provided a method for treating wastewater, comprising the steps of: (a) providing an electric field; (b) causing a flow of the wastewater through the electric field in order to precipitate metal ions from the wastewater; (c) substantially separating at least part of the wastewater prior to leaving the electric field into a first flow which includes the metal ions and a second flow; and (d) subsequent to the step of separating, performing at least one operation, selected from a group consisting of filtering of the wastewater and causing a sedimentation from the wastewater, the operation being performed separately and selected from the group separately, for the first flow and the second flow.

According to a further feature of the present invention, there is also included the step of: (e) only passing the wastewater of the first flow through a catalyst.

Brief description of the drawings

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is a schematic diagram of a wastewater treatment system that is constructed and operable in accordance with a preferred embodiment of the present invention;

Fig. la is a schematic diagram of a section of the wastewater system of Fig. 1 that is constructed and operable in accordance with an alternate embodiment of the present invention;

Fig. 2 is an isometric view of a filtration apparatus for use with the wastewater treatment system of Fig. 1;

Fig. 3 is a top view of a filtration element of the filtration apparatus of Fig.2;

Fig. 4 is an axial-sectional view of the filtration apparatus of Fig. 2 along line A-A;

Fig. 5 is an axial-sectional view of a wastewater sedimentation apparatus for use with the wastewater treatment system of Fig. 1;

Fig. 6 is a schematic illustration of laminar flow through an electric field for use with a wastewater treatment system that is constructed and operable in accordance with a preferred embodiment of the present invention;

Fig. 7 is an isometric view of an electrolytic reactor for use with the wastewater treatment system of Fig. 1;

Fig. 8 is a cross-sectional view of the electrolytic reactor of Fig. 7 along line A-A;

Fig. 9 is an expanded cross-sectional view of an electrolytic cell of the electrolytic reactor of Fig. 8;

Fig. 10 is a cross-sectional view of the electrolytic cell of Fig. 9 along line A-A;

Fig. 11 is an expanded view of the region labeled with a letter B in Fig. 9;

Fig. 12 is an expanded view of the region labeled with a letter C is Fig. 9;

Fig. 13 is front view of the electrolytic reactor of Fig. 7 with its front cover removed;

Fig. 14 is a cross-sectional view of the electrolytic reactor of Fig. 7 along line B-B not showing the cell contents in the central cells;

Fig. 15 is a top view of an electrolytic cell ready for insertion into the electrolytic reactor of Fig. 14;

Fig. 16 is a cross-sectional view of the electrolytic reactor of Fig. 7 along line B-B only showing one electrolytic cell;

Fig. 17 is an isometric view of a filtration apparatus for use with the wastewater treatment system of Fig. 1;

Fig. 18 is an exploded view of two plates of the filtration apparatus of Fig. 17;

Fig. 19 is a cross-sectional view of a plate of the filtration apparatus of Fig. 18 along line A-A;

Fig. 20 is a cross-sectional view of a wastewater aerator for use with the wastewater treatment system of Fig. la;

Fig. 21 is a cross-sectional view of catalytic filtration apparatus for use with the wastewater treatment system of Fig. 1; and

Fig. 22 is a cross-sectional view of the catalytic filtration apparatus of Fig. 21 along line A-A.

Description of the preferred embodiments

The present invention is a wastewater treatment system and method of operation thereof.

The principles and operation of the wastewater treatment system according to the present invention may he better understood with reference to • the drawings and the accompanying description.

Reference is now made to Fig. 1, which is a schematic view of a wastewater treatment system 10 that is constructed and operable in accordance with a preferred embodiment of the invention. Wastewater, typically produced by an industrial process is initially filtered by a filtration apparatus 12. It should be noted that although the term wastewater typically refers to water containing impurities due to an industrial process, the terminology wastewater as used herein implies any water which contains impurities independent of how the impurities became disposed therein, including a process stream. Filtration apparatus 12 is configured to filter particles which are 100 microns or larger. Therefore, filtration apparatus 12 removes large particles, including grease particles which could damage other parts of wastewater treatment system 10, especially the electrolytic reactor 22 discussed below. Filtration apparatus 12 is discussed in more detail with reference to Fig. 2. The wastewater filtered by filtration apparatus 12 is pumped through a one-way valve 14 by a pump 16. One-way valve 14 prevents the wastewater from flowing back into filtration apparatus 12. Pump 16 is typically a stainless steel centrifugal pump which is capable of pumping 5000 liters of liquid per hour. Pump 16 pumps the wastewater at a very low pressure of approximately 1.5 bars to ensure that the flow of the wastewater through wastewater treatment system 10 is kept laminar for the sections of wastewater treatment system 10 relating to electrolysis of the wastewater and sedimentation filters. After the wastewater flows through pump 16, the flow rate of the wastewater is controlled by a regulation valve 18. The flow rate of the wastewater at this stage is checked by a flow-meter 20. The flow rate of the wastewater entering electrolytic reactor 22 is very important. If the flow rate is too low, the temperature of the wastewater in electrolytic reactor 22 overheats and reduces the effectiveness of the purification process. The typical working range of electrolytic reactor 22 is between 1 degree centigrade and 50 degrees centigrade. If the flow rate is too high, the wastewater may flow turbulently, as will be described in more detail with respect to Fig. 6. In accordance with a most preferred embodiment of the present invention, regulation valve 18 is operated automatically by a computerized control unit 24 which processes flow rate measurements taken in various parts of wastewater treatment system 10, for example by flow-meter 20, as well as temperatures in electrolytic reactor 22. In accordance with an alternate embodiment of the present invention, regulation valve 18 is operated manually based on flow rate and temperature measurements. Electrolytic reactor 22 as well as all the other apparatus of wastewater treatment system 10 are powered by a central power unit 52.

The wastewater then enters a wastewater sedimentation apparatus 26. Particles in the wastewater settle to the bottom of wastewater sedimentation apparatus 26 into a sludge tank 28. Sludge tank 28 has a outlet valve 30 to allow emptying of sludge tank 28 of sludge. Wastewater sedimentation apparatus 26 is discussed in more detail with reference to Fig. 5.

The wastewater is then pushed out of the top of sedimentation apparatus 26 due to water build therein. The wastewater then enters a water divider 34 which divides the wastewater into four separate streams for processing by electrolytic reactor 22. It is important for the flow rates of each stream to be substantially identical so that all the wastewater undergoes the same amount and type of processing within electrolytic reactor 22. The means for achieving substantially identical flow rates is described in more detail with respect to Fig.

The wastewater is processed by electrolytic reactor 22 which first recovers any precious metal ions, such as gold, silver, cobalt and platinum from the wastewater and then performs an electrolysis process which produces hydroxyl ions which precipitate the positive base metal ions or cations from the wastewater as metal hydroxides. Protons produced by the electrolysis process precipitate the negative ions or anions from the wastewater. The anions may include complexes which include ammonia. The process of precipitation of the metal ions and anions from the wastewater continues after the wastewater has exited electrolytic reactor 22. Therefore, after the wastewater exits electrolytic reactor 22, the wastewater flows through a series of filtration and sedimentation chambers for long enough for all the metal to precipitate and be removed from the wastewater. Electrolytic reactor 22 is described in more detail with reference to Figs. 6 to 16. The wastewater exits electrolytic reactor 22 in three streams. One stream 36 contains mainly metals and the other two streams 38 contain non-metal substances such as organic substances. Stream 36 is a high pH level (alkaline) and two streams 38 have a low pH level (acidic). Stream 36 now enters a sedimentation apparatus 40 which is configured to cause the precipitated metals to sediment to the bottom of sedimentation apparatus 40. Sedimentation apparatus 40 has a sludge tank 44. Sedimentation apparatus 40 is substantially the same as wastewater sedimentation apparatus 26. Stream 38 now enters a sedimentation apparatus 42 which is configured to cause the non-metal substances to sediment to the bottom of sedimentation apparatus 42. Sedimentation apparatus 42 has a sludge tank 46. Sedimentation apparatus 42 is substantially the same as wastewater sedimentation apparatus 26.

In accordance with a most preferred embodiment of the present invention, stream 36 is treated separately from stream 38. The main reason for treating stream 36 and stream 38 separately is that stream 36 which contains the metals typically requires a more aggressive process which typically includes using catalysts for removing metals from the wastewater. These catalysts are very expensive and if they are used with stream 38, these catalysts are wasted on removing organic substances which do not require such an aggressive treatment. Additionally, the wastewater is generally processed to a higher degree of purity when stream 36 and streams 38 are treated separately. This is because the metal hydroxides in stream 36 may be dissolved back into the wastewater if mixed with the acidic wastewater of streams 38. Therefore, it is desirable according with this most preferred embodiment of the present invention to treat stream 36 and stream 38 separately. In accordance with an alternate embodiment of the present invention, the metal stream 36 and the non-metal stream 38 are now combined for the remainder of the wastewater treatment processing.

It should be noted that for the sake of simplicity, the description hereinbelow assumes that stream 36 and two streams 38 are now combined in a tank 48 after being filtered by a semi-permeable envelope 50. Semi-permeable balloon 50 is especially effective at filtering the metal hydroxide gels, but is also effective for filtering more crystalline structures. Semi- permeable envelope 50 has an inlet 54 configured to allow the wastewater to enter semi- permeable envelope 50. Semi-permeable envelope 50 has a plurality of holes 56. The diameter of the holes is within the range of 100 to 150 microns. When the impurities in the wastewater adhere near holes 56, the water pressure inside semi-permeable envelope 50 increases. This increased water pressure causes semi-permeable envelope 50 to stretch whereby the cross- sectional area of holes 56 parallel to the surface of semi-permeable envelope 50 enlarge in order to maintain a substantially constant filtering throughput of the wastewater through semi- permeable envelope 50. Semi-permeable envelope 50 is typically formed from a jersey knit fabric which uses polyamide thread. Polyamide is a preferred fiber as it has good stretching qualities.

The wastewater leaves tank 48 from the bottom thereof and enters a tank 58. Tank 58 has a sedimentation apparatus 60 therein. The wastewater is pumped up through tank 58 and tank 64 successively by a pump 62. Impurities within the wastewater are caused to sediment within sedimentation apparatus 60. Sedimentation apparatus 60 is described in more detail with reference to Figs. 17, 18 and 19. Pump 62 is typically a centrifugal pump. Pump 62 is substantially the same as pump 16. Pump 62 pumps the wastewater from the top of tank 58 into a tank 64.

In accordance with a preferred embodiment of the present invention, a semi-permeable envelope 66 is used to filter the wastewater which is entering tank 64. Semi-permeable envelope 66 is formed substantially the same way as semi-permeable envelope 50.

The wastewater is aerated within tank 64 by an aeration apparatus 68. It should be noted that aeration apparatus 68 is also optionally installed within tank 48. Aeration apparatus 68 includes a pipe 70 configured for connection to a fluid supply, such as water which is pumped back by pump 62 after this water has already left tank 64 or air via a central air compressor 32. It is important for the wastewater to be aerated at this stage in order to prepare the wastewater for later treatment by catalysts, in catalytic columns 88 as described below, which require oxygenated water for their effective performance at removing metals. Aeration apparatus 68 also includes a discharge head 72 which has a plurality of very narrow channels disposed therein. The discharge head 72 is configured for insertion into the wastewater which is in tank 64. Aeration apparatus 68 is operationally connected to pipe 70 such that, when the fluid supply is activated, the fluid from the fluid supply flows through pipe 70 and through the channels of discharge head 72 into the wastewater which is in tank 64. The cross-sectional area of the channels of discharge head 72 is small enough that when the fluid supply is activated, a low pressure region is set up in the wastewater adjacent to the channels of discharge head 72 caused by the fast speed of the fluid exiting the channels of discharge head 72. Each of these channels typically has a diameter of approximately 0.8mm. This low-pressure region causes the wastewater to enter this low-pressure region at high speed so that parts of the wastewater collide with other wastewater and/or the fluid supply producing a plurality of micro-bubbles which aerate the wastewater.

A wastewater level sensor 76 is disposed in tank 64. Level sensor 76 is configured in conjunction with computerized control unit 24 to stop pump 62 when the wastewater level in tank 64 is down to the top of discharge head 72 of aeration apparatus 68. When tank 64 is half full with the wastewater, level sensor 76 in conjunction with computerized control unit 24 activates pump 62. When tank 64 is nearly full with the wastewater, level sensor 76 in conjunction with computerized control unit 24 stops pump 16 until the wastewater level within 5 tank 64 drops to the half full level.

Reference is now made to Fig. la which is a schematic diagram of a section of wastewater treatment system 10 that is constructed and operable in accordance with an alternate embodiment of the present invention. In accordance with this alternate embodiment, a filtration apparatus 262 which is substantially the same as filtration apparatus 12 filters the wastewater in tank 48 as it leaves tank 48. It should be noted that filtration apparatus 262 generally has a filtration specification of 50 micron. Sedimentation apparatus 60 removes impurities from the wastewater within tank 58. In this alternate embodiment, filtration apparatus 262 replaces semi-permeable balloons 50. A wastewater aerator 78 is disposed between tank 58 and tank 64. Aerator 78 oxygenates the wastewater as well as quickening the flow of the wastewater from tank 58 to tank 64. Aerator 78 is described in more detail with reference to Fig. 20. Tank 64 also includes aeration apparatus 68 with pipe 70 and discharge head 72. Tank 64 also includes level sensor 76.

Reference is again made to Fig. 1. After the wastewater is pumped out of tank 64 by pump 62, the wastewater travels through pump 62, a one way valve 80 and a flow meter 82. One way valve 80 prevents the wastewater flowing back into tank 64. Flow meter 82 measures the flow rate of the wastewater to ensure that the wastewater is not flowing too fast for processing by the next stages of wastewater treatment system 10 which include catalyst processing. Flow meter 82 is configured in conjunction with computerized control unit 24 to regulate the flow of the wastewater by controlling pump 62. It will be apparent to those skilled in the art of water treatment by catalysts how the flow rate of the wastewater needs to be adjusted depending on the volume and type of catalyst as well as the number of impurities still within the wastewater.

The wastewater now enters a mechanical filter 84 having a filtering specification of 50 microns. The wastewater then enters a second mechanical filter 86 having a filtering specification of 5 microns. Mechanical filters meeting these specifications are known to those skilled in the art.

After exiting mechanical filter 86, the wastewater enters a series of catalytic columns 88. The pipe carrying the wastewater to catalytic columns 88 has a gas release valve to enable escape of accumulated gas from catalytic columns 88. This gas release valve can either be manually operated or automatically operated by computerized control unit 24. Catalytic columns 88 are either arranged in: (i) parallel, as illustrated, such that the wastewater exiting mechanical filter 86 is divided among catalytic columns

88 for processing; or (ii) in series, such that the wastewater exiting mechanical filter 86 flows through each of catalytic columns 88. It will be apparent to those skilled in the art that appropriately placed bypass pipes and valves will enable switching between a serial and parallel set up of catalytic columns 88. If catalytic columns 88 are arranged in parallel it is important to ensure that each catalytic column 88 processes the same amount of the wastewater so that the catalysts within catalytic columns 88 are exhausted at the same time so that the catalysts can be replaced at the same time. This can be achieved by varying the quantity of the catalysts within catalytic columns 88 to adjust for the non-uniform flow of the wastewater among the catalytic columns 88, such that the catalysts are exhausted at the same time. It should be noted that between 80% to 90% of the impurities within the wastewater have been removed before the wastewater arrives at catalytic columns 88. Catalytic columns 88 are configured to remove the metals which still remain in the wastewater. Catalytic columns 88 are described in more detail with reference to Figs. 21 and 22.

The wastewater now flows through a series of diagnostic equipment including a flow rate meter 90 and a water analyzer 92, which is configured to analyze the conductivity and pH level of the exiting wastewater. The information recorded by flow rate meter 90 and water analyzer 92 is typically sent by a modem 94, which is controlled by computerized control unit 24, to a service control center to monitor the performance of wastewater treatment system 10. Finally, the wastewater flows through a filtration apparatus 96. Filtration apparatus 96 is constructed in the same way as filtration apparatus 12, but filtration apparatus 96 is configured to filter particles which are 5 microns or larger.

Reference is now made to Fig. 2, which is an isometric view of filtration apparatus 12 for use with wastewater treatment system 10 of Fig. 1. Reference is also made to Fig. 3, which is a top view of a filtration element 98 for use with filtration apparatus 12. Reference is also made to Fig. 4, which is an axial-sectional view of filtration apparatus 12 of Fig. 2 along line A-A. Filtration apparatus 12 includes a plurality of filtration elements 98 which are configured to filter the wastewater of an impurity. Filtration elements 98 are generally formed from polypropylene. Each filtration element 98 has two major surfaces 104 which are annular. There is a hole 102 in the center of each filtration element 98 which connects surfaces 104 of one filtration element 98. Each of surfaces 104 has a plurality of grooves 100 thereon which connect the outer circumference of surface 104 to the inner circumference of surface 104. Grooves 100 typically have a depth and width of 100 microns. Filtration elements 98 are stacked so that grooves 100 of one surface 104 of one filtration elements 98 are non-aligned with grooves 100 of an adjacent surface 104 of an another filtration element 98. Filtration elements 98 are mechanically connected by four rods 106. Filtration apparatus 12 has a base 108 which is mechanically connected to the lowest filtration element 98 in the stack. At the top of the stack, a pipe 110 connects filtration apparatus 12 to pump 16. Pump 16 pumps the wastewater from a tank 11-2 via filtration apparatus 12. The wastewater in tank 112 enters filtration apparatus 12 through the outer circumference of surfaces 104 via grooves 100, represented by arrows 113. Grooves 100 prevent large particles from passing through surfaces 104. The wastewater then enters a central column 114 of filtration apparatus 12 and is then pumped out of central column 114 by pump 16 represented by an arrow 115. Base 108 prevents the wastewater from entering central column 114 without first flowing through filtration elements 98. Any dirt or grease particles which are lodged in or near grooves 100 of filtration elements 98 are cleaned by compressed air which is blown in pulses, during nornial operation of filtration apparatus 12, via an air tube 116 into central column 114 by central air compressor 32.

