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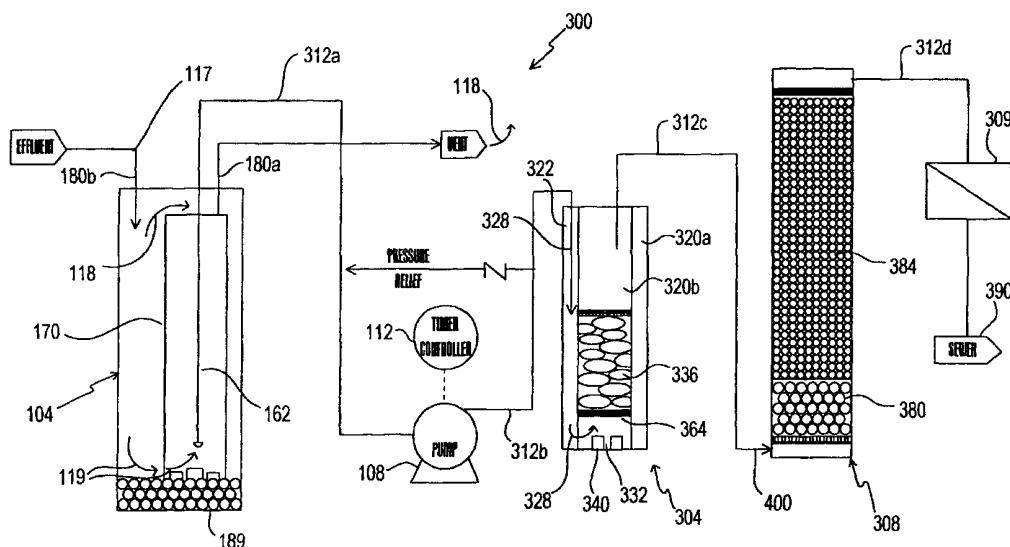
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(54) Title: APPARATUS AND METHOD FOR REMOVING MERCURY AND MERCURIC COMPOUNDS FROM DENTAL EFFLUENTS



(57) Abstract: The present invention is directed to a system for removing amalgam particles and/or dissolved metals, such as mercury and silver from dental effluent (117) which consists of a three-phase mixture of gas, solids and liquid. The effluent (117) passes into vessel (104) having gas phase output line (180a) and output line (312a) for liquid and residual solids. The liquid and residual solids may pass on to one or more of a filter (309), chemical doser (304) or sorbent column (308) to remove dissolved mercury.

APPARATUS AND METHOD FOR REMOVING MERCURY AND MERCURIC COMPOUNDS FROM DENTAL EFFLUENTS

FIELD OF THE INVENTION

5 The present invention relates generally to removing mercury and mercury-containing compounds from liquid wastes and specifically to removing mercury and mercury-containing compounds from dental effluents.

BACKGROUND OF THE INVENTION

Each year tens of thousands of pounds of mercury-containing wastes are discharged by dental offices into municipal waste systems. Amalgam fillings typically contain about
10 50% mercury by weight. Mercury is a known environmental contaminant, classified by the USEPA as a persistent, bioaccumulative, and toxic material. Waste water treatment plants must meet strict limits on the amount of mercury they can release. The discharged form of mercury is typically highly toxic (i.e., unstable) and in violation of applicable environmental regulations. Although particulate removal systems used in some dental offices remove
15 mercury-containing particles, they do not remove dissolved mercury and mercury-containing compounds. Examples of such devices are described in U.S. Patents 5,885,076; 5,797,742; 5,795,159; 5,577,910; 5,227,053; 4,753,632; 4,591,437; 4,385,891; and 5,114,578, all of which are incorporated herein by this reference.

SUMMARY OF THE INVENTION

20 The present invention provides a method and apparatus for removing solid amalgam particles and/or soluble forms of mercury and other metals (such as silver) and other contaminants from dental effluents.

In one embodiment, a contaminant removal system is provided for treating a three-phase effluent. The system includes:

- 25 (a) a particle collection vessel for separating a gas phase, a liquid phase, and a solid (particulate) phase in the three-phase of effluent;
- (b) a first discharge line from the vessel for removing the liquid phase from the vessel;
- (c) a second discharge line from the vessel for removing the gas phase from the
30 vessel; and optionally

(d) a liquid treatment device for removing and/or stabilizing contaminants in the liquid phase to form a treated liquid phase. The contaminant can be any undesirable organic or inorganic material in the effluent. Examples include metals (e.g., mercury, lead, arsenic, etc.), metal compounds, bacteria, pathogens, inorganic and organic solvents, and mixtures thereof.

The particle collection vessel can be of any suitable design. For example, the vessel can be a settling tank, a sedimentation device, a centrifuge, or any other device that utilizes gravity or centrifugal forces for effectuating solids/liquid separation. In one configuration, the particle collection vessel includes one or more baffles to facilitate solid/liquid/gas separation.

To remove the liquid phase from the particle collection vessel, the system can include a timer connected to a pump on the first discharge line to cause periodic removal of the liquid phase from the vessel during periods when no waste is incoming (e.g., overnight). In this manner, the liquid is provided with a relatively quiescent period for effective settlement of entrained particles such as amalgam particles.

The liquid treatment device can be any suitable device for removing and/or stabilizing contaminants in the liquid phase to form the treated liquid phase. In one configuration, the liquid treatment device includes one or more devices for adding chemical additives, such as one or more of a pH adjustor, an oxidant, a reductant, and a precipitant with the liquid phase. In one configuration, the liquid treatment device includes one or more sorbent columns that contact the liquid phase with one or more sorbents.

The effluent can be any contaminated effluent regardless of the source. In a preferred configuration, the effluent is produced by dental work on a patient. The effluent is collected by a liquid collection device, such as a sink, suction tube or, evacuation line, and conveyed to the particle collection vessel via a waste discharge line. A single particle collection vessel can service a plurality of such liquid collection devices corresponding to a plurality of dental chairs.

In another embodiment, a process is provided for removing dissolved contaminants from the three-phase effluent. The process includes the steps of:

- (a) introducing the three-phase effluent into a particle collection vessel;
- (b) reducing the velocity of and/or redirecting the direction of movement of the effluent, thereby causing a solid phase and a liquid phase to separate from a gas phase;

(c) removing the gas phase from the collection vessel;
(d) removing the liquid phase from the collection vessel; and optionally
(e) contacting the liquid phase with at least one of an additive and a sorbent to form a treated liquid phase.

5 As noted, the liquid phase can be removed discontinuously from the collection vessel to provide more effective separation of the entrained particles from the liquid phase.

In one configuration, the contacting step further includes the steps of;

(f) first contacting the liquid phase with one or more of a reductant, an oxidant, a participant, and a pH adjustor I (typically prior to removal of the liquid phase); and
10 (g) second contacting the liquid phase with a sorbent to remove mercury therefrom. In another configuration, step (g) is optional.

As will be appreciated, the additive, preferably a reactant (a compound that will react with the contaminant, such as a reductant, oxidant, and/or precipitant), may be used in the absence of (or without) a sorbent. For example, the reactant could be a precipitant that forms
15 a precipitate with the contaminant. The precipitate could be removed from the effluent by filtration techniques, gravity separation techniques, etc. A flocculent, such as aluminum or commercially available polymers, could be further added to the effluent to act as a filter and/or settling aid.

The system and method can provide numerous benefits. For example, the system can
20 remove not only solid amalgam particles but also remove and/or stabilize dissolved elemental mercury and speciated mercury. The system and method can be effective at capturing a high percentage of the amalgam particles. The vessel typically captures or collects at least most and more typically at least about 95% of all amalgam particles that are about 10 microns or greater in size. The chemical treatment device can further remove at least most of the
25 amalgam particles that are less than about 10 microns in size. Amalgam particles typically represent at least 95% of the total mercury sent to the system. Any of the system components can be used as a recycling device. For example, the collection vessel or sorbent column can be operated for a predetermined period (typically 6-12 months) after which the vessel and/or column is replaced. The used vessel and/or column is shipped to a recycling facility to
30 recover the captured amalgam particles and/or elemental and speciated mercury. The system can operate effectively without a sorbent. Proper selection of the additives can remove the need for a sorbent.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a perspective view of a particulate collection vessel in accordance with one embodiment of the present invention;

Figure 1B is a flow schematic of the embodiment of Fig. 1A;

5 Figure 2 is a side view of the vessel;

Figure 3 is a side view of the baffle assembly;

Figure 4 is a side view of the cap to the vessel;

Figure 5A is a plan view of the cap;

Figure 5B is a cross-sectional view of the particulate collection vessel in operation;

10 Figure 6 is a top view of the cap according to another embodiment of the present invention;

Figure 7 is a perspective view of the particulate collection system;

Figure 8 is a side view of the baffle assembly engaging the spacing assembly;

Figure 9 is a top view of the spacing assembly;

15 Figure 10 is a side view of the cap;

Figure 11 is a block diagram showing the various components of a mercury removal system according to another embodiment of the present invention;

Figure 12 is a view of the various components installed in an enclosure;

Figure 13 is a cross-sectional view taken along line 10-10 of the sorbent column of

20 Figure 9;

Figure 14 is a graph of final mercury concentration (PPB) (vertical axis) against reagent (horizontal axis); and

Figure 15 is a plot of mercury concentration (ppb) (vertical axis) versus sample number (horizontal axis).