Reference is now made to Fig. 5, which is an axial -sectional view of sedimentation apparatus 26 for use with wastewater treatment system 10 of Fig. 1. Sedimentation apparatus 26 includes a water tank 118 having an inlet 120 which is configured to allow entry of the wastewater into tank 118. Sedimentation apparatus 26 also includes a plurality of deflecting elements 122 disposed within tank 118. Deflecting elements 122 are configured to enhance sedimentation of the wastewater within tank 118. Each of deflecting elements 122 is substantially a truncated cone which has one or more radial projections 124 configured to enhance the sedimentation process. There are typically thirty-five deflecting elements 122 in tank 118. Deflecting elements 122 typically have a diameter of 170 mm. Each radial projections 124 typically has a height of 50mm. Sedimentation apparatus 26 also includes a distribution member 126 disposed within tank 118. Distribution member 126 is configured to distribute the wastewater which enters tank 118 among deflecting elements 122. Distribution member 126 is a perforated pipe. The holes of distribution member 126 typically have a diameter of 4 mm. There are typically six holes in distribution member 126 for distributing the wastewater to each deflecting element 122. Deflecting elements 122 and distribution member 126 are co-axially arranged. Sedimentation apparatus 26 also includes a plurality of spacer members 128. Each spacer member 128 is disposed between distribution member 126 and two of deflecting elements 122. Distribution member 126 has a group of one or more entry holes 125 for each spacer members 128. to allow the wastewater to enter each spacer members 128. Each spacer member 128 has an equal number of exit holes 127 corresponding to entry holes 125. Exit holes 127 allow water to exit from each spacer member 128 to between two deflecting elements 122. Exit holes 127 have a larger cross-sectional area than entry holes 125 thereby preventing turbulent flow of the wastewater when it exits distribution member 126. Therefore, spacer members 128 maintain a laminar flow of the wastewater within tank 118 in order to enhance sedimentation of the wastewater, the wastewater exits tank 118 via a pipe 119. Any gas accumulating at the top of tank 118 is removable by opening a gas release valve 121. Release valve 121 is either manual or automatically operated by computerized control unit 24.

Reference is now made to Fig. 6, which is a schematic illustration of laminar flow through an electric field for use with a wastewater treatment system that is constructed and operable in accordance with a preferred embodiment of the present invention. As discussed above, it is important to maintain a laminar flow of wastewater during electrolytic purification. It is also important that the wastewater comes into contact with the electrodes as much as possible. This is generally difficult with a laminar flow of wastewater. Additionally, for the process to be commercially viable it must allow for a high throughput of wastewater. A high velocity of water flowing between the electrodes enhances the electrolytic purification process. Therefore, it is important to maintain a fast laminar flow of wastewater where the wastewater comes into contact with the electrodes and all portions of the wastewater are travelling with the same speed between the electrodes. By way of example, according to the present invention, wastewater enters a first vertical chamber 130. A pair of electrodes 132 is disposed inside a second vertical chamber 134. Electrodes 132 are very close to each other and therefore the wastewater flowing through second vertical chamber 134 comes into close contact with electrodes 132. The horizontal cross-sectional area of first vertical chamber 130 is much greater than the horizontal cross-sectional area of second vertical chamber 134. Therefore, even if water is added laminarly to first vertical chamber 130, this introduction causes a highspeed laminar flow of the wastewater in second vertical chamber 134 between electrodes 132. The flow of wastewater from first vertical chamber 130 to second vertical chamber 134 is caused by air pressure in first vertical chamber 130 and second vertical chamber 134 equalizing the water levels of the wastewater in first vertical chamber 130 and second vertical chamber 134. As the outlet of second vertical chamber 134 is lower than the inlet of first vertical chamber 130, an addition of water to second vertical chamber 134 causes the wastewater to flow through and out of second vertical chamber 134. Therefore, high speed, laminar flow of wastewater is achieved using the above principle. It is important to note that first vertical chamber 130 should have contours which do not promote turbulent water flow. If first vertical chamber 130 has sharp comers, such as square comers, then these comers may set up a turbulent water flow within first vertical chamber 130 as is the case with prior art reactors such as that of U.S. Patent No.- 6,139,714.

Reference is now made to Fig. 7, which is an exploded isometric view of electrolytic reactor 22 for use with wastewater treatment system 10 of Fig. 1. Reference is also made to Fig. 8, which is a cross-sectional view of electrolytic reactor 22 of Fig. 7 along line A-A. The wastewater is divided by water divider 34 into four streams. The first stream enters electrolytic reactor 22 through an inlet 136 into a vertical chamber 138 of electrolytic reactor 22. Vertical chamber 138 as well as the other vertical chambers of electrolytic reactor 22 are typically 45 mm wide, up to 600 mm high and 110 mm deep. The second stream enters electrolytic reactor 22 through an inlet 140 into a vertical chamber 142 of electrolytic reactor 22. The third stream enters electrolytic reactor 22 through an inlet 144 into a vertical chamber 146 of electrolytic reactor 22. The final stream enters electrolytic reactor 22 through an inlet 148 into a vertical chamber 150 electrolytic reactor 22. Inlets 136, 140, 144, 148 are disposed within a front cover 162 of electrolytic reactor 22. There is an air hole 123 disposed between vertical chamber 138 and vertical chamber 142. Air hole 123 allows accumulated gas within vertical chamber 142 to exit periodically through a gas release valve 131. It is important to remove gas periodically to prevent trapped gas causing turbulence within the system. Gas release valve 131 is disposed in front cover 162 adjacent to vertical chamber 138. Likewise, gas accumulated within vertical chamber 138 exits through gas release valve 131. Gas release valve 131 is either manually operated or automatically operated by computerized control unit 24. Additionally, air hole 123 ensures that the air pressure at the top of vertical chamber 138 and vertical chamber 142 are substantially identical. Similarly, there is an air hole 133 disposed between vertical chamber 146 and vertical chamber 150. Similarly, there is a gas release valve 135 disposed in front cover 162 adjacent to vertical chamber 150. Vertical chambers 138,142,146 and 150 are configured for accumulating the wastewater therein. The flow of the incoming wastewater is controlled by computerized control unit 24 such that the wastewater level within vertical chamber 138, 142, 146 and 150 does not exceed the level of air holes 123 and 133, shown by a line 143.

It should be noted that vertical chambers 138, 142, 146 and 150 do not have sharp comers which might induce turbulence within the wastewater. Moreover, the contours of vertical chambers 138, 142, 146 and 150 are shaped and rounded in order to maintain a laminar flow of the wastewater within vertical chambers 138, 142,146 and 150 for the complete flow of the wastewater therein.

Electrolytic reactor 22 includes four precious metal recovery apparatuses 152, which recover precious metal ions -from the wastewater by electroplating before the electrolytic purification process begins. Each precious metal recover}- apparatus 152 includes an anode 154 and two cathodes 156. One precious metal recovery apparatus

152 is disposed within each of vertical chamber 138, vertical chamber 142, vertical chamber 146 and vertical chamber 150. Precious metal recovery apparatuses 152 are configured to electroplate cathodes 156 with any precious metal ions which are present in the wastewater. Cathodes 156 are typically formed from a material having a high surface area to volume ratio which cannot be achieved with classic solid cathodes such as metals and other conducting materials. The material is typically an absorbent and/or fibrous conducting material formed from a treated fabric or fibers such as a Carbographite material. An absorbent and/or fibrous material increases the available electroplating surface area of cathodes 156. Carbographite is chosen for its strength, long life. Moreover, Carbographite does not significantly decompose, which would add contaminants to the wastewater. Cathodes 156 and anode 154 are typically formed by pyrolysis of discs of viscose fabric. The processed discs of viscose fabric are then stacked in groups of five and each group is then subjected to pyrolysis again. The processed groups of discs are then stacked to form a cylinder 160 which extends to the depth of vertical chambers 138, 142,146, 150 (see Fig. 14). A conducting metal rod 158, generally formed of solid stainless steel or titanium, is then disposed along the axis of cylinder 160. Precious metal recovery apparatus 152 is powered by connecting conducting metal rod 158 to central power unit 52. When the surface area of cathodes 156 is completely coated with precious metal, the Carbographite discs of cathodes 156 are placed in a furnace which destroys the Carbographite discs in order to recover the precious metal that is deposited on the discs. Cathodes 156 and anode 154 are connected to central power unit 52 via a plurality of contacts 166 disposed in front cover 162. Cathodes 156 and anode 154 are removed from electrolytic reactor 22 through a plurality of openings 164 in front cover 162. Reference is additionally made to Fig. 9, which is an expanded cross-sectional view of an electrolytic cell of electrolytic reactor 22 of Fig. 8. Electrolytic reactor 22 includes a vertical chamber 168. A pair of electrodes 172 which are configured to produce an electric field are disposed within vertical chamber 168. Pair of electrodes 172 are powered by a DC voltage.

Computerized control unit 24 (Fig. 1) in conjunction with central power unit 52 (Fig. 1) is configured to direct high voltage peaks of electricity to pair of electrodes

172. The voltage peaks are typically up to 100 V and up to 50A. The duration of the voltage peaks is typically one fiftieth of a second with a frequency of 50 Hz. Pair of electrodes 172 includes two electrodes, a cathode 180 and.an anode 182. Negative voltage peaks can be applied to pair of electrodes 172 to prevent electroplating of cathode 180. Cathode 180 and anode 182 are typically formed from stainless steel, titanium, carbon-carbon, stainless steel with titanium nitrate plating or stainless steel with a conducting polymer plating. Combinations of the above are possible, for example, a stainless steel cathode and a titanium anode, a carbon-carbon cathode and a titanium anode, a titanium cathode and a carbon-carbon cathode. In addition, the surface of cathode 180 and anode 182 can be protected using a carbon-carbon fabric which also increases the conducting surface area of the electrodes with the wastewater. Cathode 180 and anode 182 can also be protected with an aluminum or iron coating which also aids electrocoagulation. The distance between cathode 180 and anode 182 is typically 6 mm. A plurality of conduits 176 connect vertical chamber 138 with vertical chamber 168 via a plurality of holes 188 which connect the major surfaces of cathode 180. There are typically between 4 to 8 of holes 188. Each hole 188 has a diameter of between 8 mm to 14 mm and a spacing between the centers of holes 188 of between 12 mm to 16 mm. A plurality of conduits 178 connect vertical chamber 142 with vertical chamber 168 via a plurality of holes 200 which connect the major surfaces of anode 182. Vertical chamber 168 includes a plurality of outlet conduits 192 configured to allow exit of the wastewater from vertical chamber 168 via a plurality of holes 196 which connect the major surfaces of cathode 180, after processing of the wastewater by the electric field. Vertical chamber 168 also includes a plurality of outlet conduits 194 configured to allow exit of the wastewater from vertical chamber 168 via a plurality of holes 198 which connect the major surfaces of anode 182, after processing of the wastewater by the electric field. Reference is additionally made to Fig. 10, which is a cross-sectional view of anode 182 of Fig. 9 along line A-A showing the positioning of holes 200 and holes 198 in anode 182. Vertical chamber 168 also includes a semi-permeable membrane 190 which is disposed half way between pair of electrodes 172. Semi-permeable membrane 190 substantially separates the wastewater which is in

vertical chamber 168 into two flows as is discussed below. Semi-permeable membrane 190 is described as "substantially separating" as there is a migration of ions on a micro level which is also discussed below. Semi-permeable membrane 190 is generally formed of polypropylene. The thickness of semi- permeable membrane 190 depends on the current and voltage applied across pair of electrodes 172. By way of illustration: (i) semi-permeable membrane 190 needs to be approximately 0.5 mm thick when a voltage of 20 V and a current of 20 A is applied across pair of electrodes 172; (ii) semi- permeable membrane 190 needs to be approximately 1.0mm thick when a voltage of 20V and a current of 60 A is applied across pair of electrodes 172; and (iii) when a voltage of 20 V and a current of 20A is applied across pair of electrodes 172 two of semi-permeable membrane 190 are required, each having a thickness of 0.5 mm.

An addition of the wastewater in vertical chamber 138 causes a substantially laminar flow of a part of the wastewater through conduits 176 via holes 188 into and up through vertical chamber 168. This is due to air pressure causing an equalization of the water levels between vertical chamber 138 and vertical chamber 168. As the wastewater enters vertical chamber 168 via holes 188 the wastewater flows parallel to the electric field of pair of electrodes 172. As the wastewater flows up between pair of electrodes 172, the wastewater flows perpendicular to the electric field of pair of electrodes 172. The wastewater travels with a very low pressure and a high speed of approximately 2 meters per second. The wastewater then exits vertical chamber 168 via holes 196 and outlet conduits 192 into a vertical chamber 202. The wastewater then flows down vertical chamber 202 to exit electrolytic reactor 22 via an outlet 204 in front cover 162. Similarly, an addition of the wastewater in vertical chamber 142 causes a substantially laminar flow of a part of the wastewater through conduits 178 via holes 200 into and up through vertical chamber 168. As the wastewater enters vertical chamber 168 via holes 200 the wastewater flows parallel to the electric field of pair of electrodes 172. As the wastewater flows up between pair of electrodes 172, the wastewater flows perpendicular to the electric field of pair of electrodes 172. The wastewater then exits vertical chamber 168 via holes 198 and outlet conduits 194 into a vertical chamber 206. The wastewater then flows down vertical chamber 206 to exit electrolytic reactor 22 via an 30 outlet 208 in front cover 162. The energy transferred by pair of electrodes 172 when the wastewater is flowing through holes 188, 200,198,196, parallel to the electric field, represents 80% of the energy transfer by pair of electrodes 172 to the wastewater. The electrolysis of the wastewater by pair of electrodes 172 initiates the precipitation metal ions from the wastewater. Oxidants of up to 150 mg per liter are produced by the electrolysis.

When the wastewater enters vertical chamber 168, positive ions (cations) are attracted to cathode 180 and negative ions (anions) are attracted to anode 182. Positive ions in the wastewater which are on anode 182 side of semi-permeable membrane 190 migrate across semi-permeable membrane 190 to cathode 180 side of semi-permeable membrane 190. Negative ions in the wastewater which are on cathode 180 side of semi-permeable membrane 190 migrate across semi-permeable membrane 190 to anode 182 side of semi- permeable membrane 190. The ions in the wastewater only have enough energy to migrate across semi-permeable membrane 190 once. Therefore, the wastewater which flows out of vertical chamber 168 through holes 198 in anode 182 contain negative ions, balanced by H^+ ions, and the wastewater which flows out of vertical chamber 168 through holes 196 in cathode 180 contains positive ions, balanced by OH' ions. It should be noted that metals are generally positive ions. The second side of electrolytic reactor 22 includes a vertical chamber 170 having a pair of electrodes 174 which are configured to produce an electric field are disposed within vertical chamber 170. Pair of electrodes 174 includes two electrodes, a cathode 184 and an anode 186. An addition of the wastewater to vertical chamber 146 and vertical chamber 150 is processed in vertical chamber 170 by pair of electrodes 174 in the same way as described above. The wastewater processed by pair of electrodes 174 includes a flow which contains positive metal ions which exits vertical chamber 170 into vertical chamber 202, and a flow which contains negative ions which exits vertical chamber 170 into a vertical chamber 210. The wastewater in vertical chamber 210 flow's downward to exit electrolytic reactor 22 via an outlet 212 in front cover 162.

There is a water hole 137 disposed between the bottom of vertical chamber 142 and vertical chamber 138. There is similarly a water hole 139 disposed between the bottom of vertical chamber 146 and vertical chamber 150. There is also a water hole 141 disposed between vertical chamber 138 and vertical chamber 150. Water holes 137, 139, 141 typically each have a diameter of between 20 mm and 40 mm. Air holes 123,133, water holes 137,139, 141 as well as gas release valves 131, 135 ensure that separate flows of the wastewater entering electrolytic reactor 22 via vertical chamber 138, 142, 146 and 150 are treated substantially identically by pair of electrodes 174 and pair of electrodes 172 even if the wastewater enters vertical chamber 138, 142, 146 and 150 at different rates and even if gas accumulates at different rates within vertical chamber 138, 142, 146 and 150. This is because air holes 123,133, water holes 137,139,141 as well as gas release valves 131,135 ensure that the water level within vertical chamber 138,142,146 and 150 is kept at substantially the same level, shown by line 143.

In accordance with an alternate embodiment of the present invention, inlet 136 and inlet 148 are not included. Instead, the wastewater enters via inlet 140 to vertical chamber 142. The wastewater then enters vertical chamber 138 from vertical chamber 142 via water hole 137. Similarly, the wastewater enters via inlet 144 into vertical chamber 146. The wastewater then enters vertical chamber 150 from vertical chamber 146 via water hole 139.

Reference is now made to Fig. 11, which is an expanded view of the region labeled with a letter B in Fig. 9. Reference is also made to Fig. 12, which is an expanded view of the region labeled with a letter C, which is Fig. 9. To enhance energy transfer from anode 182 and to prevent the wastewater eroding the edges of anode 182 when entering vertical chamber 168 via holes 200, an edge protector 214, typically formed from carbon, is disposed around holes 200. Edge protector 214 typically has a length which is longer that the depth of anode 182 measured perpendicular to the major surfaces of anode 182. Similarly, an edge protector 216, typically formed from carbon is disposed around holes 196 of cathode 180 when the wastewater exits vertical chamber 168. All entry and exit holes of all the electrodes of electrolytic reactor 22 are protected similarly with edge protectors.