25 DETAILED DESCRIPTION

The Particulate Collection System

A first embodiment of the present invention is depicted in Figures 1-5 and 7. The particulate collection system 100 includes a collection vessel 104, a pump 108 (*e.g.*, a peristaltic pump), and a timer 112 (*e.g.*, an electronic 24/7 timer). The collection vessel 104
30 is located between the vacuum line 116 to the chairs 118a-n and the vacuum line 120 to the vacuum pump 124. Thus, the vessel 104 is typically installed on the suction side of the

vacuum pump 124, preferably close to the vacuum pump. A liquid discharge line 128 is connected to the pump 108 and from the pump 108 to the exhaust hose 132 from the vacuum pump 124 to the sewer (not shown).

5 The timer 112 is connected to the pump 108 to cause discontinuous discharge of the liquid waste (or liquid phase) from the collection vessel 104. The timer 108 ensures that there is a sufficient (predetermined) settling time (in which the liquids and solid phases are relatively quiescent) prior to activating the pump 108 to discharge the (supernatant) wastewater or liquid phase. Typically, the predetermined settling time (between pump activation cycles) ranges from about 1 to about 24 hrs and more typically from about 8 to
10 about 12 hrs. The discharge is performed at a controlled, slow rate (typically in the range of from about 10 to about 1000 ml/min and more typically in the range of from about 20 to about 1200 ml/min).

Figures 2-5 depict the various components of the collection vessel 104. The collection vessel 104 includes a central housing 150, a base 154 attached to the bottom of the
15 housing 150, a cap 158 attached to the top of the housing 150, a dip tube 162 connected to passage 166 in the cap 158, and a baffle assembly 170. The dimensions of the vessel 104 typically range from about 10 to about 25 inches high and about 5 to about 125 inches in diameter.

The baffle assembly 170 includes a cylindrical baffle tube 174 having a plurality of
20 supporting legs 178a-c spaced at intervals around the bottom of the baffle tube 174. The inner and outer radii of the baffle tube 174 are less than the inner radius of the housing 150 so that the baffle assembly can be received inside of the housing. Typically, the inner and outer radii of the baffle tube 174 are no more than about 50% of the inner housing 150 radius and typically are no less than about 10% of the inner housing 150 radius. The baffle tube
25 174, of course, has a hollow interior to permit fluids to flow upwardly and/or downwardly through the tube as shown. The dip tube 162 is positioned inside of the baffle tube 174 during use and at or near the central vertical axes of the housing 150. The baffle tube 174 is located such that the dip tube 162 and the cap outlet port 180a are located inside the cylindrical housing of the tube.

30 The cap 158 includes two conduits 180a,b that pass through the cap 158 and project a distance "D₁" (typically from about 0.5 to about 3 inches below the cap surface 184. The conduits 180a,b connect to the vacuum lines 120 and 116, respectively. The distance "D"

is sufficient to hold the baffle tube 174 in position within the housing 150 (i.e., under ports 166 and 180a) during use.

The collection vessel 104 and baffle assembly 170 can be made of any suitable material, with corrosion resistant plastics, such as PVC being preferred.

5 In operation, a three-phase mixture 117 of gas, solids or particles (e.g., mercury amalgam particles), and liquid from the dental chair(s) passes through vacuum line 116 and into the annular area 190 between the exterior surface 192 of the baffle tube 170 and the interior surface 188 of the housing 150. The velocity of the mixture is slowed by the large flow area within the vessel, causing solid particles 189 to settle out of the mixture and collect
10 in the bottom of the housing 150. The gas phase 118 of the mixture passes above (i.e., the top 190 of the baffle tube 170 is typically spaced from the cap bottom 184) and around baffle tube 170 (i.e., the baffle tube exterior 192 is typically spaced from the housing interior around the baffle tube's periphery). The liquid phase 119 also settles out of the gas phase (due to the decrease in gas velocity) and collects in the bottom of the housing with the particles. Baffle
15 tube 170 forces the liquid flow between legs 178a-c in order to exit vessel 150 via either dip tube 162 or outlet port 180a. This flow path will create some particle separation (albeit less than in normal operation) in the event that the vessel 150 overflows. Periodically, the pump 108 is activated by the timer 112 and draws collected liquid phase out of the bottom of the housing via dip tube 162 and discharges the liquid phase through discharge line 128 into the
20 exhaust hose 132. The pump 108 is typically activated at a time interval ranging from about 5 mins. to about 12 hrs, more typically from about 2 to about 12 hours, and even more typically from about 2 to about 6 hours. The flow rate of pump 108 is low enough, typically about 0.02 to about 1 l/min., to prevent entrainment of the settled particles. The dip tube 162 design prevents particles from being withdrawn with the liquid and, therefore, the particles
25 remain in the bottom of the housing 150.

The system has numerous operational benefits. The system can be effective at capturing about 95% of all particles that are greater than about 10 micron in size. This fraction of particles typically amounts to about 95% of the total mercury sent to the system. The system can be a self-priming system and will hold a vacuum when turned off. The pump
30 can run dry without damaging the motor or the drive unit. The unit can be used as a recycling device. After the unit operates for a predetermined period (typically six to twelve months) the vessel is replaced with a new vessel and the used vessel shipped to a recycling facility to

recover the captured amalgam particles. The vessel can remove fine amalgam particles that can damage the dental vacuum pump.

Installation of the system depends on the application. The system is designed to work with either wet- or dry-vacuum systems. In a dry-vac system, it is preferred that the vessel
5 be installed upstream of the dry vac's air/water separator. The existing air/water separator may be removed; however, it is recommended that the existing air/water separator be left in place to protect the vacuum pump in the event that the vessel overfills. Because liquids will not damage a wet-vac pump, no such precaution is required for a wet system. If installed downstream of an existing air/water separator, the system is typically installed to receive the
10 liquid outlet flow from the air/water separator. Different size clinics can be accommodated by adjusting the overall size of the system. In one configuration, the system is designed so that if any problem occurs with the unit, fluid flow will bypass the vessel and allow continued operation of the dental suction system.

Figures 6 and 8-10 show a particle collection system according to another
15 embodiment of the present invention. The baffle assembly 200 includes a spacer assembly 204 that engages the upper end of the baffle tube 170. Spacers 208a-c are positioned at intervals around the periphery of the baffle tube 170 to maintain the correct, spaced relationship between the tube wall and the housing interior. Because the spacer assembly 204 maintains the tube exterior in a spaced apart relationship relative to the housing wall, the cap
20 210 does not require downwardly projecting conduits 180a,b.

The Combined Particulate Removal and Purification System

Referring to Figures 11-13, the combined particulate removal and purification system
300 will now be discussed. The system removes and/or stabilizes soluble forms of mercury as well as solid-phase mercury. Soluble forms of mercury are typically present in the dental
25 wastewater from the reaction of the mercury in amalgam particles with the wastewater which releases soluble forms of mercury into the wastewater.

The system 300 includes the particulate collection vessel 104 described above and, in addition, a chemical doser 304 and a sorbent column 308 and sub-micron filter 309. The doser 304 and sorbent column 308 are in communication with discharge line 312 and pump
30 108. Pump output line 312b is connected to the doser 304 and an output line 312c from the

doser 304 is connected to the sorbent column 308. The output line 312d from the sorbent discharges into the sewer or line 128.

As will be appreciated, the dissolved mercury-containing compounds, colloidal mercury, and small (*e.g.*, less than about 10 microns) amalgam particles in the waste liquid
5 from the particulate collection vessel are removed and/or stabilized by the doser 304 and sorbent column 308 and polishing sub-micron filter 309.

One or more dosers 304 can be used to directly reduce mercury levels in the wastewater and/or adjust wastewater chemistry. A doser will typically release one or more suitable additives to the wastewater to maintain desirable chemical properties, to convert
10 dissolved mercury to a less soluble form of mercury, or enhance the performance of a mercury-selective sorbent in the sorbent column 308 in removing dissolved mercury from dental amalgam wastewater, and/or to kill or neutralize organic material in the wastewater. Suitable solid additives are preferably nontoxic and sparingly soluble in the wastewater so that they are slowly released into the water. Alternately, the additive could be added by any
15 other suitable technique. For example, the additive can be slowly added (as a liquid, solid, or gas) via a dosing mechanism (*e.g.*, a pump) or by encapsulation in a slowly dissolving substance.

In another embodiment, the reagent can be added to the collection vessel via the dental suction line. For example, most dental offices flush a suction line cleaning solution
20 through their evacuation system. The reagent could be added in the same method, or be co-blended, with the line cleanser. In this case, the additive is added to and in the effluent upstream of the collection vessel and further additive addition(s) in or downstream of the collection vessel is/are optional. The blending could be done during or after production of the cleanser. The blending can be done by known techniques such as by using a ribbon
25 blender. Typical dental line cleansers contain surfactants and disinfectants and may range in pH from acid to highly basic. Active ingredients include sodium hydroxide (Alprojet™), chloramine T (Tiutol™, Aseptoclean 2™), sodium perborate or another percarbonate, hydrogen peroxide (Orotol Ultra™), ammonium chloride (S&M matic™, Vacusol™), sodium hypochlorite (bleach), pyridine compounds (Green & Clean™), phosphoric acid
30 (Purevac™), glycolic acid, citric acid, isopropanol, chlorhexidine gluconate (Biovac™), and/or enzymes (Vacukleen™). In this case, any of these cleansers would further include one or more of the additives of the present invention.

The doser 304 can be of any suitable design. The doser may include a separator contacting chamber or may add reagent directly into collection vessel 104. In one design, the doser 304 includes inner and outer containment vessels 320a,b forming annulus 322 therebetween and a bed 336 of additive particles contained within the inner containment vessel 320b. Wastewater 328 flows in the annulus 322 between the inner and outer containment vessels, through the space 332 between the bottoms 336, 340 of the inner and outer containment vessels 320b,a, and through the (fluidized) bed 336 in the inner containment vessel 320b. In another design, the dosing occurs within the amalgam separator 104 itself.

In one configuration, the doser contacts an additive (or pH adjustor) for controlling wastewater pH. The additive can be any suitable substance for controlling pH, such as a base, e.g. hydroxides, carbonates, and phosphates with hydroxides and carbonates being preferred, or acid, e.g., organic acid and mineral acids, with mineral acids being preferred. Sufficient pH adjustor added to maintain a pH preferably ranging from about pH2 to about pH6 or from about pH8 to about pH10, depending on the application. pH adjustment is used to enhance the performance of other additives or of sorbent materials. Sorbents often work better at low pH, whereas many precipitating additives require a high pH.

In one configuration, the doser 304 contacts an oxidant with the wastewater to oxidize organic matter before passing the wastewater through the sorbent column. As will be appreciated, organic matter can clog, bio-foul, or otherwise impair the performance of the sorbent material. Any suitable oxidant can be used. Preferred oxidants include organic halogen derivatives (e.g., symclosene, oxyhalide salts (e.g., hypochlorite), ozone, hydrogen peroxide and/or organic peroxides). In typical applications, the amount of oxidant added will range from about 10 to about 1000 ppm.

In another configuration, a reductant is contacted by the doser with the wastewater to reduce mercury-containing compounds and materials. Reducing agents minimize oxidation and release of mercury from captured amalgam and helps to chemically reduce incoming oxidized mercury, thereby making it less soluble. For example, reduced elemental mercury has a very low solubility - on the order of 20 micrograms/L. Any suitable reductant can be used. Preferred reductants include stannous chloride, iron, tin oxalate, bisulfites, and/or polyvalent metals.

A reducing additive should create a solution oxidation/reduction potential capable of reducing oxidized forms of mercury back to elemental mercury. The standard electrode potentials (E°) for mercurous ($\text{Hg}_2^{++} + 2e = 2\bar{\text{e}}$) and mercuric ($\text{Hg}^{++} + 2e = \text{Hg}$) reduction are about +0.789 V and +0.854 V respectively. These are measured versus a standard hydrogen electrode. Thus to create a solution environment where the concentration of oxidized mercury is no greater than that for elemental mercury (the assumed minimum limit for a solution in contact with amalgam) the required potential is given by:

$$Eh = E^\circ + 0.059 \log \frac{[\text{Hg}_{\text{oxidized}}]}{a_{\text{Hg}}} \quad \text{Eq.(1)}$$

at 25°C. In Equation (1), the activity of elemental mercury, a_{Hg} , is equal to unity by convention, and $[\text{Hg}_{\text{oxidized}}]$ represents the molar concentration of oxidized mercury. The equation is exact if species activity is used in place of concentration. Assuming a desired minimum concentration of 10^{-7} molar (~20 ppb), the solution Eh is preferably about $\leq +0.38$ V. In typical applications, the amount of reductant added will range from about 10 to about 1000 ppm.

In another configuration, a precipitant is contacted by the doser with the wastewater to cause precipitation of mercury-containing compounds as insoluble mercury precipitates. Any suitable precipitant can be used. Preferred precipitants include iodates, sulfides and polysulfides, thioamides (e.g., thioacetamide), carbamates and thiocarbamates (e.g., sodium diethylthiocarbamate), polycarbamates, thiocarbamides, and polymeric or immobilized variants of these functional groups and mixtures and derivatives thereof. Carbamates are preferred as they are generally nontoxic and pH insensitive. In general, the precipitant can be any chemical which forms a sparingly soluble or readily filterable complex with mercury or mercury-bearing compounds. In typical applications, the amount of precipitant added will range from about 10 to about 1000 ppm.

In some configurations, the processes and compositions of U.S. Patents 5,880,060; 5,667,695; 5,370,827; 5,330,658; 5,080,799; 4,108,769; and/or 4,072,605, all of which are incorporated herein by this reference, are used as or in lieu of the doser.

When a precipitant is used, a particle filter, such as a fine screen or membrane, can be located in or downstream of the doser and in or upstream of the sorbent column (if a sorbent column is present) to remove precipitated mercury particles. The filter preferably has a pore size sufficient to remove the particles, which typically ranges from about 10 to about

0.45 microns. In one configuration, the particle filter is located downstream of the sorbent column (Figure 11).

The sorbent column 308 can be of any suitable design. The sorbent column can be configured to contain one or multiple sorbent beds of the same or differing sorbents. The typical column design is a packed-bed of sorbent particles. Other column designs include
5 monolithic sorbent structures and fluidized bed designs.

Referring to Figure 13, the sorbent column 308 of one design includes a column housing 350, a bottom 354 having an input port 358, a top 362 having an output port 366, a plurality of retaining rings 370a-c, and a plurality of screens 374a-c. The screens prevent
10 intermixing of the sorbent beds 380 and 384 and restrain movement of the sorbent particles in the beds so as to prevent clogging of the input port 358 or output port 366 or removal of the sorbent particles from the column with the wastewater.

The sorbent can be any sorbent capable of collecting mercury. Preferred sorbents include one or more of activated carbon, ion exchange resins such as cellulosic resins (e.g.,
15 as discussed in U.S. Patent 5,907,037 which is incorporated herein by this reference) chelating resins and porous silica, and zeolites.

In a preferred configuration, the first sorbent bed 380 of activated carbon is located near the input port 358 to remove dissolved mercury and residual oxidant (if added previously by a chemical doser 304) from liquid 119 and the second sorbent bed 384 of an
20 ion exchange resin is located above the first sorbent bed near the output port 366 to remove further dissolved mercury from liquid 119.

The purified wastewater 390 is fully compliant with pertinent environmental regulations. Typically, the purified wastewater 390 contains no more than about 10 ppb mercury.

25 In operation, the wastewater 328 is removed from the vessel 104 as described above and passed through the input at the top of the doser 304, through the annulus 322 and through the additive bed 336, and is removed through the output at the top of the doser 304 to form a treated wastewater. The treated wastewater 400 is introduced into the sorbent column 308 through input 358, passed sequentially first through sorbent bed 380 and second through
30 sorbent bed 384 to form a purified wastewater 390. The wastewater is filtered with a polishing filter 308 to remove sorbent residue. Purified wastewater 390 can be discharged directly into the sewer.

EXPERIMENTAL

ISO CERTIFICATION

The international organization for standardization (ISO) is a worldwide federation of national standards bodies. ISO standards provide safety and performance guidelines for a variety of equipment categories, including dental equipment. International standard ISO 11143 was prepared by the ISO dentistry technical committee to assess the performance of dental amalgam separators.

Amalgam separators are defined as items of dental equipment designed to retain amalgam particles carried by the wastewater from the dental treatment system, so as to reduce the number of amalgam particles and therefore the mercury entering the sewage system. The use of a centrifuge, filtration, sedimentation or combination of any of these methods may achieve separation of the amalgam particles.

ISO 11143 specifies requirements for amalgam separators used in connection with dental equipment in the dental treatment system. It specifies the efficiency of the amalgam separator (minimum of 95%) in terms of the level of retention of the amalgam based on a laboratory test. The standard also describes the test procedure for determining this efficiency, as well as requirements for the safe functioning of the separator, labeling, and instructions for use of the device. The ground amalgam sample for the efficiency test of the amalgam separator is divided into three different fractions:

- 6.0 g of particles sized 3.15 mm to 0.5 mm
- 1.0 g of particles sized 0.5 mm to 0.1 mm
- 3.0 g of particles smaller than 0.1 mm

In addition, 50% of the fine fraction particles should be less than 0.01 mm. The test sample used to assess the efficiency of the amalgam separator has a particle size distribution that reflects the situation found in dental treatment systems. The size fractions used in the standard are based on investigations that have been carried out to determine the particle size distribution of amalgam particles in water from dental treatment systems.