Reference is now made to Fig. 13, which is front view of electrolytic reactor 22 of Fig. 7 with front cover 162 removed. Reference is also made to Fig. 14, which is a cross-sectional view of electrolytic reactor 22 of Fig. 7 along line B-B. Note that neither Fig. 13 nor Fig. 14 shows the contents of vertical chambers 168 and 170. Electrolytic reactor 22 includes a shell structure 218 which is typically formed from molded plastic. Shell structure 218 forms vertical chambers 138, 142, 146, 150, 168, 170, 202, 206 and 210. All the vertical chambers have slanted sides, as seen in Fig. 14. The slant angle of the sides is approximately 1.5 degrees. The reason for the slant angle is due to the method of molding shell structure 218 as well as the need for a tight fit for the contents of vertical chamber 168 and vertical chamber 170 which is described in more detail with reference to Fig. 15 and 16. Shell structure 218 also has a pluralityof holes 224 at the back of shell structure 218. Holes 224 help electrolytic reactor 22 maintain a low temperature by dissipating heat.

Reference is now made to Fig. 15, which is a top view of an electrolytic cell 226 ready for insertion into shell structure 218 of electrolytic reactor 22 of Fig. 14. Electrolytic cell 226 includes pair of electrodes 172, semi-permeable membrane 190, two flexible plastic outer walls 228, two inner plastic walls 230, and two spacer members 232. Spacer members 232 are formed from a resilient material, such as polyurethane or other resilient plastics. Electrolytic cell 226 is constructed such that when electrolytic cell 226 is inserted into shell structure 218 a pressure fit between flexible plastic outer walls 228, inner plastic walls 230, spacer members 232, pair of electrodes 172 and shell structure 218 ensures that all the wastewater which flows through vertical chamber 168 flows between pair of electrodes 172 and not bypassing pair of electrodes 172. Reference is now made to Fig. 16, which is a cross-sectional view of electrolytic reactor 22 of Fig. 7 along line B-B only showing electrolytic cell 226 inserted into vertical chamber 168 of shell structure 218. The other electrolytic cell of electrolytic reactor 22 is formed and inserted in the same way as electrolytic cell 226.

Reference is again made to Figs. 13 and 14. Shell structure 218 has a plurality of threaded screw holes 220 disposed therein configured to enable front cover 162 to be fastened securely to shell structure 218 providing a watertight fit. Front cover 162 has a plurality of holes 222 corresponding to threaded screw holes 220 of shell structure 218. In addition to fastening front cover 162 with screws to shell structure 218, polyurethane glue is applied to all contact surfaces between front cover 162 and shell structure 218. The polyurethane glue forms a foam which provides a very good watertight protection.

Reference is now made to Fig. 17, which is an isometric view of sedimentation apparatus 60 for use with wastewater treatment system 10 of Fig. 1. Sedimentation apparatus 60 includes a plurality of plates 234 which are stacked to form sedimentation apparatus 60. Plates 234 are configured to cause the wastewater to take a non-linear path between the surfaces of plates 234 thereby causing impurities in the wastewater to sediment on the surfaces of plates 234. Plates 234 are typically formed from plastic sheeting with a thickness of approximately 0.2mm. Plates 234 are generally spaced between 8 mm to 20 mm between adjacent plates 234. Reference is now made to Fig. 18, which is an exploded view of two of plates 234 of sedimentation apparatus 60 of Fig. 17. Each of plates 234 has a surface which has a plurality of ridges and grooves 236 thereon. Grooves 236 of one of the surfaces are nonparallel, preferably cross-aligned, with grooves 236 of an adjacent surface in order to cause the wastewater to take a non-linear path between the surfaces of plates 234 thereby causing impurities in the wastewater to sediment on the surfaces of plates 234.

Reference is now made to Fig. 19, which is a cross-sectional view of one of plates 234 of sedimentation apparatus 60 of Fig. 18 along line A-A. Grooves 236 of plates 234 are generally formed by formed by vacuum forming of plastic. The grooves typically have a width and depth of between 8 mm to 20 mm. It should be noted that the exact shape of the grooves is not important, various shapes can be used such as square and rounded shapes.

Reference is now made to Fig. 20, which is a cross-sectional view of aerator 78 for use with wastewater treatment system 10 of Fig. la. Aerator 78 includes a pipe 238 configured to carry the wastewater from tank 58 to tank 64. Aerator 78 also includes a pipe 240 configured for connection to a fluid supply. Pipe 240 is partially disposed within pipe 238. The fluid supply is either water which is pumped back by pump 62 (Fig. 1) after this water has already left tank 64, air via central air compressor 32 (Fig. 1) Aerator 78 also includes a discharge head 242 having at least one. channel 244. Discharge head 242 has a conical outer surface having an apex that points opposite to the direction of flow of the wastewater in pipe 238. Discharge head 242 is mechanically connected to pipe 240. Channel 244 is configured to operationally connect pipe 240 to pipe 238. Channel 244 has a cross-sectional area which is small enough that when the fluid supply is activated, a low-pressure region is set up in pipe 238. This low-pressure region causes the wastewater to enter this low-pressure region at high speed so that parts of the wastewater collide with other wastewater and/or the fluid supply producing a plurality of micro-bubbles which aerate the wastewater. This low-pressure region also quickens the flow of the wastewater from tank 58 to tank 64.

Reference is now made to Fig. 21, which is a cross-sectional view of a catalytic column 88 for use with wastewater treatment system 10 of Fig. 1. Catalytic column 88 includes a tank 250 and a granular catalyst 246 which is configured to remove impurities, specifically, metals, from the wastewater. Granular catalyst 246 is generally activated carbon, titanium phosphate, circonium phosphate, cationite, or anionite. Granular catalyst 246 is contained within a semi-permeable envelope 248. Semi-permeable envelope 248 prevents granular catalyst 246, as it becomes contaminated, leaking into the wastewater which leaves tank 250 after processing by catalytic column 88. Semi-permeable envelope 248 is configured to stretch when impurities in the wastewater adhere near holes of semi-permeable envelope 248 thereby maintaining a substantially constant throughput of the wastewater through semi-permeable envelope 248. Semi-permeable envelope 248 is formed in a similar manner to semi-permeable envelope 50 described with reference to Fig. 1. Reference is also made to Fig. 22, which is a cross-sectional view of catalytic column 88 of Fig. 21 along line A-A. Catalytic column 88 includes a water disperser 252 which is configured to distribute the wastewater entering tank 250 over the upper surface of semi-permeable envelope 248 in order to maximize the use of granular catalyst 246. Water disperser 252 is a plate which has a plurality of holes 254 therein. Water disperser 252 is disposed horizontally below the inlet of tank 250.Catalytic column 88 also includes an outlet 258 at the base of tank 250 configured to allow drainage of the wastewater from tank 250. Catalytic column 88 also includes a water integrator 256 configured to prevent any part of semi-permeable envelope 248 from obstructing drainage of the wastewater via outlet

258. Water integrator 256 is a plate, similar to water disperser 252, which has a plurality of holes 260 therein. Water integrator 256 is disposed horizontally above outlet 258.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and sub-combinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art which would occur to persons skilled in the art upon reading the foregoing description.

What is claimed is:

1. A treatment system for wastewater, comprising:

(a) a first chamber;

(b) a second chamber having a pair of electrodes configured to produce a first electric field; and

(c) a conduit configured to connect said first chamber to said second chamber, wherein at least one of said first chamber, said second chamber and said conduit are formed such that a flow of the wastewater through said first electric field is substantially laminar.

2. The system of claim 1, further comprising:

(d) a semi-permeable membrane which is disposed between said pair of electrodes.

3. The system of claim 2, wherein said semi-permeable membrane substantially separates at least a part of the wastewater which is in said second chamber into a first flow and a second flow; and wherein said second chamber includes a first outlet and a second outlet such that said first flow exits from said second chamber via said first outlet and said second flow exits from said second chamber via said second outlet.

4. The system of claim 1, wherein the wastewater is configured to flow first

substantially parallel and then substantially perpendicular to said first electric field.

5. The system of claim 1, wherein the wastewater is configured to flow first substantially perpendicular and then substantially parallel to said first electric field.

6. The system of claim 1, wherein at least one of said pair of electrodes is configured so that upon at least one of entering and exiting said second chamber, the wastewater flows substantially parallel to said first electric field.

The system of claim 1, wherein at least one of said pair of electrodes has two major surfaces and a hole extending between said two major surfaces so that upon at least one of entering and exiting said second chamber, at least part of the wastewater flows through said hole.

7. The system of claim 7, further comprising:

(d) an edge protector having a length perpendicular to said major surfaces; said length being longer than a depth of said one electrode measured perpendicular to said major surfaces, said edge protector being configured to enhance an energy transfer between said one electrode and the wastewater which is flowing through said hole.

8. The system of claim 1, wherein at least one of said first chamber, said second chamber and said conduit are formed such that separate flows of the wastewater through said first electric field are treated substantially identically.

9. The system of claim 9, further comprising:

(d) a third chamber; and

(e) a second conduit configured to connect said third chamber to said second chamber, wherein at least one of said first chamber, said second chamber, said third chamber, said conduit and said second conduit are formed such that a flow of the wastewater through said first electric field is substantially laminar and separate flows of the wastewater through said first electric field are treated substantially identically.

10. The system of claim 10, further comprising:

(f) a fourth chamber having a second pair of electrodes configured to produce a second electric field; wherein the system is configured such that the wastewater is treated substantially identically by said first electric field and said second electric field.

11. The system of claim 1, further comprising a filtration apparatus which includes:

(a) a plurality of filtration elements configured to cooperate to filter the wastewater of an impurity; and

(b) an air pump configured to clean said filtration elements of at least a part of said impurity during a normal operation of said filtration apparatus.

12. The system of claim 12, wherein each of said filtration elements includes a member having a plurality of grooves thereon.

13. The system of claim 1, farther comprising a precious metal recovery apparatus which includes:

(a) a first electrode formed from a material having a high surface area to volume ratio; and

(b) a second electrode, said first electrode and said second electrode being configured for connection to a power supply to enable recovery of the precious metal from the wastewater by electroplating of said first electrode with at least part of the precious metal.

14. The system of claim 14, wherein said material is an absorbent conducting material.

15. The system of claim 14, wherein said material is a carbographite material.

16. The system of claim 1, further comprising a semi-permeable envelope for filtering an impurity from the wastewater, said envelope including:

(a) an inlet configured to allow the wastewater to enter said envelope; and

(b) a plurality of holes configured to:

(i) allow exit of the wastewater from said envelope; and

(ii) trap at least part of the impurity inside said envelope; wherein said envelope is configured to stretch to maintain a substantially constant filtering throughput of said envelope when said at least part of the impurity adheres near said holes.

17. The system of claim 17, wherein said envelope is substantially formed of a knitted fabric.

18. The system of claim 18, wherein said knitted fabric includes a polyamide thread.

19. The system of claim 1, further comprising a wastewater sedimentation apparatus which includes:

(a) a plurality of deflecting elements configured to cooperate to enhance sedimentation of impurities from the wastewater; and

(b) a distribution member configured to distribute the wastewater among said deflecting elements.

20. The system of claim 20, wherein each of said deflecting elements is shaped substantially as a truncated cone.

21. The system of claim 21, wherein said truncated cone has at least one projection.

22. The system of claim 22, wherein said projection is substantially radial.

23. The system of claim 20, wherein said distribution member is a perforated pipe.

24. The system of claim 24, wherein said deflecting elements and said distribution member are co-axially arranged.

25. The system of claim 20, further including a plurality of spacer members, each of said spacer members being disposed between said distribution member and two of said deflecting elements, said spacer members configured to maintain a laminar flow of the wastewater in order to enhance sedimentation of impurities from the wastewater.

26. The system of claim 1, further comprising a filtration apparatus to filter an impurity from the wastewater, said filtration apparatus including:

(a) a first surface having a plurality of ridges and grooves; and

(b) a second surface having a plurality of ridges and grooves wherein said first surface is disposed facing said second surface such that, said grooves of said first surface are nonparallel to said grooves of said second surface in order to cause at least part of the wastewater to take a non-linear path between said first surface and said second surface thereby filtering at least part of the impurity.

27. The system of claim 27, wherein said grooves of said first surface are substantially cross-aligned with said grooves of said second surface.

28. The system of claim 1, further comprising a filtration apparatus for filtering an impurity from wastewater, said filtration apparatus including:

(a) a granular catalyst configured to remove at least part of the impurity from the wastewater; and

(b) a semi-permeable envelope having a plurality of holes, said envelope being configured to contain said granular catalyst, said plurality of holes being configured to allow exit of the wastewater from said envelope, wherein said envelope is configured to stretch to maintain a substantially constant filtering throughput of the envelope when at least part of the impurity adheres near said holes.

29. The system of claim 29, wherein said envelope has an upper surface, said filtration apparatus further including:

(c) a tank configured to hold said envelope; and

(d) a water disperser configured to distribute the wastewater entering said tank over said upper surface of said envelope in order to maximize contact of the wastewater with said granular catalyst.

30. The system of claim 30, wherein said water disperser includes an element havinga plurality of holes therein, wherethrough the wastewater flows.

31. The system of claim 29, wherein said filtration apparatus further includes:

(c) a tank configured to hold said envelope, said tank having an outlet configured to allow a drainage of the wastewater from said tank; and

(d) a water integrator configured to prevent said envelope from obstructing the drainage of the wastewater via said outlet.

32. The system of claim 32, wherein said water integrator is an element having a plurality of holes therein, wherethrough the wastewater flows.

33. The system of claim 29, wherein said envelope is substantially formed of a knitted fabric.

34. The system of claim 34, wherein said knitted fabric includes a polyamide thread.

35. The system of claim 1, farther comprising an apparatus for aerating the wastewater, said apparatus including:

(a) a pipe configured for connection to a fluid supply; and

(b) a discharge head operationally connected to said pipe, said discharge head including at least one channel having a cross-sectional area, at least part of said channel being configured for insertion into the wastewater, said cross-sectional area being small enough that when a flow of a fluid from said fluid supply is activated, a low pressure region is set up in the wastewater, thereby producing a plurality of micro-bubbles which aerate the wastewater.

36. The system of claim 36, wherein said fluid is air.

38. The system of claim 36, wherein said fluid is recycled water.

39. The system of claim 1, further comprising an apparatus for aerating wastewater, said apparatus including:

(a) a first pipe configured to introduce the wastewater to said apparatus;

(b) a second pipe configured for connection to a fluid supply; and

(c) a discharge head having at least one channel, said channel being configured to operationally connect said second pipe to said first pipe, said channel having a cross- sectional area that is small enough that when a flow of a fluid from said fluid supply is activated, a low pressure region is set up in said first pipe that:

  (i) produces a plurality of micro-bubbles which aerate the wastewater; and

  (ii) quickens a flow of the wastewater into said apparatus.

40. The system of claim 39, wherein said second pipe is at least partially disposed within said first pipe.

41. The system of claim 39, wherein said discharge head has a conical surface having an apex that points opposite to a direction of flow of the wastewater in said first pipe.

42. A filtration apparatus, comprising:

(a) a plurality of filtration elements configured to cooperate to filter wastewater of an impurity; and

(b) an air pump configured to clean said filtration elements of at least a part of said impurity during a normal operation of the filtration apparatus.

43. The filtration apparatus of claim 42, wherein each of said filtration elements includes a member having a plurality of grooves thereon.

44. A precious metal recovery system, comprising:

(a) a first electrode formed from a material having a high surface area to volume ratio; and

(b) a second electrode, said first electrode and said second electrode being configured for connection to a power supply to enable recovery of the precious metal from wastewater by electroplating of said first electrode with at least part of the precious metal.

45. The system of claim 44, wherein said material is an absorbent conducting material.

46. The precious metal recovery system of claim 44, wherein said material is a carbographite material.

47. A semi-permeable envelope for filtering an impurity from wastewater, comprising:

(a) an inlet configured to allow the wastewater to enter the envelope; and

(b) a plurality of holes configured to:

(i) allow exit of the wastewater from the envelope; and

(ii) trap at least part of the impurity inside the envelope; wherein the envelope is configured to stretch to maintain a substantially constant filtering throughput of the envelope when said at least part of the impurity adheres near said holes.

48. The apparatus of claim 47, wherein said envelope is substantially formed of a knitted fabric.

49. The apparatus of claim 48, wherein said knitted fabric includes a polyamide thread.

50. A wastewater sedimentation apparatus, comprising:

(a) a plurality of deflecting elements configured to cooperate to enhance sedimentation of impurities from the wastewater; said deflecting elements being shaped substantially as a truncated cone; said truncated cone having at least one projection; and

(b) a distribution member configured to distribute the wastewater among said deflecting elements; said distribution member being a perforated pipe, wherein said deflecting elements and said distribution member are co-axially arranged.

51. The apparatus of claim 50, wherein said projection is substantially radial.

52. The apparatus of claim 50, further comprising a plurality of spacer members, each of said spacer members being disposed between said distribution member and two of said deflecting elements, said spacer members configured to maintain a laminar flow of the wastewater in order to enhance sedimentation of impurities from the wastewater.

53. A filtration apparatus to filter an impurity from wastewater, comprising:

(a) a first surface having a plurality of ridges and grooves; and

(b) a second surface having a plurality of ridges and grooves wherein said first surface is disposed facing said second surface such that, said grooves of said first surface are nonparallel to said grooves of said second surface in order to cause at least part of the wastewater to take a non-linear path between said first surface and said second surface thereby filtering at least part of the impurity.

54. The apparatus of claim 53, wherein said grooves of said first surface are substantially cross-aligned with said grooves of said second surface.

55. A filtration apparatus for filtering an impurity from wastewater, comprising:

(a) a granular catalyst configured to remove at least part of the impurity from the wastewater: and

(b) a semi-permeable envelope having a plurality of holes, said envelope being configured to contain said granular catalyst, said plurality of holes being configured to allow exit of the wastewater from said envelope, wherein said envelope is configured to stretch to maintain a substantially constant filtering throughput of the envelope when at least part of the impurity adheres near said holes.

56. The apparatus of claim 55, wherein said envelope has an upper surface, the apparatus further comprising:

(c) a tank configured to hold said envelope; and

(d) a water disperser configured to distribute the wastewater entering said tank over said upper surface of said envelope in order to maximize contact of the wastewater with said granular catalyst.

57. The apparatus of claim 56, wherein said water disperser includes an element having a plurality of holes therein, wherethrough the wastewater flows.