In summer 2000, the BullfroHg™ amalgam separator was independently tested following ISO 11143. The separator received a score of 99.6% removal efficiency when empty and 98.6% efficiency when full, easily passing the required test efficiency of 95%.

ISO CERTIFICATION TEST RESULTS

	Reference/Equipment:	Amalgam Separator BullfroHg™
5	Rating:	Rated voltage: 120 V AC Rated current: 1.5 amp
	Date of receipt:	6/22/00
	Type of examination:	Alternate construction test.
	Test regulations:	ISO 11142: 1999-12
	Testing period:	July/August 2000
10	Test location:	Technology Centre of RWTUV Analagentchnik GmbH - Classification: Type 2: Sedimentations system - Amalgam sample: Becker MeBtechnik GmbH, 71364 Winnenden, Germany ISO 10g, January 2000
15		-Maximum water floutrate: 750 ml/mn., 10 ℓ altogether - Type of membrane filters: Schleicher + Schuell Membrane filters AE 100+ ME29 + ME28 - Number of tests performed: 6
20		- Separation degrees of empty amalgam separator: after 12 to 14 hours 1. 99.9% 2. 99.7%
25		3. 99.3% Average 99.6% - Separation degrees of full amalgam separators: after 12 to 14 hours 1. 99.0%

2. 98.0%

3. 97.9%

Average: 98.3%

5 - Value of the efficiency: 98.3%

Annex (No. Of pages): None

Test result: The referenced units are in compliance with the above requirements.

Test program ISO 11143 Dental Equipment-Amalgam Separators: 1999

10 Test object: Amalgam Separator Model BullfroHg™

- Classification: Type 2: Sedimentation system

- Amalgam sample: Becker MeBtechnik GmbH
71364 Winnenden, Germany
ISO 10g, January 2000

15 - Maximum water flow/rate: 750 ml/min., 10 l altogether

- Type of membrane filters: Schleicher + Schuell
Membrane Filters AE 100 + ME29 + ME28

- Number of tests performed: 6

- Separation degrees of empty amalgam separator: after 12 to 14 hours

20 1. 99.9%

2. 99.75

3. 99.3%

Average: 99.6%

- Separation degrees of full amalgam separators after 12 to 14 hours

25 1. 99.0%

2. 98.0%

3. 97.9%

Average.

- Value of the efficiency: 98.3%

30 The BullfroHg™ Hg amalgam separator passed the test.

In addition to the ISO test, ADA further performed an initial screening of the doser concept. The tests were intended to demonstrate that mercury levels could be reduced by reagent addition. Dental waste from a Denver-area clinic was used in these tests. The wastewater was first filtered through a 10-micron filter to remove large particles. Some of the wastewater was sent through a 0.45-micron filter to determine the amount of "soluble" mercury. The tests consisted of 150 mL of waste and 10 g of reagent placed into 250-mL shaker flasks. The flasks were shaken overnight and the solutions in each flask were again filtered with a 10-micron filter to remove solids. Half of the samples were then filtered through a 0.45-micron filter. The results are plotted in Figure 16.

Sixteen different reagent combinations were tested in these first trials. Several reduced the amount of mercury in the wastewater sample. Of those tested, iron, calcium carbonate, potassium iodate and tin oxalate appear to yield the best results. Some tested reagents successfully reduced the mercury levels, but are not believed to be practical for other reasons.

These initial tests were intended to demonstrate that mercury levels could be reduced by addition of a reagent. Reagents other than those tested are also possible.

In addition to the above tests, the City of Toronto carried out independent testing of a system as depicted in Figure 11 and 12. The system was connected to a city dental clinic suction system and the effluent 390 was analyzed for total mercury concentration. The results are depicted in Figure 15. The system consistently reduced the mercury concentration to less than 10 micrograms per liter - levels that could not be achieved through particle separation alone.

The foregoing description of the present invention has been presented for purposes of illustration and description. Furthermore, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, in the skill or knowledge of the relevant art, are within the scope of the present invention. For example, the particulate collection vessel can be used without the addition of an additive or the use of a sorbent. The embodiments described here and above are further intended to explain best modes for practicing the invention and to enable others skilled in the art to utilize the invention in such, or other, embodiments and with various modifications required by the particular applications or uses of the present invention. It is intended that the appended claims be construed to include alternative embodiments to the extent permitted by the prior art.

What is claimed is:

1. A contaminant removal system for treating a three-phase effluent, comprising:
a particle collection vessel for removing a particulate solid phase and a liquid phase
from the three-phase effluent;
5 a first discharge line from the vessel for removing the liquid phase from the vessel;
a second discharge line from the vessel for removing the gas phase from the vessel;
and
a liquid treatment device for removing and/or stabilizing a contaminant in the liquid
phase to form a treated liquid phase.
- 10 2. The contaminant removal system of Claim 1, wherein the particle collection
vessel includes one or more baffles.
3. The contaminant removal system of Claim 1, further comprising a timer
connected to a pump on the first discharge line to cause periodic removal of the liquid phase
from the vessel.
- 15 4. The contaminant removal system of Claim 1, wherein the liquid treatment
device includes one or more chemical dosers that contact one or more of a pH adjustor, an
oxidant, a reductant, and a precipitant with the liquid phase.
5. The contaminant removal system of Claim 1, wherein the liquid treatment
device includes one or more sorbent columns that contact the liquid phase with one or more
20 sorbents.
6. The contaminant removal system of Claim 1, wherein the particle collection
vessel is connected by a waste discharge line to at least one liquid collection device adjacent
to a dental chair and wherein the waste discharge line transports the effluent from the sink
to the particle collection vessel.
- 25 7. A process for removing a contaminant from a three-phase effluent,
comprising:
introducing the three-phase effluent into a particle collection vessel;
reducing the velocity of and/or redirecting the direction of movement of the effluent,
thereby causing a solid phase and a liquid phase to separate from a gas phase;
30 removing the gas phase from the collection vessel;
removing the liquid phase from the collection vessel; and
contacting the liquid phase with at least one of an additive and/or a sorbent to form
a treated liquid phase.

8. The method of Claim 7, wherein the liquid phase is removed discontinuously from the collection vessel and the contaminant.

9. The method of Claim 7, wherein the contacting step comprises:
first contacting the liquid phase with one or more of a reductant, an oxidant, a precipitant, and a pH adjustor; and
5 second contacting the liquid phase with a sorbent to remove metal therefrom.

10. The method of Claim 7, wherein the contacting step comprises contacting the liquid phase with one or more precipitants prior to discharging the liquid.

11. The method of Claim 10, wherein the precipitant is a sulfide, thioamide, or
10 thiocarbamate.

12. The method of Claim 7, wherein the additive is one or more of a reductant, an oxidant, a precipitant, and a pH adjustor.

13. A process for removing entrained particles from a three-phase effluent produced by a dental process, comprising:
15 introducing the three-phase effluent into a particle collection vessel;
reducing the velocity of and/or redirecting the direction of movement of the effluent in the particulate collection vessel, thereby causing a solid phase and a liquid phase to separate from a gas phase;

removing the gas phase from the collection vessel; and
20 removing the liquid phase from the collection vessel

14. The method of Claim 13, further comprising:
contacting the liquid phase with at least one of an additive and a sorbent to form a treated liquid phase.

15. The method of Claim 13, wherein the liquid phase is removed discontinuously
25 from the collection vessel.

16. The method of Claim 14, wherein the contacting step comprises:
first contacting the liquid phase with one or more of a reductant, an oxidant, a precipitant, and a pH adjustor;
second contacting the liquid phase with a sorbent to remove metal therefrom.

17. The method of Claim 14, wherein the contacting step comprises contacting
30 the liquid phase with one or more precipitants prior to discharging the liquid.

18. The method of Claim 17, wherein the precipitant is sulfide, thioamide, or thiocarbamate.

19. The method of Claim 14, wherein the additive is one or more of a reductant, an oxidant, a precipitant, and a pH adjustor.

20. A system for treating a three-phase effluent from a dental operation, comprising:

5 a particle collection vessel for removing a particulate solid phase and a liquid phase from the three-phase effluent;

a first discharge line from the vessel for removing the liquid phase from the vessel;

a second discharge line from the vessel for removing the gas phase from the vessel;

and

10 an input line for carrying the three-phase effluent from a liquid collection device located at or near a dental chair to the particulate collection vessel.

21. The system of Claim 20, further comprising:

a liquid treatment device for removing and/or stabilizing a contaminant in the liquid phase to form a treated liquid phase.

15 22. The system of Claim 20, wherein the particle collection vessel includes one or more baffles.

23. The system of Claim 20, further comprising a timer connected to a pump on the first discharge line to cause periodic removal of the liquid phase from the vessel.

20 24. The system of Claim 20, wherein the liquid treatment device includes one or more chemical dosers that contact one or more of a pH adjustor, an oxidant, a reductant, and a precipitant with the liquid phase.

25. The system of Claim 20, wherein the liquid is contacted with one or more precipitants prior to discharging the liquid.

25 26. The system of Claim 25, wherein the precipitant is a sulfide, thioamide, or thiocarbamate.

27. The system of Claim 20, wherein the liquid treatment device includes one or more sorbent columns that contact the liquid phase with one or more sorbents.

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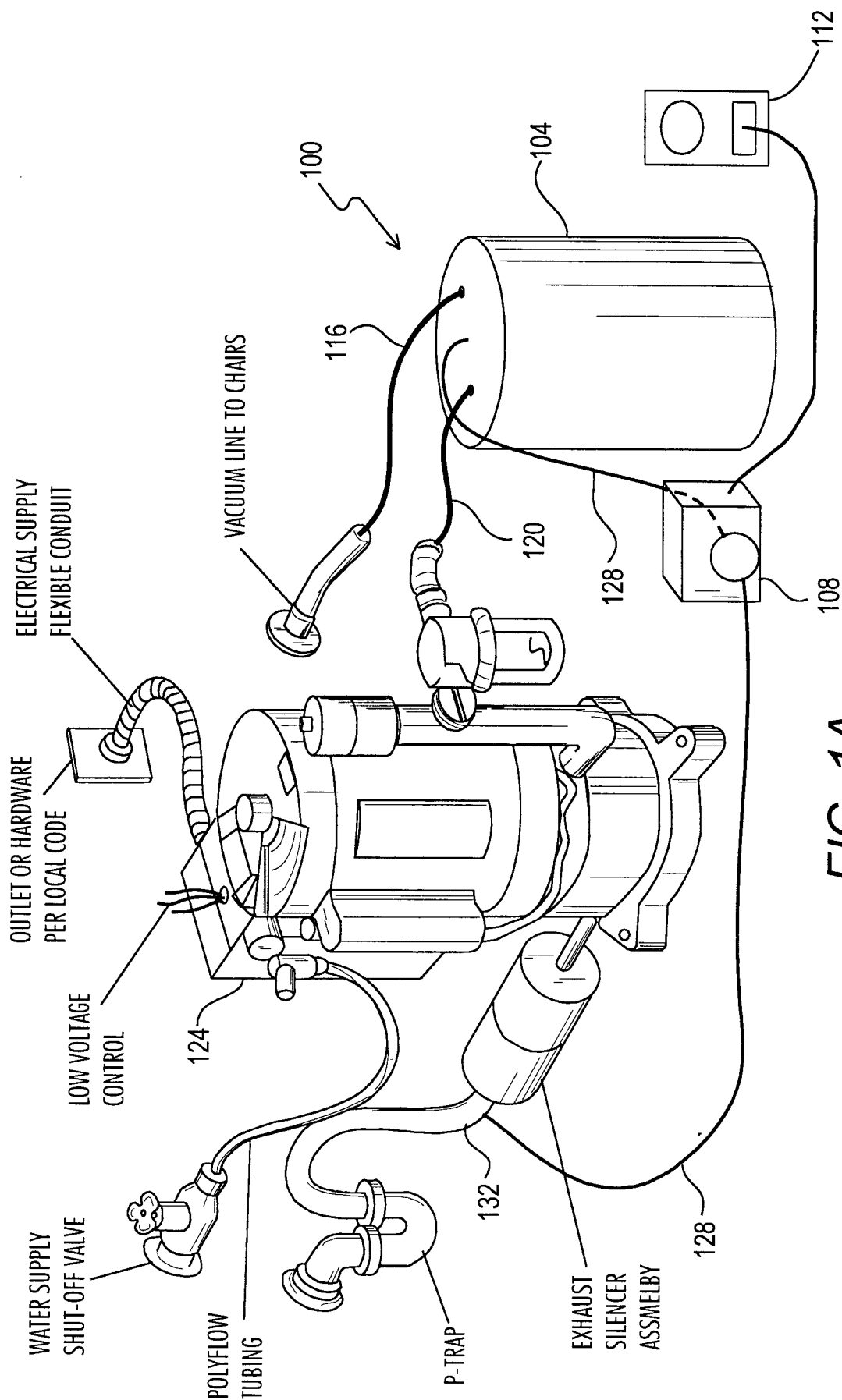
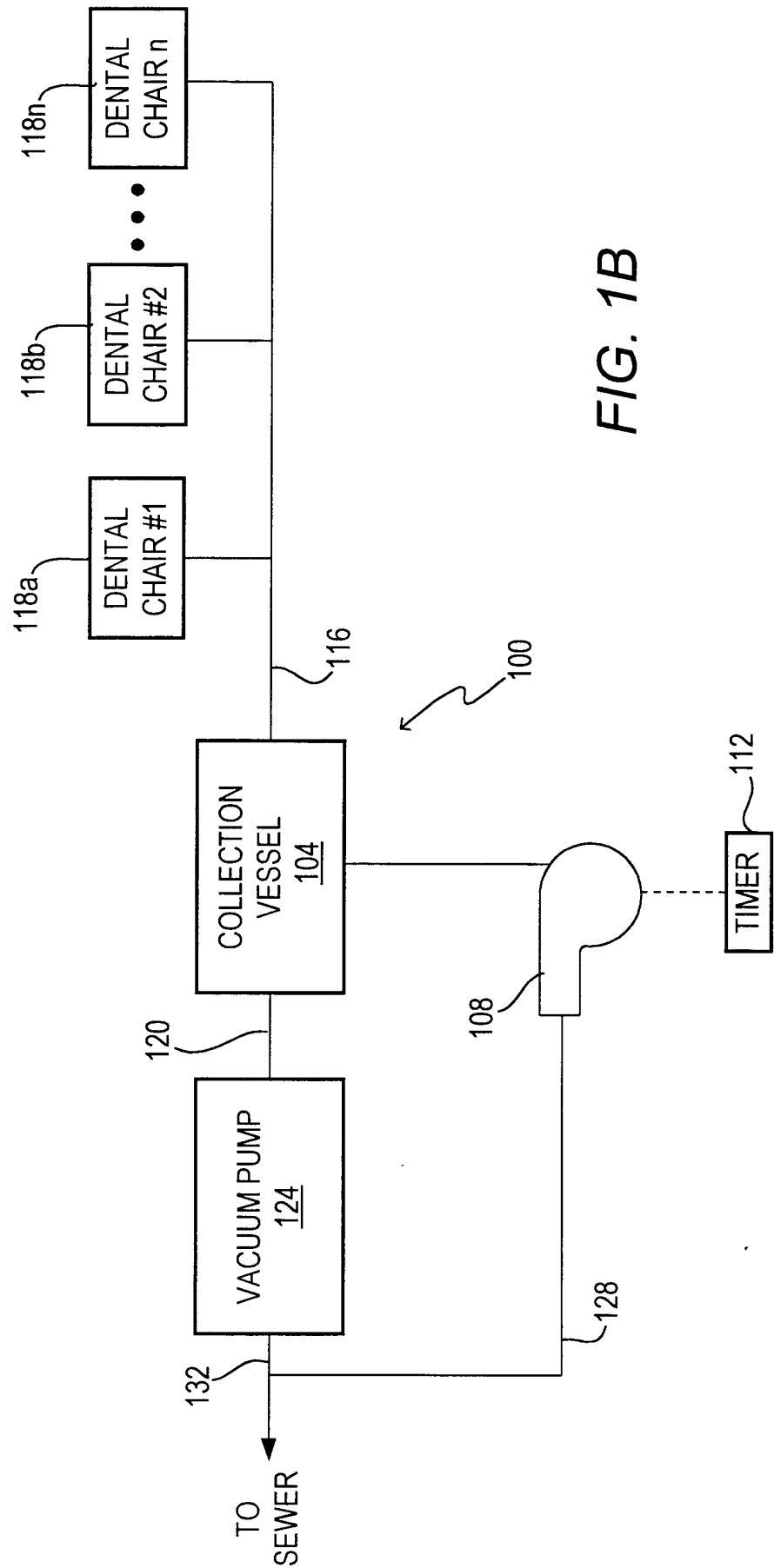