58. The apparatus of claim 55, further comprising:

(c) a tank configured to hold said envelope, said tank having an outlet configured to allow a drainage of the wastewater from said tank; and

(d) a water integrator configured to prevent said envelope from obstructing the drainage of the wastewater via said outlet.

59. The apparatus of claim 58, wherein said water integrator is an element having a plurality of holes therein, wherethrough the wastewater flows.

60. The apparatus of claim 55, wherein said envelope is substantially formed of a knitted fabric.

61. The apparatus of claim 60, wherein said knitted fabric includes a polyamide thread.

62. A apparatus for aerating wastewater, comprising:

(a) a pipe configured for connection to a fluid supply; and

(b) a discharge head operationally connected to said pipe, said discharge head including at least one channel having a cross-sectional area, at least part of said channel being configured for insertion into the wastewater, said cross-sectional area being small enough that when a flow of a fluid from said fluid supply is activated, a low pressure region is set up in the wastewater, thereby producing a plurality of micro-bubbles which aerate the wastewater.

63. The apparatus of claim 62, wherein said fluid is air.

64. The apparatus of claim 62, wherein said fluid is recycled water.

65. An apparatus for aerating wastewater, comprising:

(a) a first pipe configured to introduce the wastewater to the apparatus;

(b) a second pipe configured for connection to a fluid supply; and

(c) a discharge head having at least one channel, said channel being configured to operationally connect said second pipe to said first pipe, said channel having a cross- sectional area that is small enough that when a flow of a fluid from said fluid supply is activated, a low pressure region is set up in said first pipe that:

(i) produces a plurality of micro-bubbles which aerate the wastewater; and

(ii) quickens a flow of the wastewater into the apparatus.

66. The apparatus of claim 65, wherein said second pipe is at least partially disposed within said first pipe.

67. The apparatus of claim 65, wherein said discharge head has a conical surface having an apex that points opposite to a direction of flow of the wastewater in said first pipe.

68. A method for treating wastewater, comprising the steps of:

(a) providing an electric field; and

(b) causing a substantially laminar flow of the wastewater through said electric field in order to precipitate a plurality of metal ions from the wastewater.

69. The method of claim 68, further comprising the step of:

(c) ensuring that separate flows of the wastewater through said electric field are treated substantially identically.

70. The method of claim 68, farther comprising the step of:

(c) performing at least one operation selected from the group consisting of filtering of said wastewater and causing sedimentation from said wastewater.

71. The method of claim 68, further comprising the step of:

(c) substantially separating at least part of the wastewater prior to leaving said electric field into a first flow which includes said metal ions and a second flow.

72. The method of claim 68, wherein said step of causing said laminar flow of the wastewater includes causing said substantially laminar flow of the wastewater first substantially parallel and then substantially perpendicular to said electric field.

73. The method of claim 68, wherein said step of causing said laminar flow of the wastewater includes causing said substantially laminar flow of the wastewater first substantially perpendicular and then substantially parallel to said electric field.

74. A method to filter an impurity from wastewater, comprising the steps of:

(a) filtering the wastewater of an impurity using a filter; and

(b) cleaning at least part of said filter of the impurity using air pressure.

References, patent and license information

Appendix 1

United States Patent	**5,658,450**
Tamarkin	**August 19, 1997**

Method of and device for industrial waste water treatment

Abstract

Waste **water** is purified by passing through a vessel in which small particles of insoluble cathodes interact with anodes to form galvanic couples. During this process, chemical reduction of ions of **heavy metals in the water** occurs by ions and hydroxides formed during **electrochemical** dissolution of anodes. The hydroxides arean excellent coagulating agent which absorbs impurities contained in the **water**.Pressurized air can saturate the waste **water** simultaneously with passing through the vessel with anodes in order to produce process floatation using hydroxides as coagulant. The temperature of the waste **water** can be increased in order to intensity the process of **treatment**.

Appendix 2

United States Patent	**7,553,418**
Khudenko , et al.	**June 30, 2009**

Method for water filtration

Abstract

This is a method of filtration of a liquid comprising steps of sequential filtration of said liquid through at least one deep bed medium producing at least one first filtrate followed by at least one membrane medium filtration producing at least one second filtrate, wherein said membrane medium is at least periodically within said deep bed media Many types of deep bed and membrane media can be used. The domain of using contact clarification (direct filtration) can be expanded towards greater solids concentration. Operation and backwash, is simplified, continuous filtration becomes possible. **Water** can be **water** from natural source **water,** process **water,** wastewater, aqueous or non-aqueous suspensions, emulsions, solutions. **Treatment** can include mechanical interception of suspended particles, chemical, physical chemical, **electrochemical,** and biological processes. In **water** and wastewater processing, control over suspended solids, BOD, COD, nitrogen and phosphorus compounds, bacteria and viruses, **heavy metals,** color, and other constituents can be dramatically improved as compared to conventional processes. The method can be accommodated in new and modified existing **treatment** systems.

Appendix 3

United States Patent **10,745,300**
Hale , et al. **August 18, 2020**

Configuration for electrochemical water treatment

Abstract

An **electrochemical water treatment** apparatus includes a **treatment** chamber formed by at least one wall and having an opening formed along the side for substantially the length of the **treatment** chamber, with a mounting plate applied to the opening. A set of cathodes and anodes are mounted to the mounting plate and positioned inside the chamber, each of the anodes having at least one cathode positioned on each of the two sides of the respective anode. At least two anode bus barsand two cathode bus bars are provided, each bus bar connectable to the power supply and connected to the respective electrodes near a respective end of the electrodes. An inlet adapter has a smaller cross sectional area at the first end connected tothe **treatment** chamber inlet end, and a larger cross sectional area at the opposite end connected to the source of **water** to be treated. An outlet adapter has a smaller cross sectional area at the first end connected to the **treatment** chamber outlet end, and a larger cross sectional area at the second end connected to the destination for the treated **water**.

Appendix 4

United States Patent **9,868,659**
Wang , et al. **January 16, 2018**

Subsurface water purification method

Abstract

A method of producing purified **water** in a subsurface environment is provided in which ambient subsurface source **water** is introduced into and through one or more ultrafiltration membrane units of a subsurface **water treatment** system and producing thereby an ultrafiltrate substantially free of solid particulates having a largest dimension greater than 0.1 microns. An **electrochemical** unit in fluid communication with at least one ultrafiltration membrane unit provides an antifoulant solution. An ultrafiltrate-rich backwash fluid and at least a portion of the antifoulant solution are delivered to at least one non-producing ultrafiltration membrane unit during a backwash cycle. A flux of source fluid through each of the ultrafiltration membrane units of less than thirty gallons per square foot per day limits the need for backwash cycles. A reduction in the number of backwash cycles enhances system autonomy and useful life, and limits the need for intervention for maintenance and component replacement.

Appendix 5

United States Patent **8,114,260**
Wilkins , et al. **February 14, 2012**

Water treatment system and method

Abstract

A **water treatment** system provides treated or softened **water** to a point of use by removing a portion of any hardness-causing species contained in **water** from a point-of-entry coming from a **water** source, such as municipal **water,** well **water,** brackish **water and water** containing foulants. The **water treatment** system typically treats the **water** containing at least some undesirable species before delivering the treated **water** to a point of use. The **water treatment** system has a controller for adjusting or regulating at least one operating parameter of the **treatment** system or a component of the **water treatment** system tooptimize the operation and performance of the system or components of the system. Aflow regulator regulates a waste stream flow to drain and can be operated to recirculatefluid through electrode or concentrating compartments of an **electrochemical** device and can opened and closed intermittently according to a predetermined schedule or based on an operating parameter of the **water treatment** system. The flow regulator can also be charged so that ionic species can be generated in the surrounding fluid, which, in turn, can lower the pH of the surrounding fluid.

Appendix 6

United States Patent **8,377,279**
Jha , et al. **February 19, 2013**

Water treatment system and method

Abstract

A **treatment** system provides treated or softened **water** to a point of use by removing at least a portion of any undesirable species contained in **water from a water** source. The **treatment** system can be operated to reduce the likelihood of formation of any scale that can be generated during normal operation of an **electrochemical** device. The formation of scale in the **treatment** system, including its wetted components, may be inhibited by reversing or substituting the flowing liquid having hardness-causing species with another liquid having a low tendency to produce scale, such as a low LSI **water**. Various arrangements of components in the **treatment** system can be flushed by directing the valves and the pumps of the system to displace liquid having hardness-causing species with a liquid that has little or no tendency to form scale.

Appendix 7

United States Patent **8,585,882**
Freydina , et al. **November 19, 2013**

Systems and methods for water treatment

Abstract

Electrochemical devices and methods for **water treatment** are disclosed. An electrodeionization device (100) may include one or more compartments (110) containing an ionselective media, such as boron-selective resin (170). Cyclic adsorption of target ions and regeneration of the media in-situ is used to treat process **water,** and may be driven by the promotion of various pH conditions within the **electrochemical** device.

Appendix 8

United States Patent **8,658,043**
Wilkins , et al. **February 25, 2014**

Water treatment system and method

Abstract

A **water treatment** system provides treated **water** to a point of use by removing at least a portion of any hardness-causing species contained in **water from a water** source, such as municipal **water,** well **water,** brackish **water and water** containing foulants. The **water treatment** system typically receives **water from the water** source or a point of entry and purifies the **water** containing at least some undesirable species before delivering the treated **water** to a point of use. The **water treatment** system has a pressurized reservoir system in line with an **electrochemical** device such as an electrodeionization device. The **water treatment** system can have a controller for adjusting or regulating at least one operating parameter of the **treatment** system or a component of the **water treatment** system. The **electrochemical** device can be operated at a low current and low flow rate to minimize **water** splitting or polarization, which minimizes scale formation.

Appendix 9

United States Patent **8,999,173**

Schwartzel , et al. **April 7, 2015**

Aqueous treatment apparatus utilizing precursor materials and ultrasonics to generate customized oxidation-reduction-reactant chemistry environments in electrochemical cells and/or similar devices

Abstract

An electrochlorination and **electrochemical** system for the on-site generation and **treatment** of municipal **water** supplies and other reservoirs of **water,** by using a custom mixed oxidant and mixed reductant generating system for the enhanced destruction of **water** borne contaminants by creating custom oxidation-reduction-reactant chemistries with real time monitoring. A range of chemical precursors are provided that when acted upon in an **electrochemical** cell either create an enhanced oxidation, or reduction environment for the destruction or control of contaminants. Chemical agents that can be used to control standard **water** quality parameters such as total hardness, total alkalinity, pH, total dissolved solids, and the like are introduced via the chemical precursor injection subsystem infrequently or in real time based on sensor inputs and controller set points.

Appendix 10

United States Patent **9,090,493**

Nyberg , et al. **July 28, 2015**

Electrochemical ion exchange treatment of fluids

Abstract

A fluid **treatment** apparatus comprises an **electrochemical** cell having fluid orifices to receive input fluid and release output fluid, the input fluid having a first level of a microorganism. First and second electrodes are about a **water**-splitting membrane in the **electrochemical** cell. A valve controls the flow of fluid through fluid orifices of the **electrochemical** cell. A power supply supplies a current to the first and second electrodes. A control module comprises program code to operate the valve to flow the input fluid into a fluid orifice of the **electrochemical** cell and provide a residence time of the fluid in the cell of at least 0.05 minutes, while controlling the power supply to supply to the first and second electrodes, a current having a current density of from about 0.01 to about 20 mA/cm.sup.2.

Appendix 11

United States Patent **9,221,696**
Li , et al. **December 29, 2015**

Wastewater treatment process by electrochemical apparatus

Abstract

A wastewater **treatment** process by an **electrochemical** apparatus, said apparatus having at least an **electrochemical** electrode (30), and said **electrochemical** electrode (30) having suitable electrode plates comprises the following steps: passing high concentration wastewater containing undesirable solutes through at leastone **electrochemical** electrode (30) to which a DC electrical current is applied to destroy the undesirable solutes in the **water** intake, so as to output **water** having a lower concentration of the undesirable solutes; the DC current applied to the **electrochemical** electrode (30) comprises at least a constant potential difference stage exerted on both ends of the **electrochemical** electrode (30), and followed by a constant current stage through the **electrochemical** electrode (30).

Appendix 12

United States Patent **9,440,866**
Legzdins **September 13, 2016**

Efficient treatment of wastewater using electrochemical cell

Abstract

An efficient method and system for the **electrochemical treatment** of waste **water** comprising organic and/or inorganic pollutants is disclosed. The system comprises an electrolytic cell comprising a solid polymer, proton exchange membrane electrolyte operating without catholyte or other supporting electrolyte. The cell design and operating conditions chosen provide for significantly greater operating efficiency.

Appendix 13

United States Patent **9,574,277**
Jha , et al. **February 21, 2017**

Electrochemical water softening system

Abstract

Systems and methods for treating **water** are provided. The systems and methods may utilize an **electrochemical water treatment** device comprising ion exchange membranes. In certain systems and methods, a concentrate stream and a dilution stream may be in fluid communication with ion exchange membranes. The ion exchange membranes may be configured to provide a ratio of a pH of the concentrate stream and a pH of the dilution stream to be less than about 1.0. In some instances, the LSI of the concentrate stream may be less than or about 1.0. In certain instances, the **electrochemical water treatment** device does not require a reverse polarity cycle.

Appendix 14

United States Patent **9,963,363**
Kim , et al. **May 8, 2018**

Continuous flow-electrode system, and high-capacity power storage and water treatment method using the same

Abstract

The present invention uses the principles of **electrochemical** ion absorption (charging) and ion desorption (discharge), and relates to a continuous flow-electrode system, a high-capacity energy storage system, and a **water treatment** method using the same, in which high-capacity electric energy is stored as electrode materials of a slurry phaseand electrolytes simultaneously flow in a successive manner within a fine flow channel structure formed on an electrode. More specifically, the present invention relates to a continuous flow-electrode system, an energy storage system, and a **water treatment** method, wherein electrode active materials consecutively flow in a slurry state whereby a high capacity is easily obtained without enlarging or stacking electrodes.

Appendix 15

United States Patent **9,963,790**
Silver , et al. **May 8, 2018**

Bio-electrochemical systems

Abstract

The present invention provides bio**-electrochemical** systems having various configurations for the **treatment of water,** wastewater, gases, and other biodegradable matter. In one aspect, the invention provides bio**-electrochemical** systems configured for treating wastewater while generating multiple outputs. In another aspect, the invention provides bio**-electrochemical** systems configured for improving the efficiency of electrodialysis removal systems. In yet another aspect, the invention provides bio-electro-chemical systems configured for use in banks and basins.

Appendix 16

United States Patent **10,604,428**
Thomas **March 31, 2020**

Waste water treatment

Abstract

A waste **water** **treatment** apparatus utilizing **electrochemical** technology. **Electrochemical** waste **water treatment** is based on the application of an electric field between an anode and a cathode to the waste **water**. The apparatus for waste **water treatment** comprise a channel extending through a housing between an inlet and an outlet and a **water treatment** zone between the inlet and outlet. The apparatus further comprise first and second spaced apart electrodes having working ends for treating waste **water in the treatment** zone, and an electrode feed arrangement for feeding the first and second electrodes towards the channel to control the spacing between the working ends of the first and second electrodes.

Appendix 17

United States Patent **10,815,134**
Sasabe , et al. **October 27, 2020**

Water treatment device

Abstract

The **water treatment** device according to the present disclosure includes: an **electrochemical** cell having electrodes including a positive electrode and a negative electrode, and a bipolar membrane; a tank; a power supply configured to apply power to the electrodes; a **water** circulation flow path having at least the tank and the **electrochemical** cell and through which **water** circulates; a circulation device configured to circulate **water in the water** circulation flow path; a raw **water** supply path configured to supply raw **water to the water** circulation flow path; and a control device. In performing **water** softening **treatment in the electrochemical** cell where power is applied to the electrodes so as to remove ions from raw **water** and soft **water** is produced, the control device drives the circulation device so as tocirculate **water in the water** circulation flow path.

Appendix 18

United States Patent **10,604,427**
Martikainen , et al. **March 31, 2020**

Electrochemical reactor, an apparatus and a system for treating water, and a method for controlling a water treatment apparatus

Abstract

A **water treatment** apparatus includes an **electrochemical** reactor including a shell structure and a support structure for supporting the shell structure on a base. The support structure includes at least one support element supporting the shell structure from the ledge. A head room portion includes, within the inner space of the shell structure, at least one shelf for receiving and supporting at least one lug portion of at least one electrode plate for suspending the electrode plate. The shelf being located, when in use, preferably directly above the ledge.

Appendix 19

United States Patent **10,507,429**
Sasabe , et al. **December 17, 2019**

Electrochemical cell, water treatment device provided with same, and operating method for water treatment device

Abstract

An **electrochemical** cell according to the present disclosure includes a casing provided with an inflow port and an outflow port, a bipolar membrane laminated body in whichtwo or more bipolar membranes are laminated so as to be opposed, electrodes disposedso as to sandwich the bipolar membrane laminated body, and a first diffusion member disposed between the inflow port and the bipolar membrane laminated body, and provided with through holes communicating between the inflow port and the bipolar membrane laminated body. The first diffusion member is formed such that each of the through holes provided in a peripheral edge portion has a larger opening area than an opening area of the through holes provided in a central portion. This can uniformize a flow of **water,** so that **water treatment** can be efficiently executed.

Appendix 20

United States Patent **10,329,173**
Salokannel , et al. **June 25, 2019**

System for treating water

Abstract

A system for treating **water** includes an **electrochemical water treatment** unit having a first self-supporting framework limiting a first inner space.An **electrochemical** reactor is arranged in the first inner space vertically below a first opening at a top side of the **electrochemical water treatment** unit. The systemincludes a maintenance unit having a second self-supporting framework limiting a second inner space. The maintenance unit includes a second opening in a bottom side. The maintenance unit is arranged above the **electrochemical water treatment** unit sothat the first opening and the second opening are aligned. A hoist is moveably arrangedalong a rail structure at the top side of the maintenance unit.