FIG. 1A



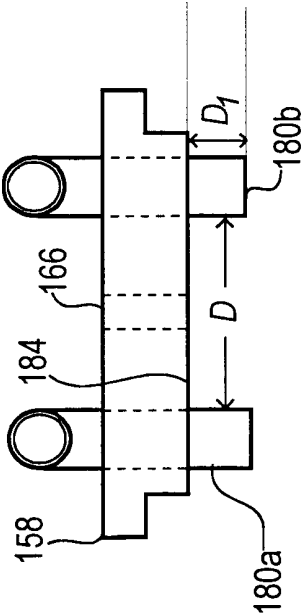


FIG. 4

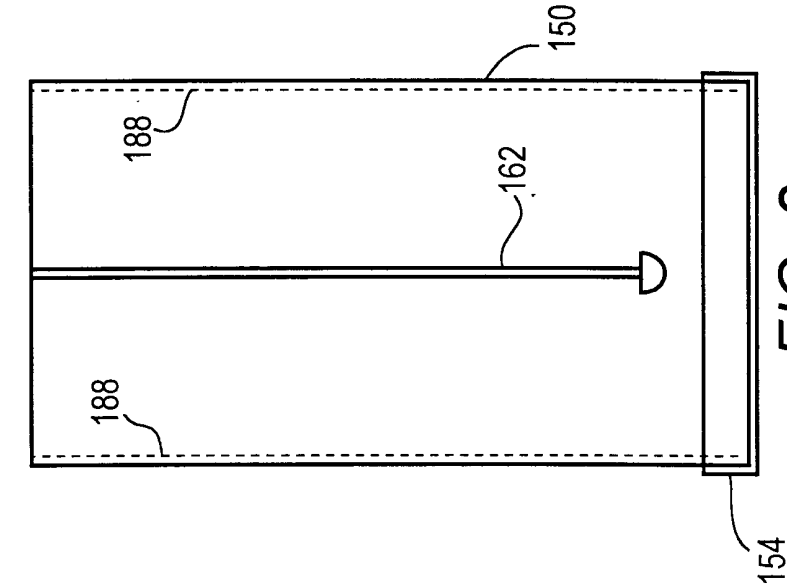


FIG. 2

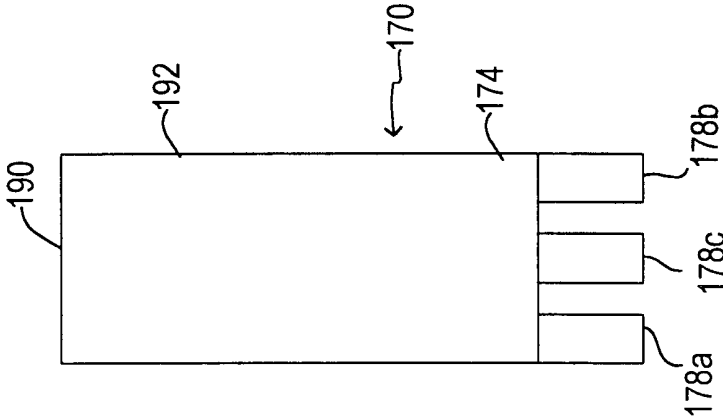


FIG. 3

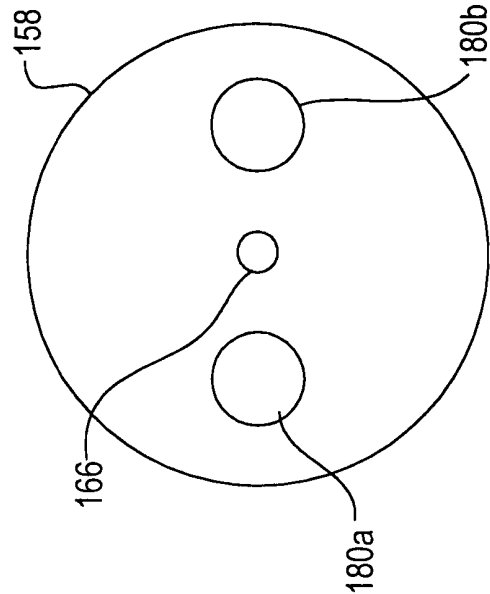


FIG. 5A

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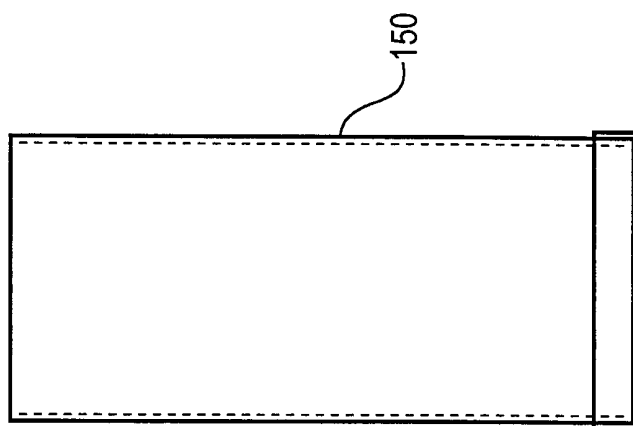
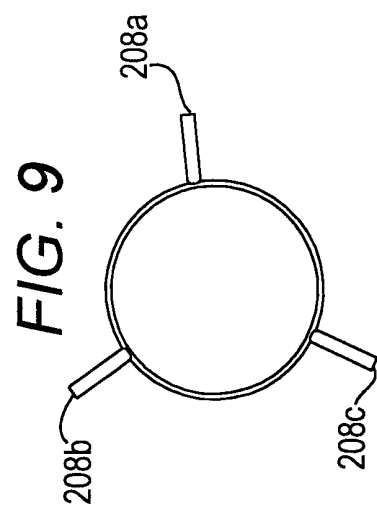


FIG. 10

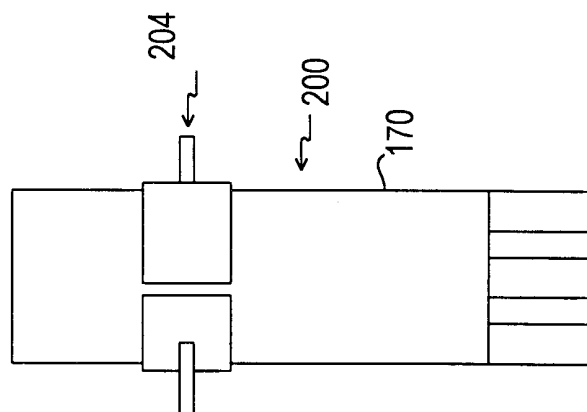
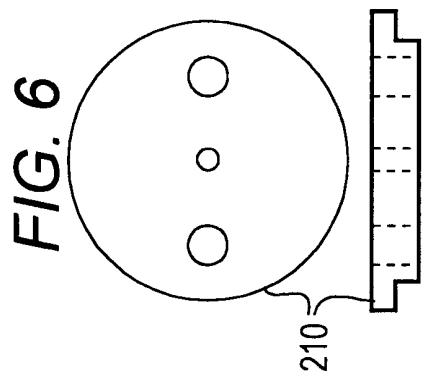
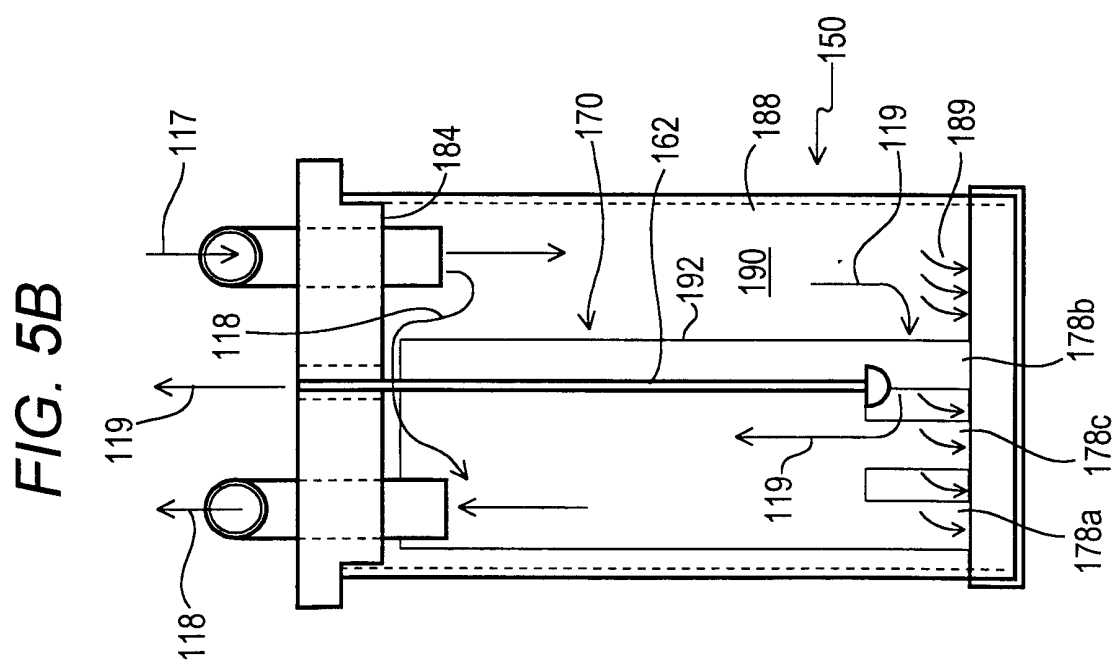


FIG. 8



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FIG. 7

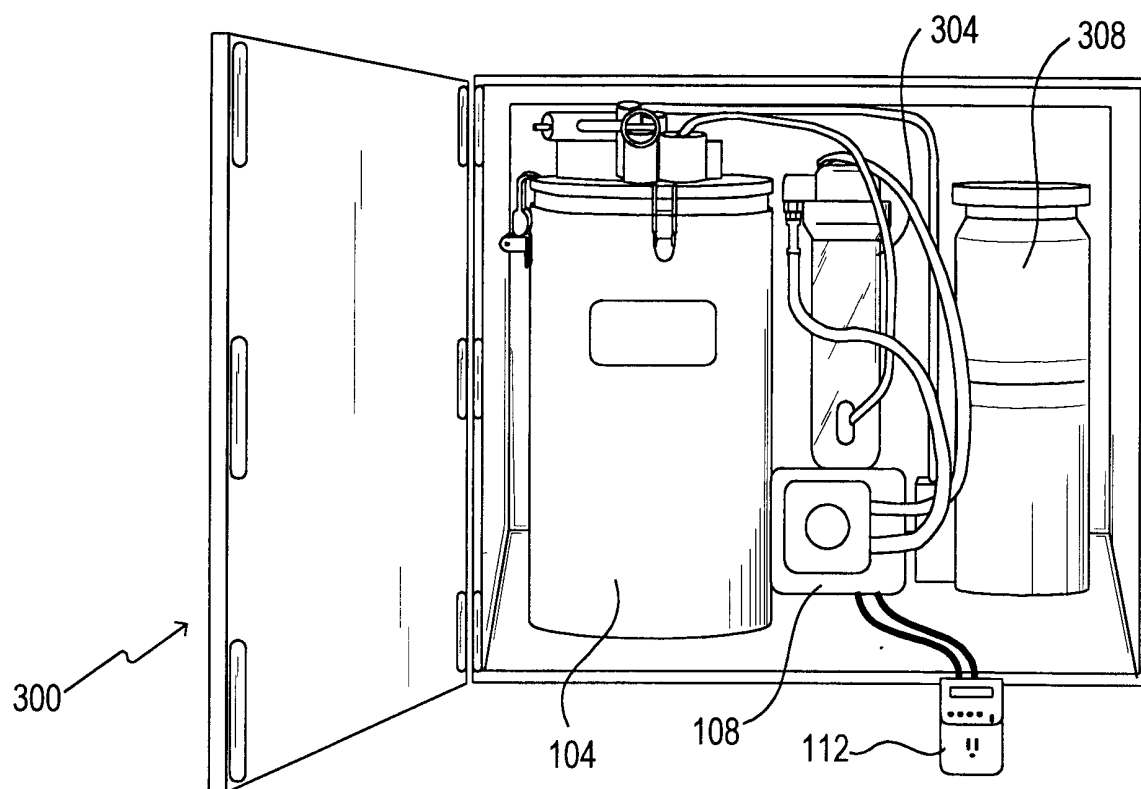
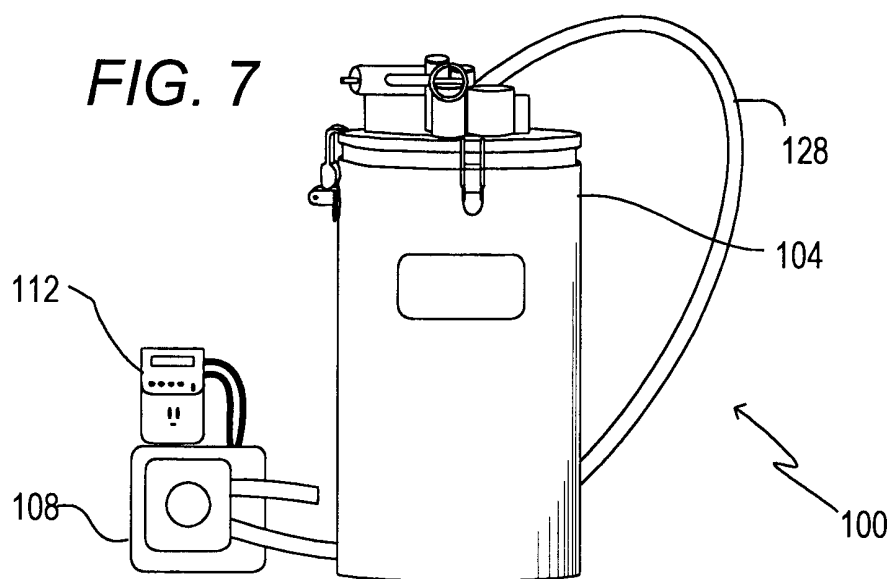


FIG. 12

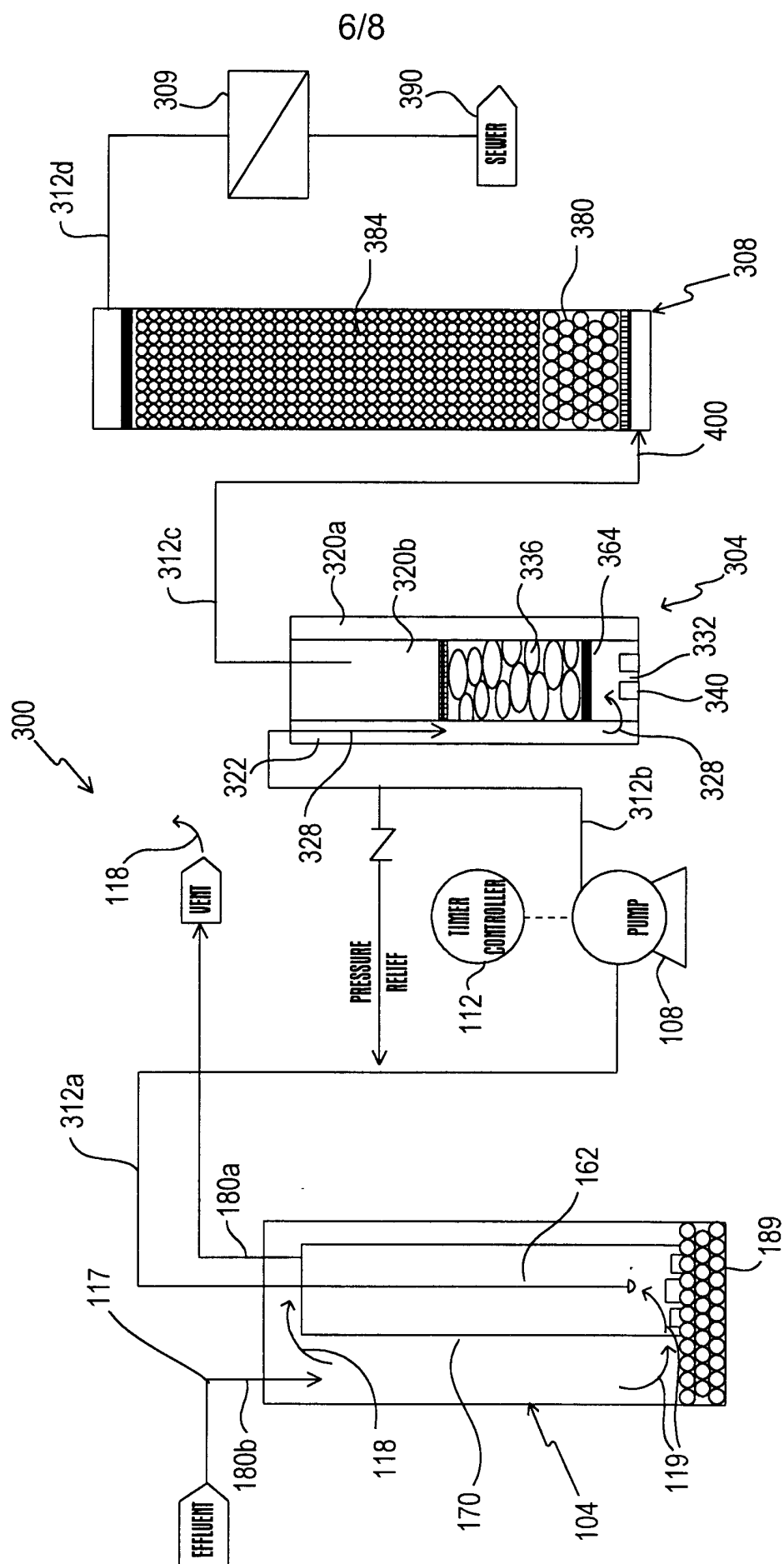
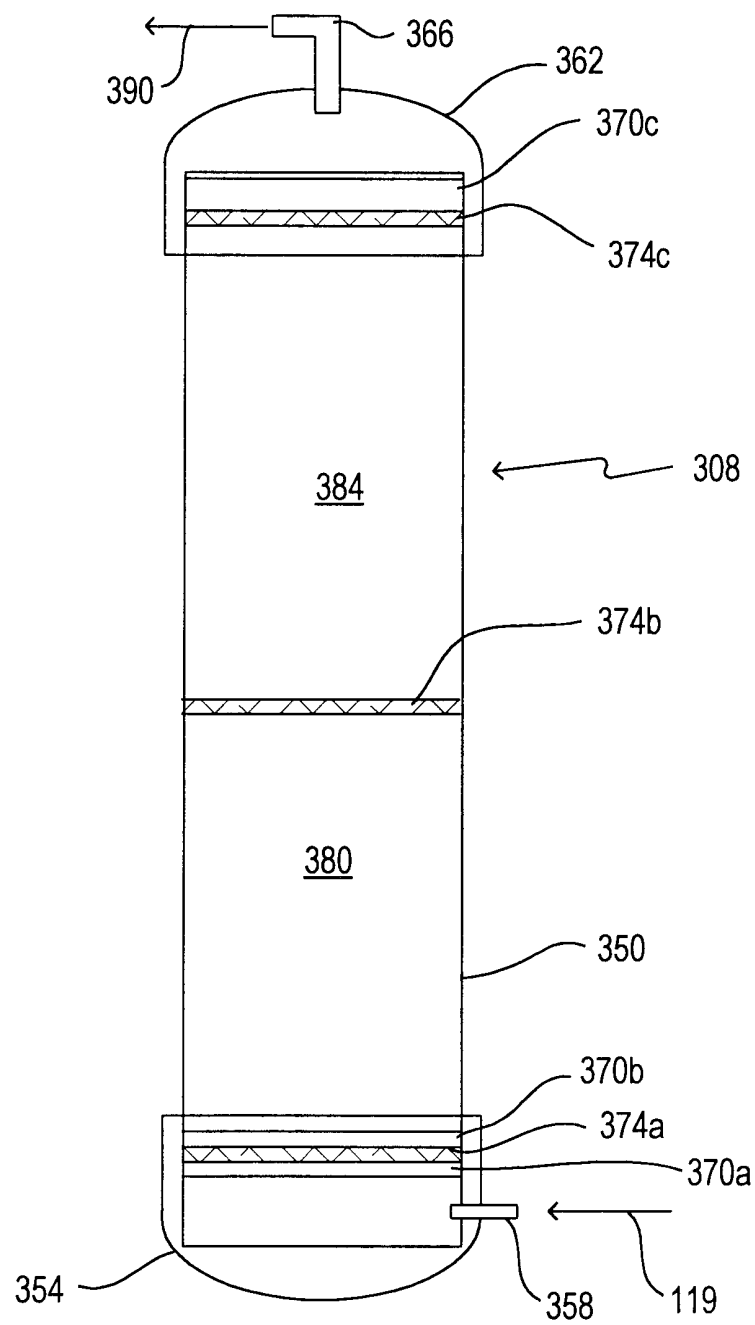