Appendix 21

United States Patent	**10,287,181**
Martikainen , et al.	**May 14, 2019**

Electrochemical reactor for electrochemically treating water, a water treatment apparatus and use of such said electrochemical reactor

Abstract

An **electrochemical** reactor for electrochemically treating **water,** including a shell structure defining an inner space. The shell structure further includes an inlet portion having an inlet for conducting a **water** flow to the inner space, and a reactor chamber in flow connection with the inlet portion, and preferably with an outlet portion. The inlet is arranged such that the **water** flow to the inner space is directed away from the reactor chamber so as to cause the **water** flow to mix by forcing the **water** flow to change direction before entering the reactor chamber. A **water treatment** apparatus having such a reactor, and the use of such a reactor are also disclosed.

Appendix 22

United States Patent	**10,266,429**
Legzdins	**April 23, 2019**

Efficient treatment of wastewater using electrochemical cell

Abstract

An efficient method and system for the **electrochemical treatment** of waste **water** comprising organic and/or inorganic pollutants is disclosed. The system comprises at least first and second solid polymer electrolyte electrolytic cell stacks in which each cell comprises a solid polymer, proton exchange membrane electrolyte operating without catholyte or other supporting electrolyte. The first and second stacks differ either in construction or operating condition. The cell stack design and operating conditions chosen provide for significantly greater operating efficiency.

Appendix 23

United States Patent	**9,701,548**
Mehmi , et al.	**July 11, 2017**

Electrochemical water softening system

Abstract

Systems and methods for treating **water** are provided. The systems and methods may utilize an **electrochemical water treatment** device comprising ion exchange membranes. In certain systems and methods, a concentrate stream and a dilution stream may be in fluid communication with ion exchange membranes. The ion exchange membranes may be configured to provide a ratio of a pH of the concentrate stream and a pH of the dilution stream to be less than about 1.0. In some instances, the LSI of the concentrate stream may be less than or about 1.0. In certain instances, the **electrochemical water treatment** device does not require a reverse polarity cycle.

Fig. 1

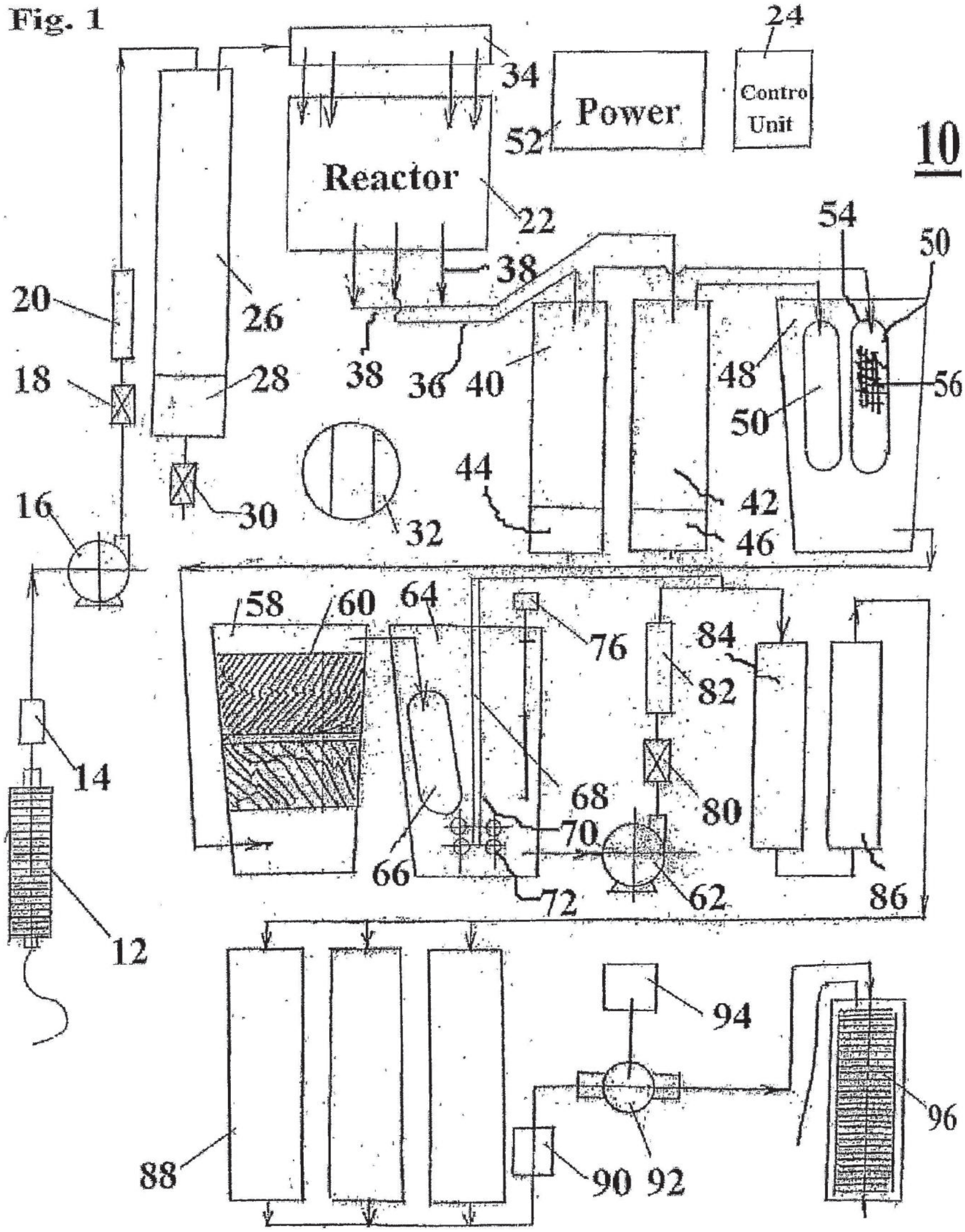
24
Contro Unit
34
Power
52
10
Reactor
22
54
50
38
20
26
38
36
40
48
56
18
28
50
44
42
16
30
32
46
58
60
64
76
84
82
14
68
80
70
66
72
62
86
12
94
96
88
90
92

Fig. 1a

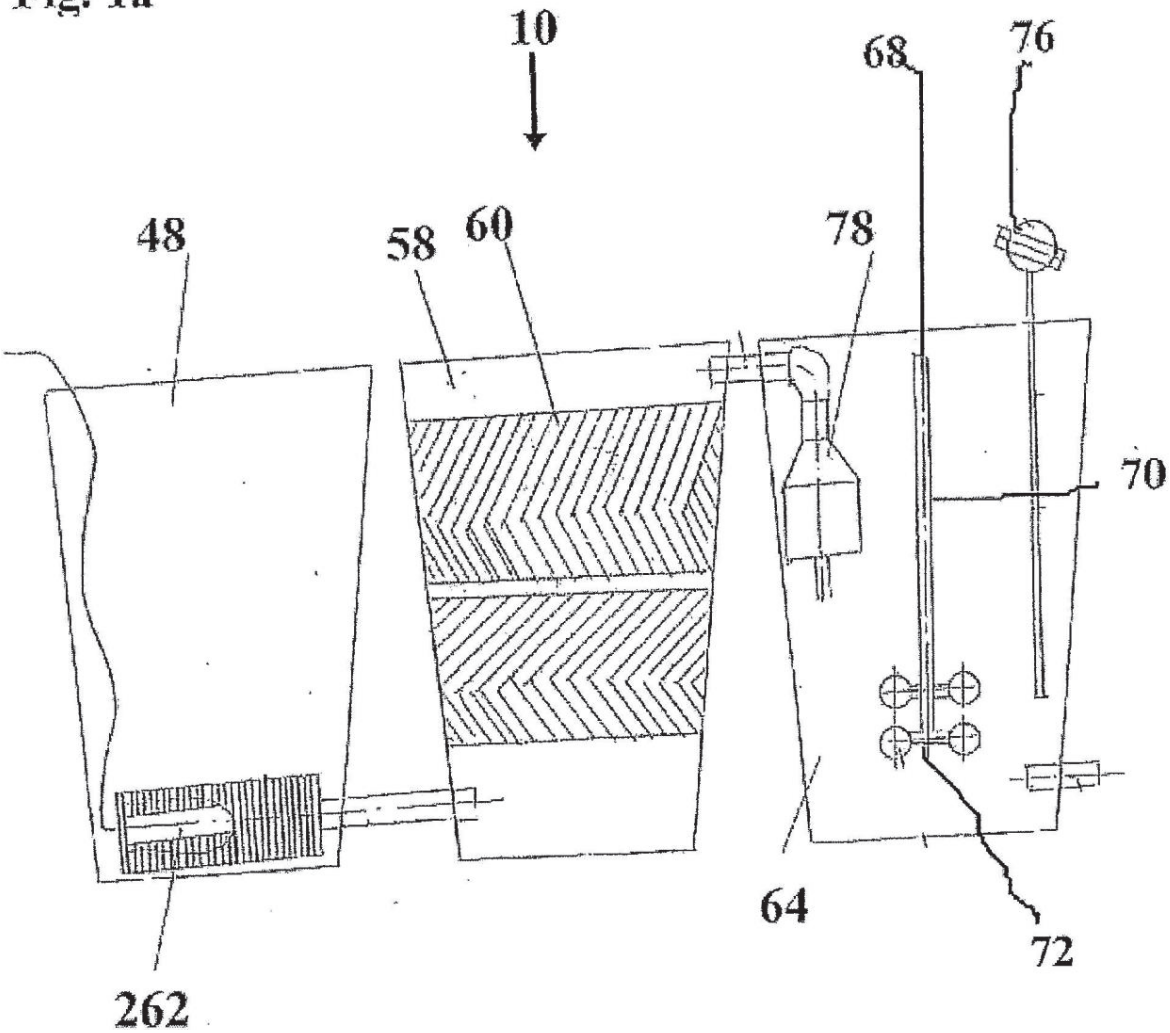

Fig. 2

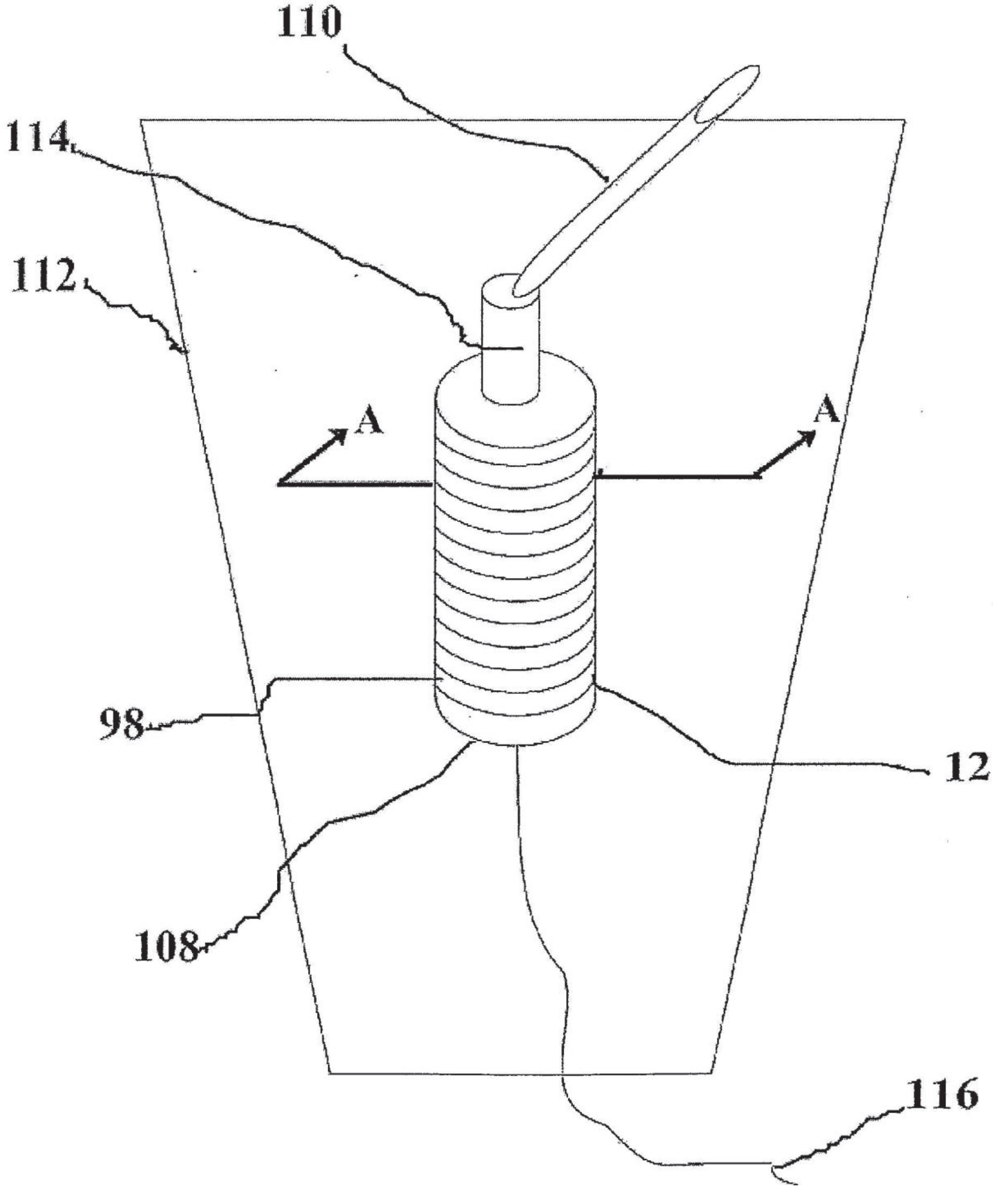

Fig. 3

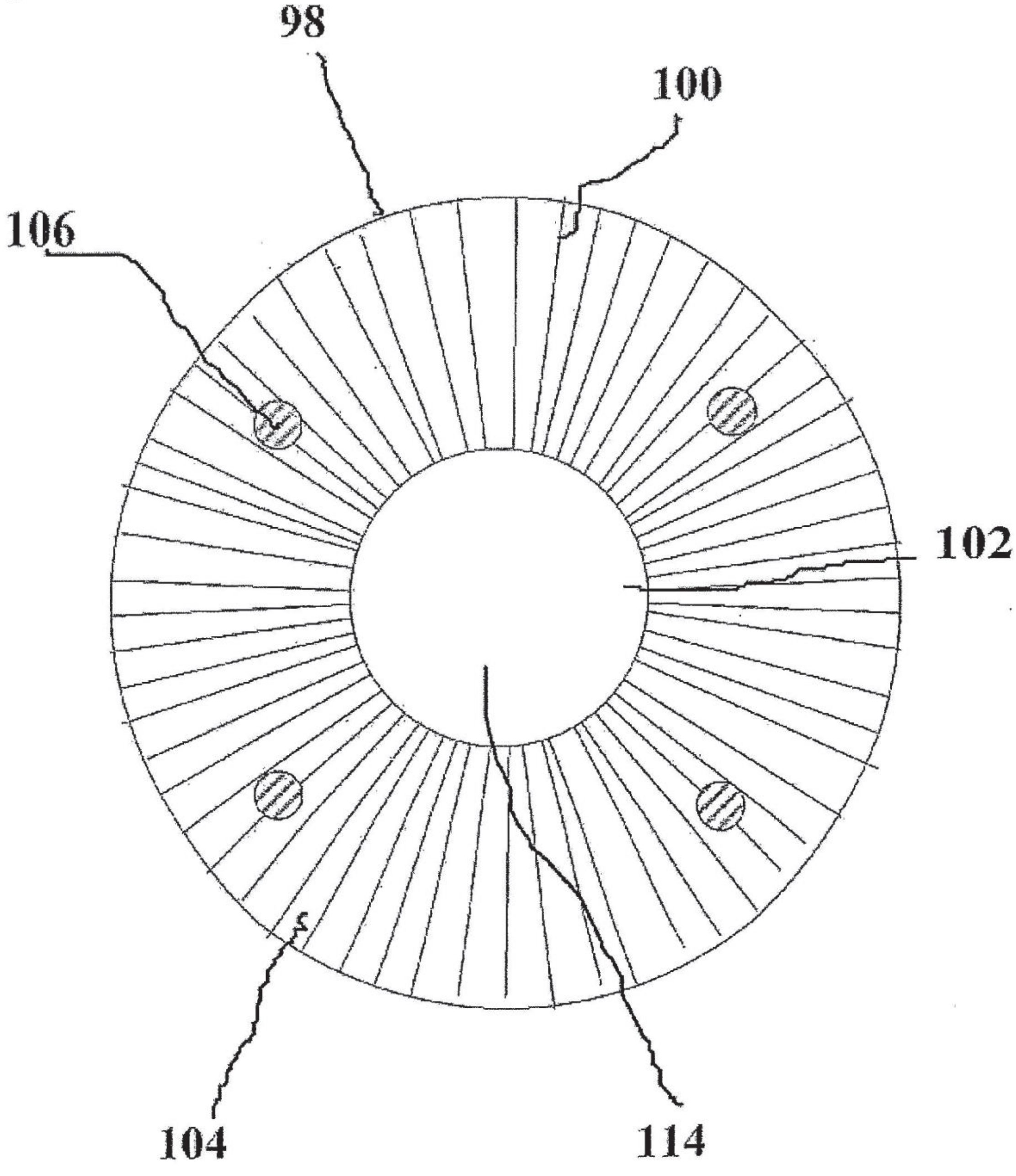

Fig. 4

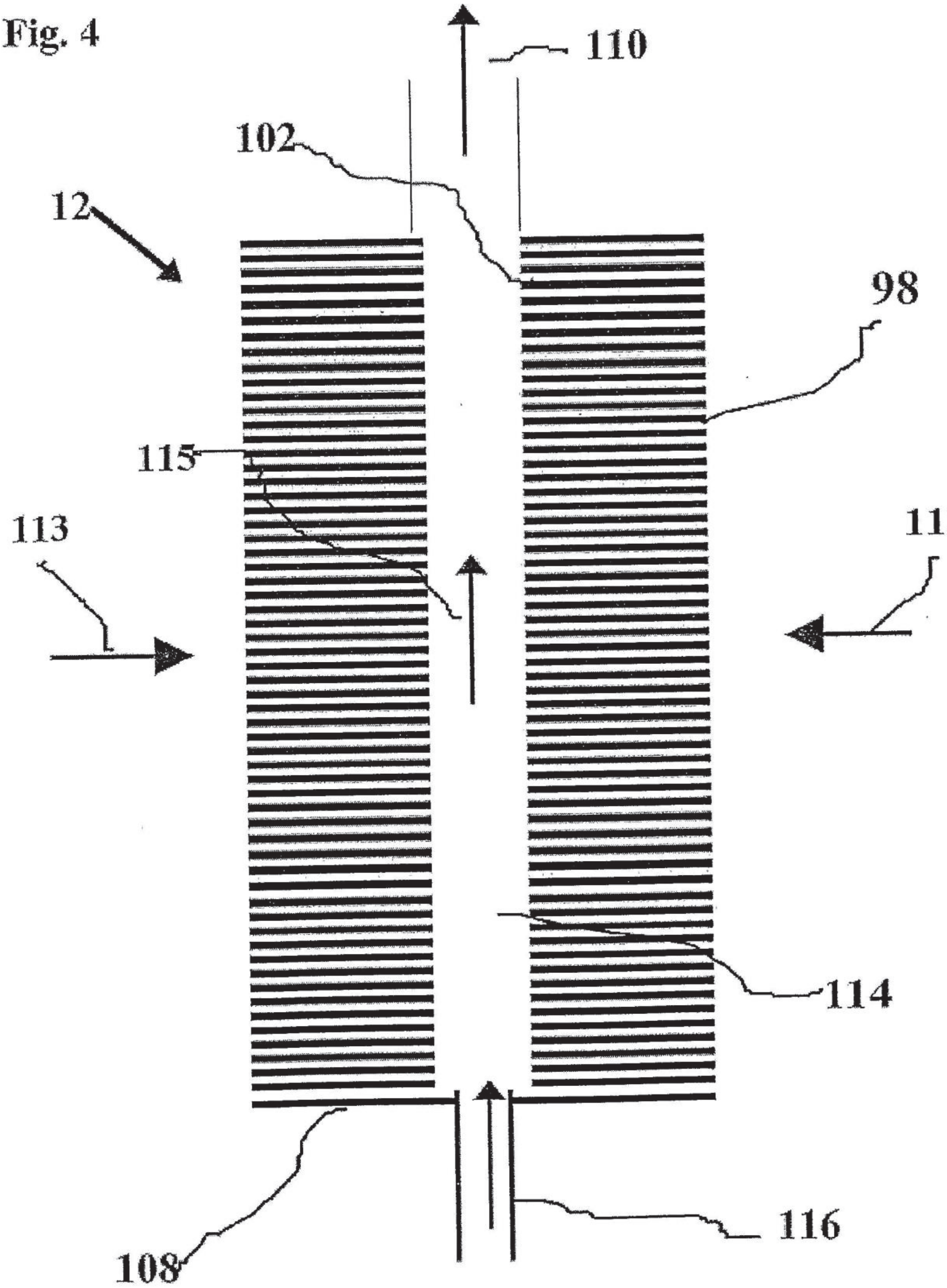

Fig. 5

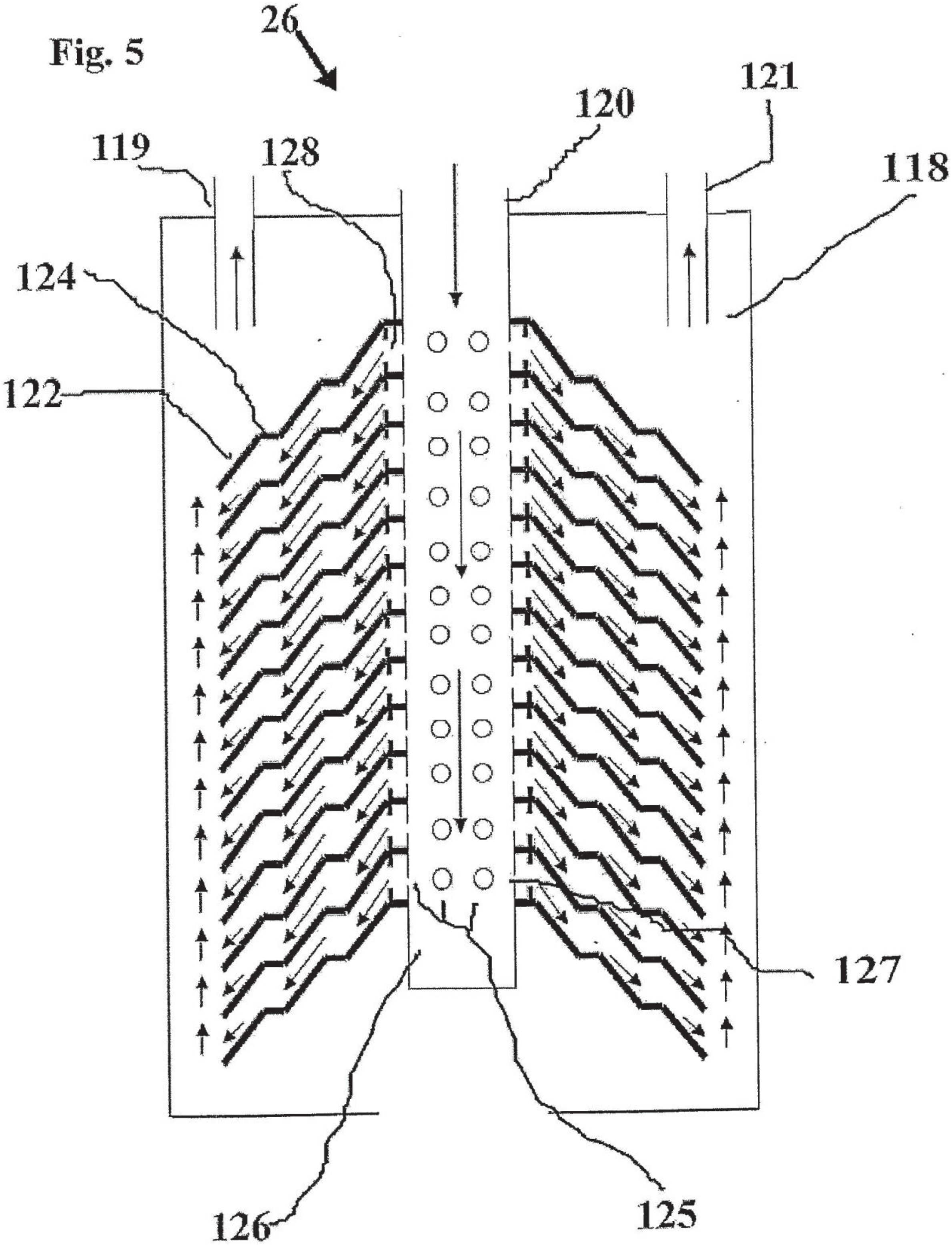

Fig. 6

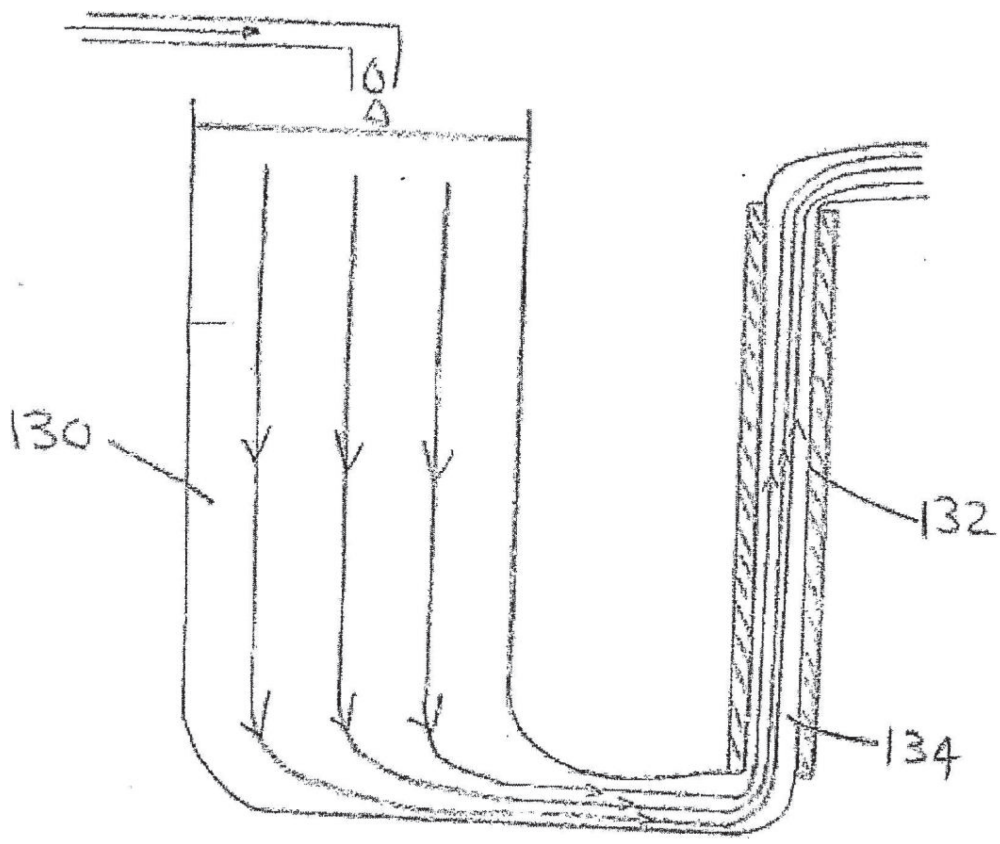

Fig. 7

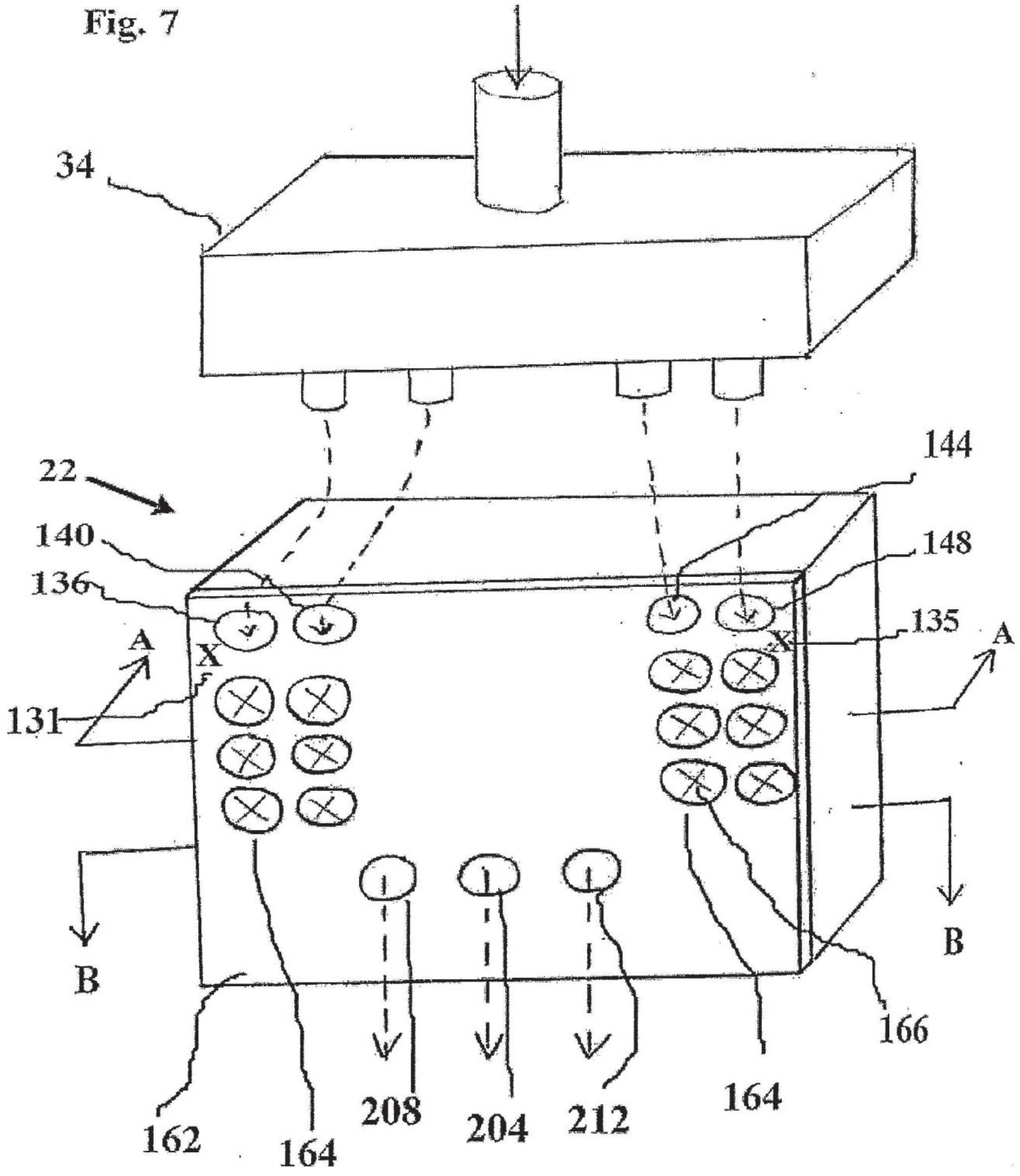

Fig. 8

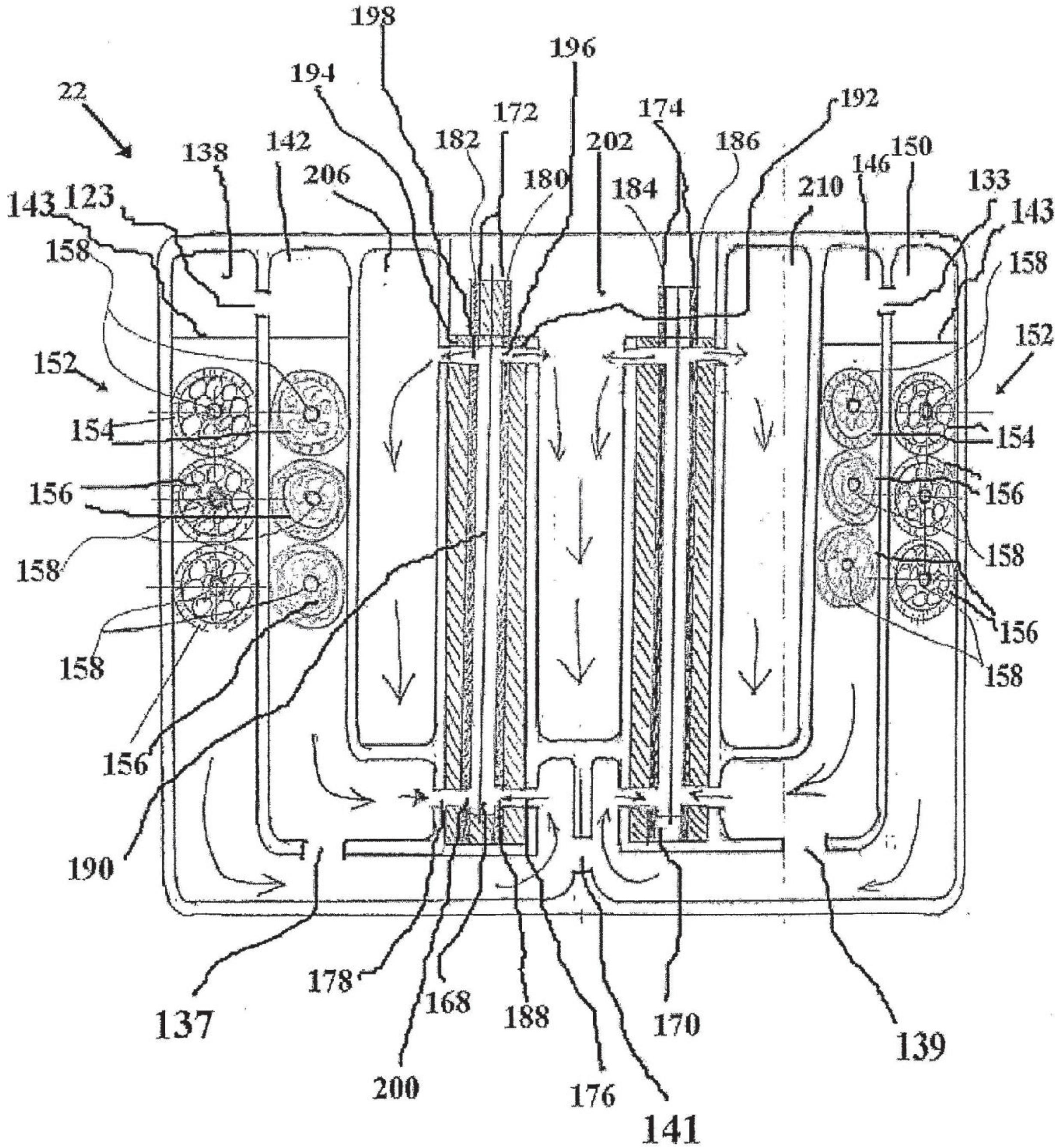
22
138
142
143
123
158
152
154
156
158
156
190
198
194
196
172
182
180
174
202
184
186
192
206
210
146
150
133
143
158
152
154
156
158
156
158
137
178
200
168
188
176
141
170
139