FIG. 11

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**FIG. 13**

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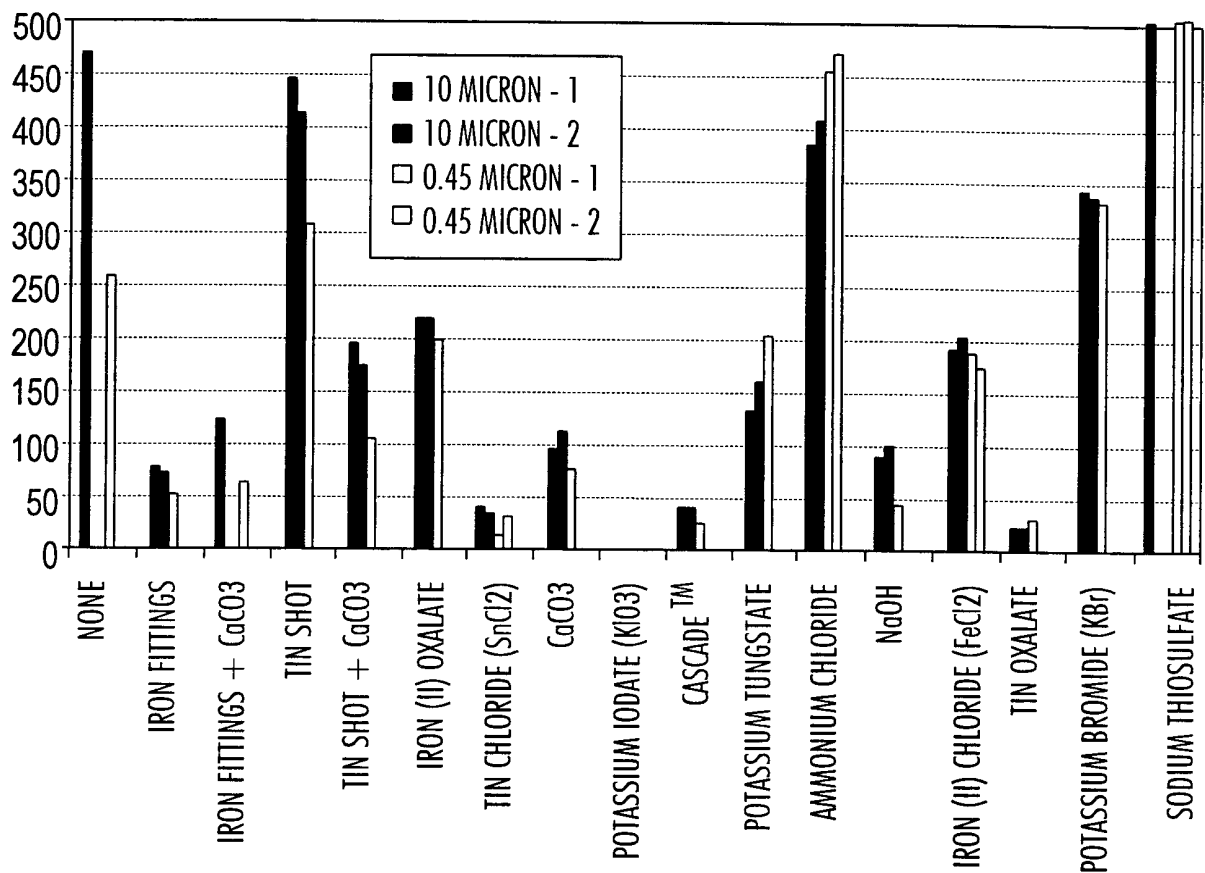


FIG. 14

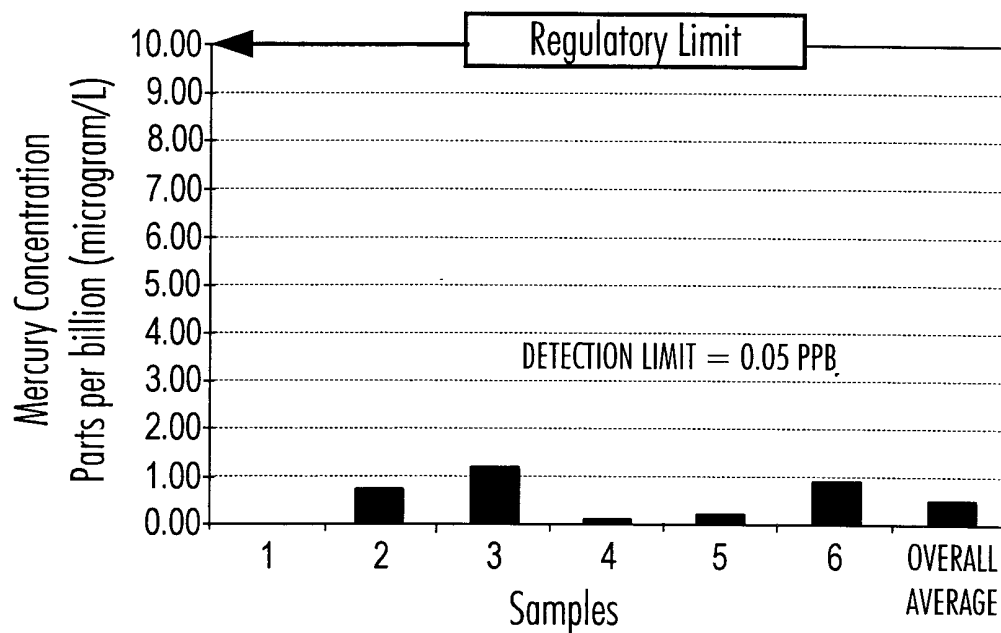


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/04144

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B01D 19/00

US CL : 210/188

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 210/188, 138, 139, 257.1, 258, 259, 513, 519, 521; 433/92, 97; 95/241, 242, 259

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,885,076 A (RALLS et al) 23 March 1999, see entire document	1-27
X --- Y	US 5,577,910 A (HOLLAND) 26 November 1996, see entire document	1-4,6,13,15,20-23 --- 5,7-12,14,1 6-19,24-27
Y	US 4,245,989 A (FOLKENROTH et al) 20 January 1981, see entire document	1-27
X --- Y	DT 3,813,264 A1 (ECK et al) 10 November 1988, see entire document and attached complete translation	1-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G*	document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

04 APRIL 2001

Date of mailing of the international search report

27 APR 2001

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