Fig. 9

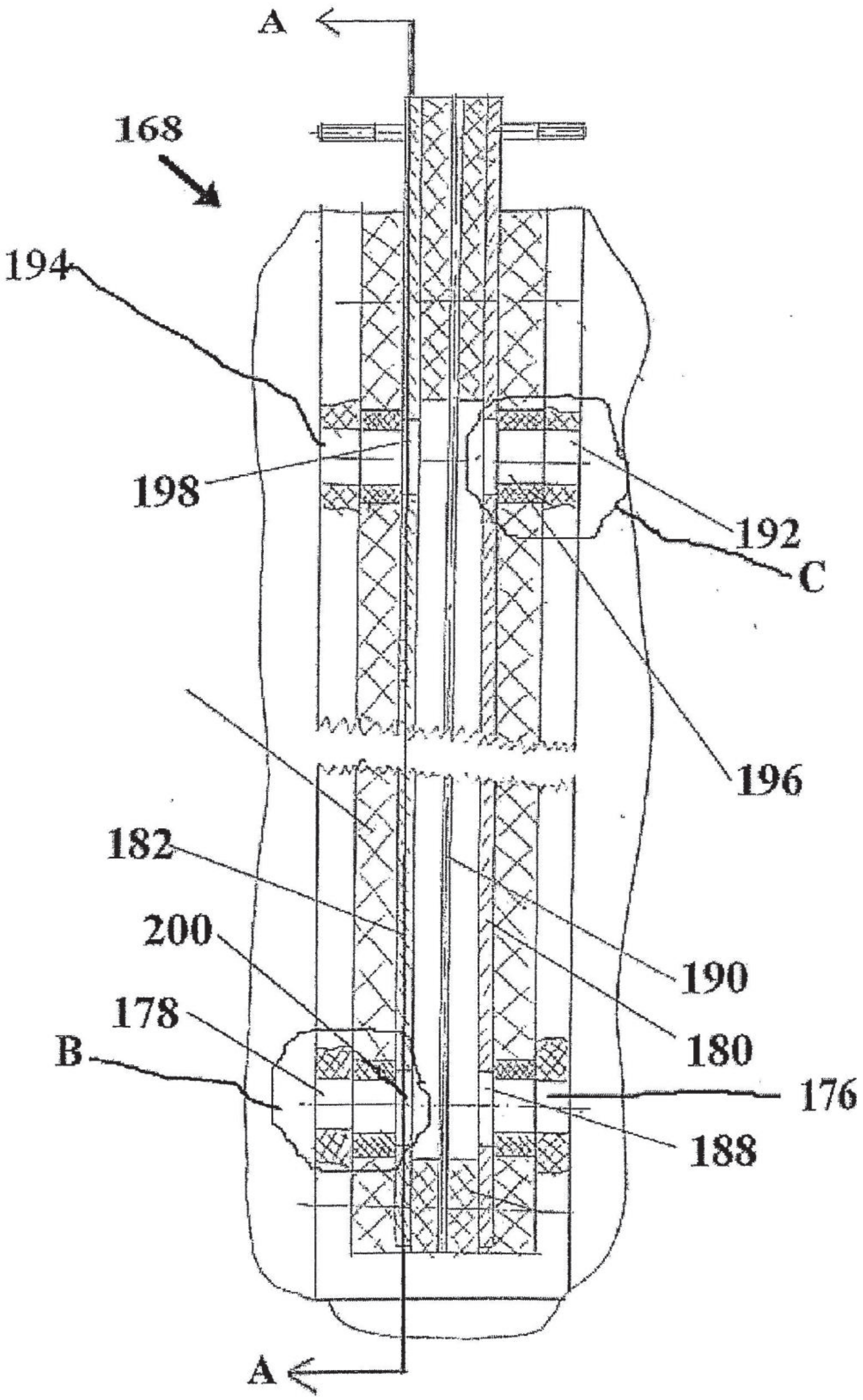

Fig. 10

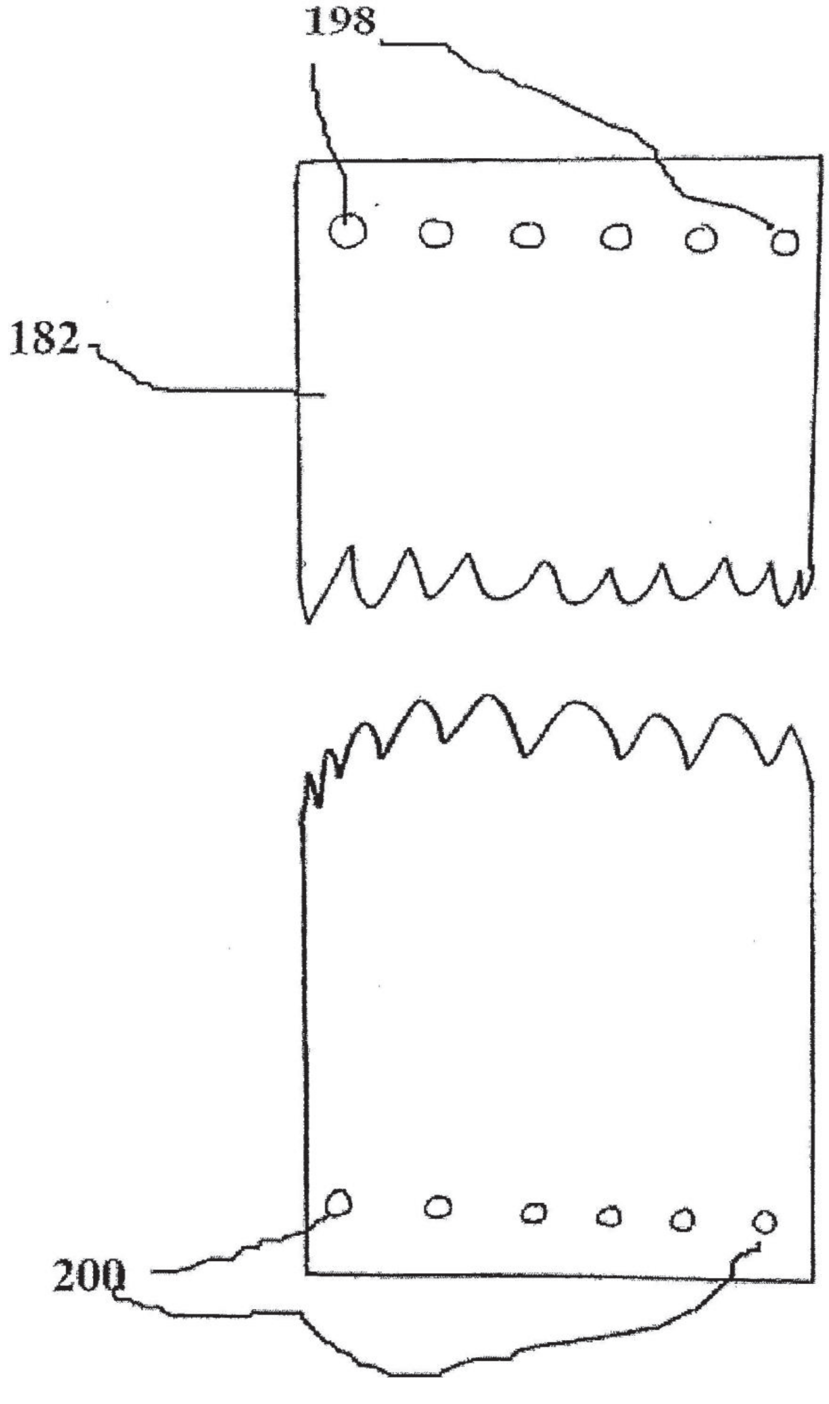

Fig. 11

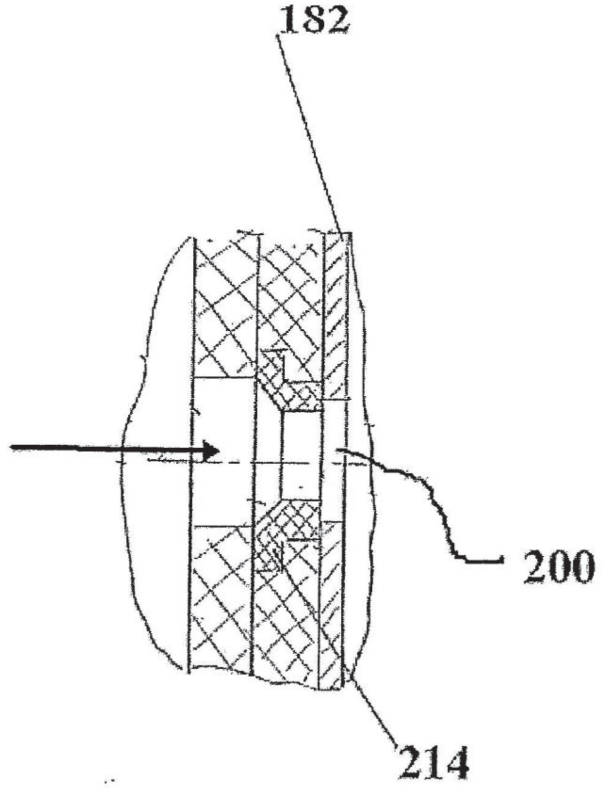

Fig. 12

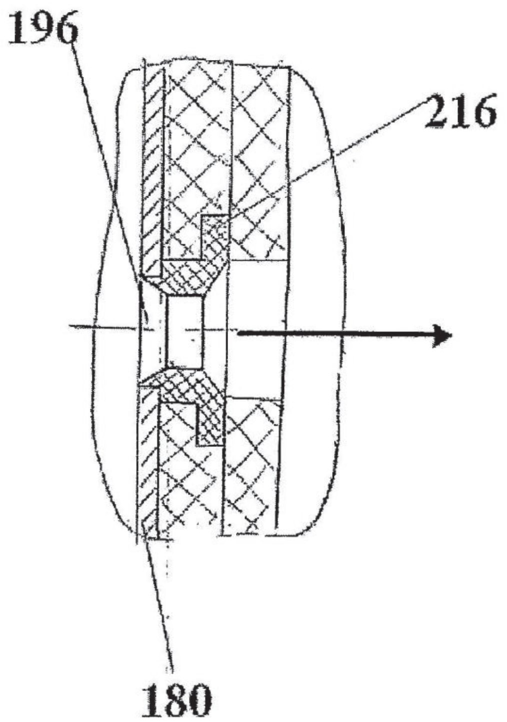

Fig. 13

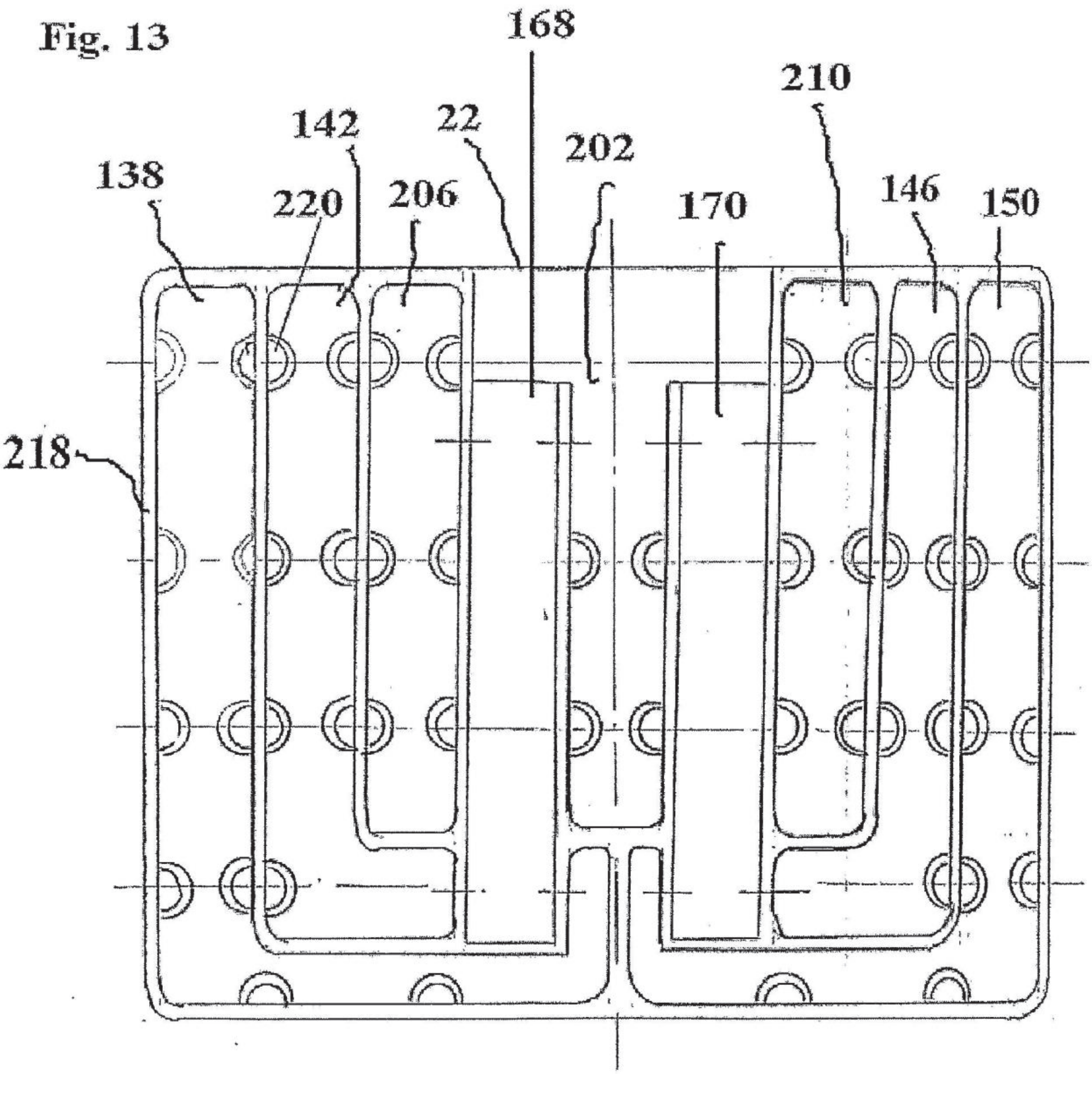

Fig. 14

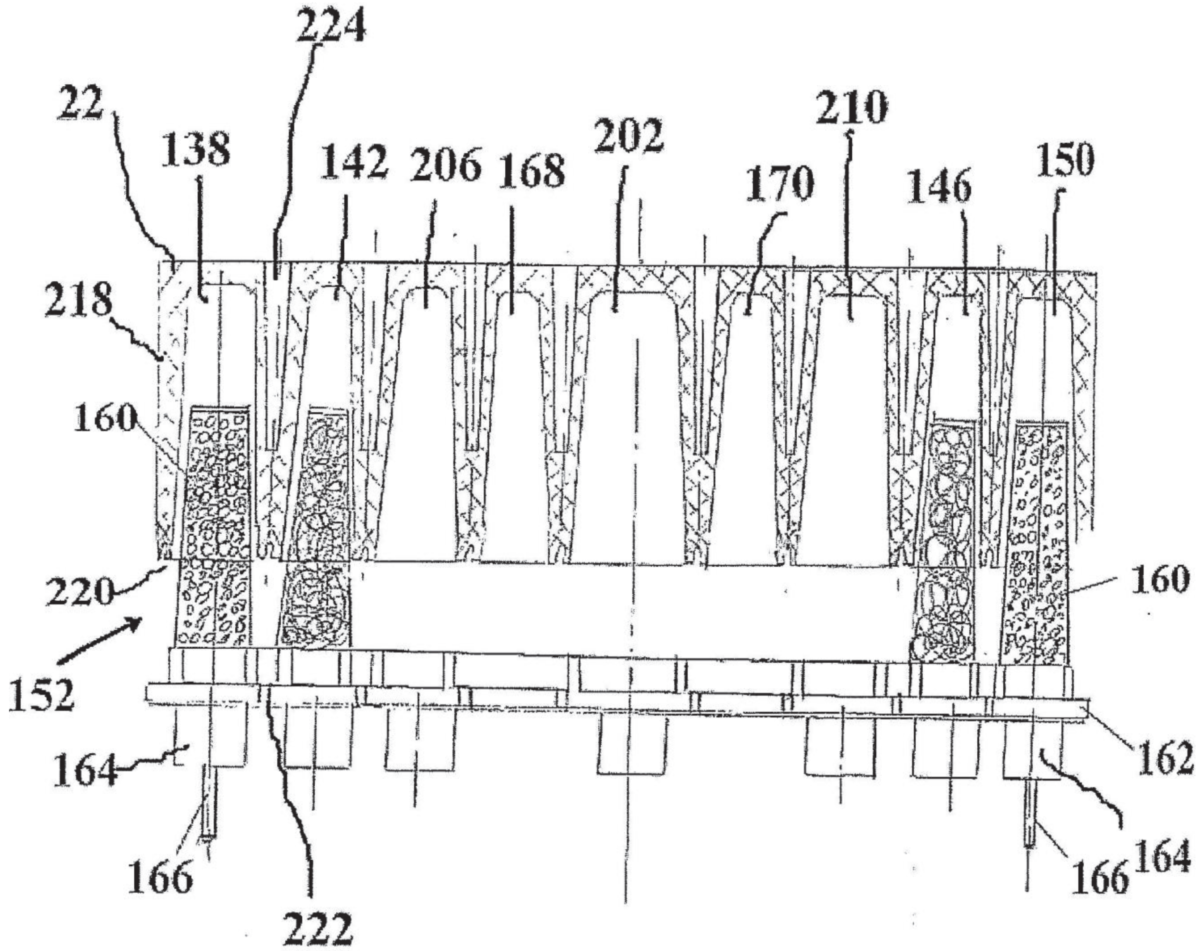
224
22
138
142
206
168
202
210
170
146
150
218
160
220
160
152
162
164
222
166
166
164

Fig. 15

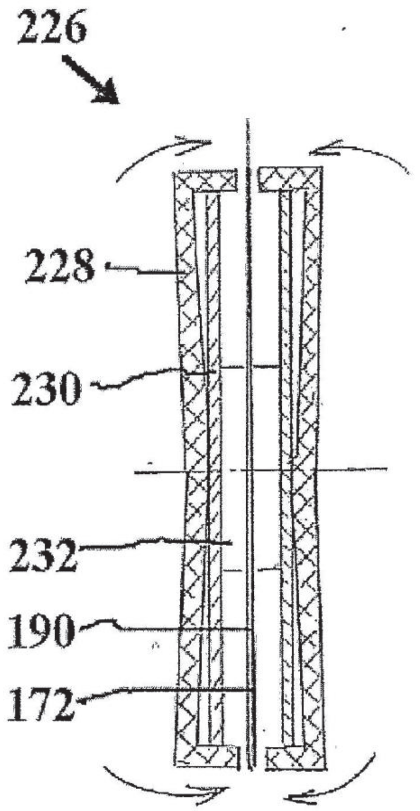

Fig. 16

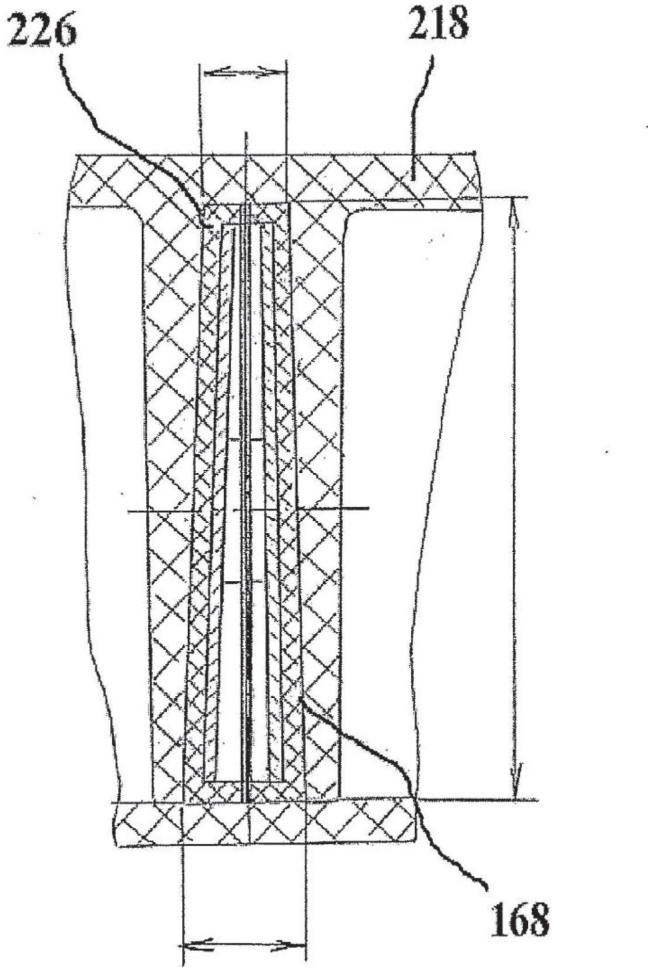

Fig. 17

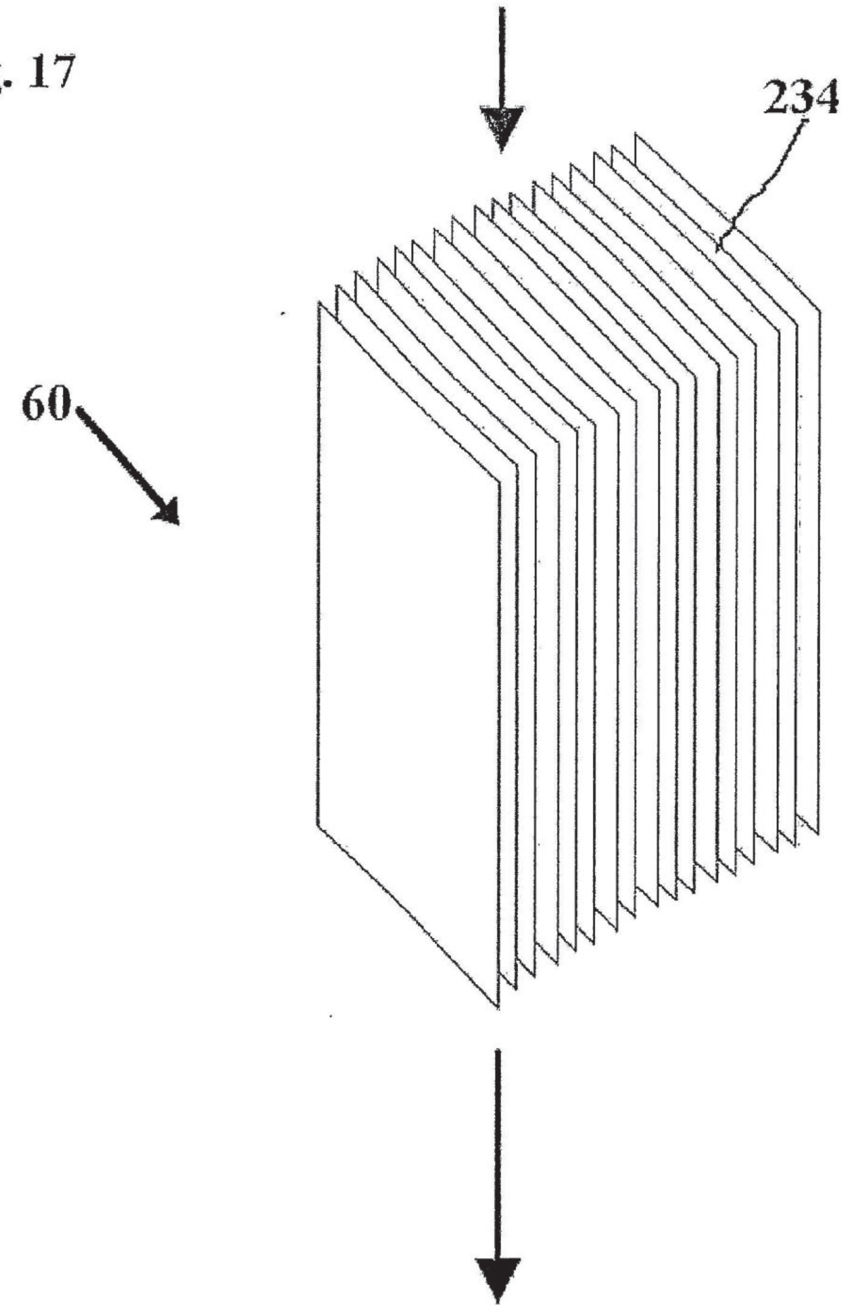

Fig .18

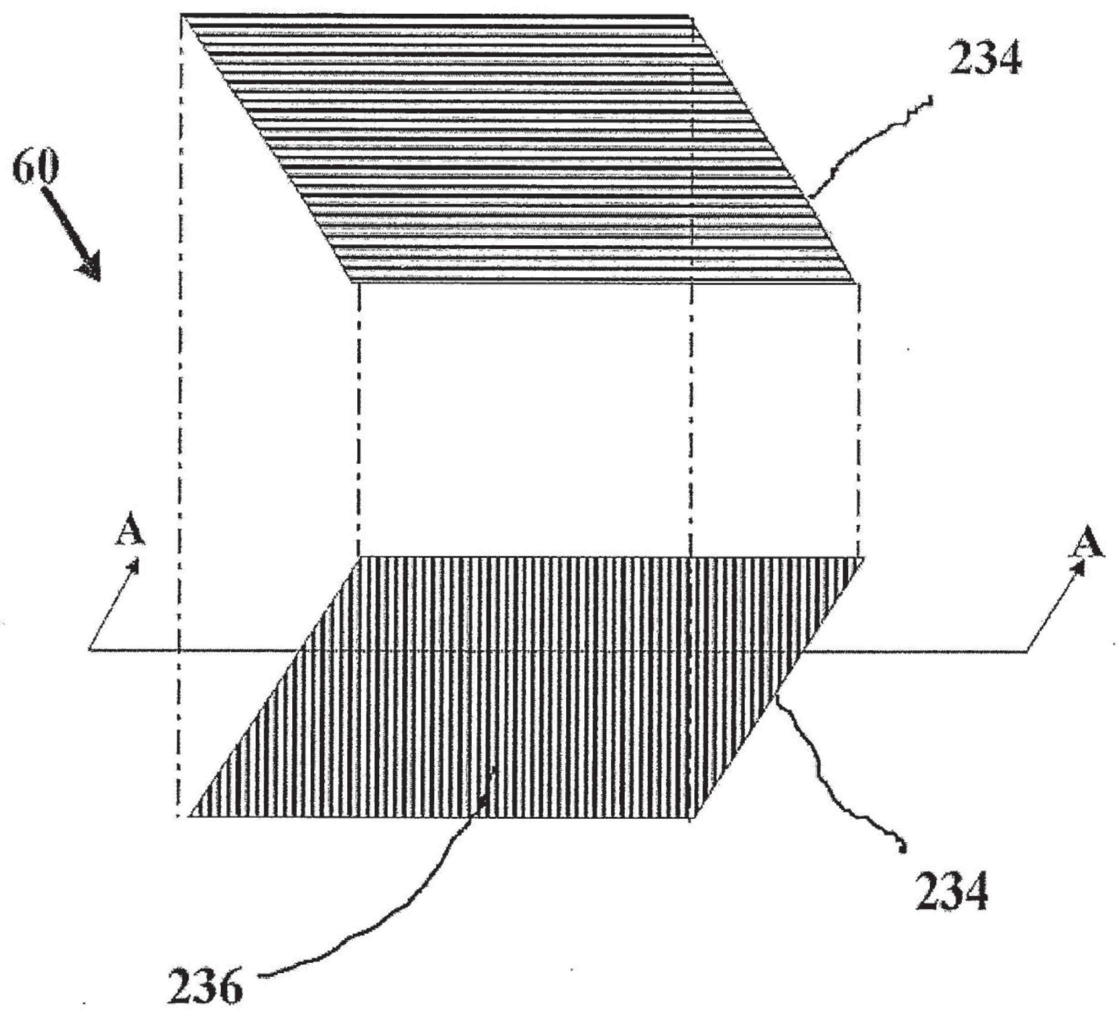

Fig. 19

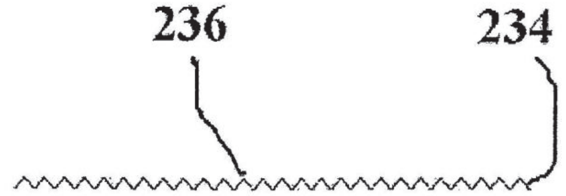

Fig. 20

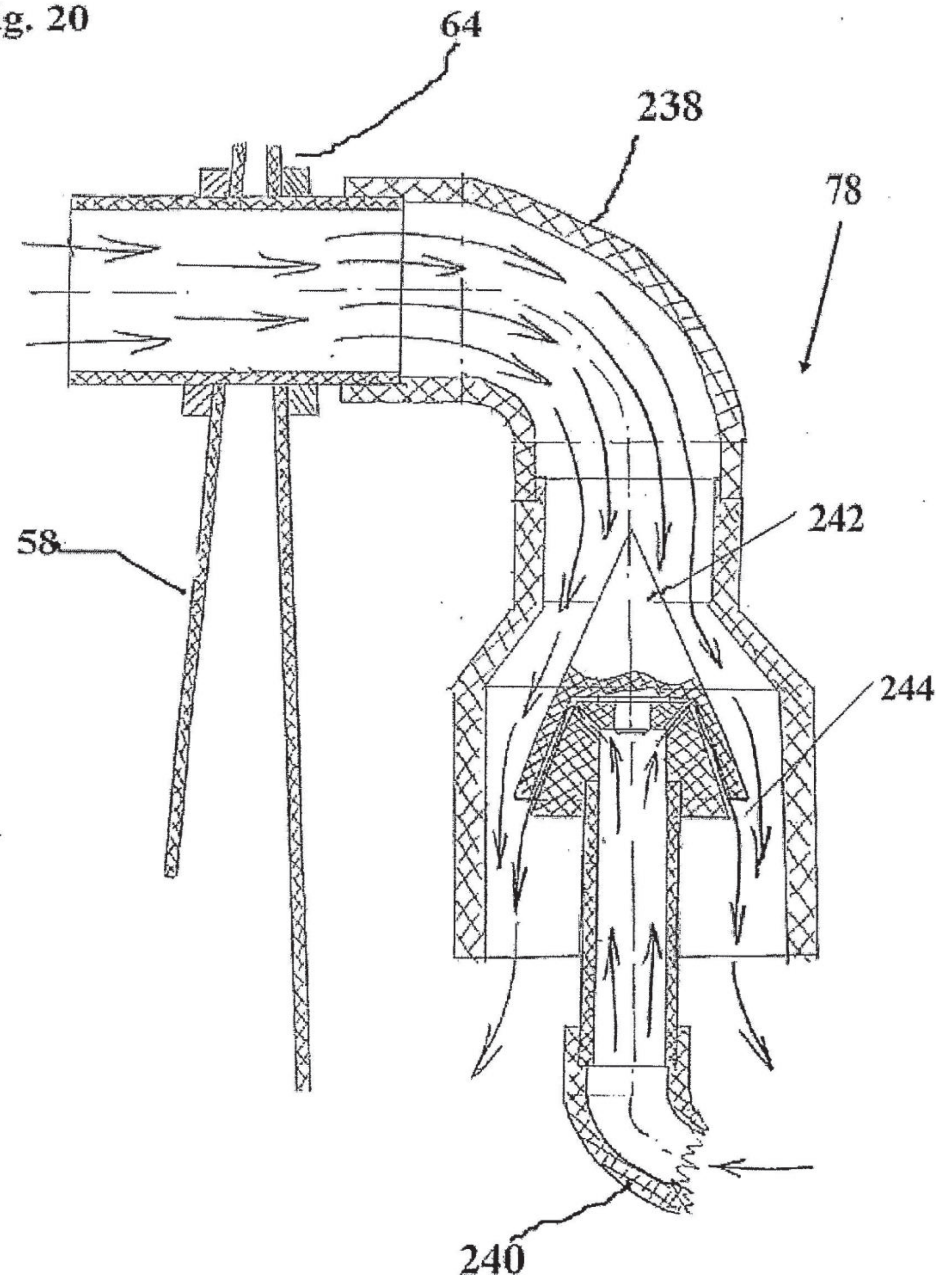

Fig. 21

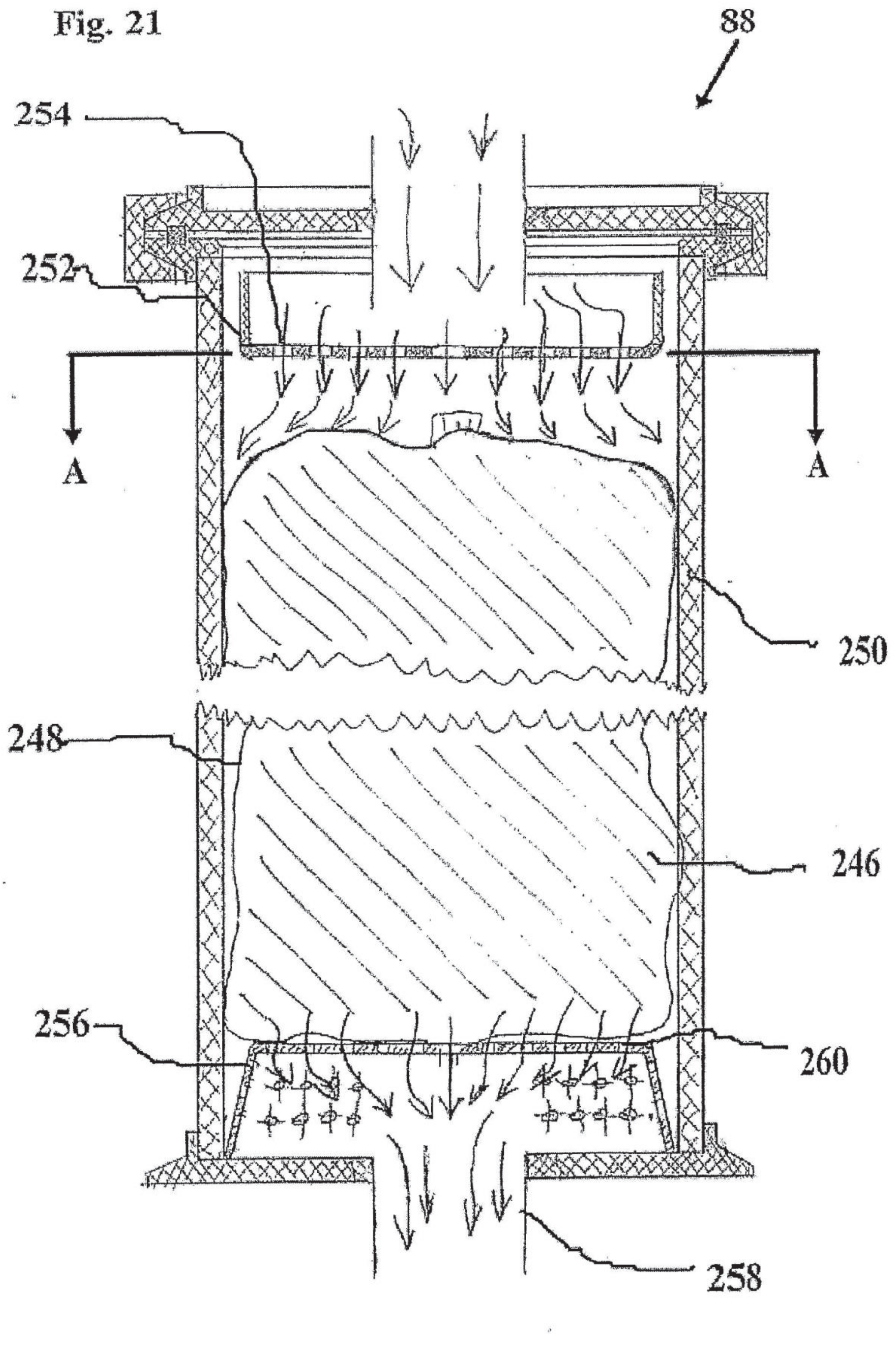

Fig. 22