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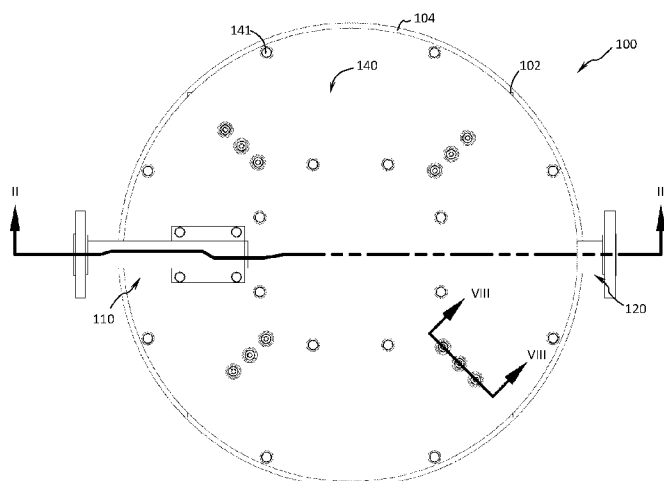


FIG. 1

(57) Abstract: A continuous electrowinning system

(100) comprising a cell body (106) configured to maintain electrolyte solution at a high pressure and/or temperature within the cell body (106); anodes (174); cathodes (172); an inlet 110 for receiving an influent stream (200) of electrolyte solution; a first outlet (120) discharging an effluent stream (220) of spent electrolyte; a second outlet (130) for removing cathode slime/sludge concentrate (230); and a residence chamber (160) to continuously transfer electrolyte solution from said inlet (110) to said first outlet (120) and increase residence time of said electrolyte solution, the residence chamber (160) comprising one or more channels (162) which are configured to provide a forced flow (212) of electrolyte therein which is strong enough to continuously dislodge and/or move cathode slime/sludge concentrate (204, 206) along and out of said one or more channels (162).

CONTINUOUS ELECTROWINNING PROCESS AND SYSTEM THEREOF

BACKGROUND OF THE INVENTION

This invention relates to systems and methods used in metal refining processes, and more particularly to electrowinning systems.

To this end, there are generally two main processes available for gold concentration and recovery: *zinc precipitation*, and *electrowinning*. *Zinc precipitation* involves crushing and grinding ore containing gold or another precious metal, and then combining the ground ore with a water and caustic cyanide solution. The resulting mud-like pulp is moved to a settling tank where the coarser gold-laden solids move to the bottom via gravity, and a lighter first pregnant solution of water, gold, and cyanide moves to the top and is removed for further processing. The gold-laden solids are agitated and aerated in a separate agitated leach process where oxygen reacts to leach the gold into the water, caustic, and cyanide forming a second pregnant solution. The second pregnant solution passes through a drum filter which further separates remaining solids. The first and second pregnant solutions are combined with zinc to precipitate out the dissolved gold. The resulting precipitated gold concentrate may then be smelted to produce refined gold bar.

Electrowinning typically involves extracting gold or another precious metal from an electrolyte produced by combining activated carbon with a pregnant gold solution in a batch process step. The activated carbon absorbs gold contained within the pregnant solution, and becomes “loaded” (that is, the carbon becomes loaded with gold removed from the pregnant gold solution). The loaded carbon is then “descaled” by sequentially washing it in three batch process steps to remove ore residue. First, the loaded carbon is moved to a washing tank and then the tank is filled with a dilute acid solution. The washing tank is then drained and the used dilute

acid solution is pumped away and disposed. The same washing tank is then filled with water to rinse remaining acid from the loaded carbon. The water becomes slightly acidic during this process. In a similar fashion to the dilute acid, the used slightly acidic rinse water is also drained from the washing tank, pumped away, and disposed. Lastly, the tank is filled with a caustic solution, and the loaded carbon is washed in the caustic solution. The used caustic is then drained from the tank, pumped away, and disposed. An optional final water rinse step may be performed by again, filling the washing tank with water, rinsing caustic residue from the loaded carbon, draining the tank of the used rinse water, and then disposing of said used rinse water.

After washing, the loaded carbon is removed from the washing tank and then added to a strip solution comprising water, caustic, and cyanide to form a strip solution/loaded carbon slurry. The strip solution/loaded carbon slurry goes through an elution process where high temperatures and pressures are used to “re-leach” gold from the loaded carbon into the strip solution of water, caustic, and cyanide to form an electrolyte solution. The electrolyte solution is then moved to an electrowinning cell where wire (e.g., reticulated) or plate cathodes collect deposited gold concentrate during electrolysis. The cathodes are then manually removed from the cell for cleaning in a batch process step, so that gold concentrate deposited thereon can be removed from the cathodes and readied for smelting. The cathodes are manually replaced within the electrowinning cell, and the entire batch process is repeated. In some instances, cathodes (e.g., wire) are not re-useable and must be recycled after processing. Therefore, new cathodes may be needed for each and every electrowinning batch, which increases overhead costs.

Extraction of gold using such conventional processes typically involves intervals of non-production downtime of the electrowinning cell, significant physical labor, premature cathode wear, and electrolyte waste. The process of using zinc to precipitate precious metals out of

pregnant solutions is also costly, may be less efficient for large-scale operations, may only work for certain metals, and may result in less precious metal recovery.

OBJECTS OF THE INVENTION

It is, therefore, an object of the invention to provide an electrowinning system configured for the continuous formation, forced flow, storage, and/or removal of cathode slime/sludge concentrate from an electrolyte, thereby avoiding the aforementioned problems associated with conventional batch processes.

It is also an object of the invention to provide an electrowinning system which is configured to operate at a higher heating and cooling efficiency than conventional electrowinning systems.

Another object of the invention is to provide an electrowinning system which is configured to have a smaller footprint than conventional electrowinning systems.

Yet another object of the invention is to provide a method of continuously winning a precious metal from a continuously flowing influent stream of electrolyte.

Moreover, it is an object of the invention to provide a method of electrowinning having fewer radiation losses and less power consumption than conventional electrowinning processes.

Another object of the invention is to provide a method of electrowinning at higher flowrates than conventional electrowinning processes.

Another object of the invention is to provide a method of electrowinning at higher temperatures than conventional electrowinning processes without the occurrence of flashing.

Another object of the invention is to provide a method of electrowinning at higher pressures than conventional electrowinning processes.

Yet other objects of the invention are to improve reaction kinetics, reduce electrolyte losses, and yield better precious material recoveries with less reagent consumption.

Another object of the invention is to reduce cathodic power consumption in comparison with conventional electrowinning cells.

Yet even another object of the invention is to lower the amount of precious material present in spent electrolyte (i.e., “barren”) solutions.

These and other objects of the invention will be apparent from the drawings and description herein. Although every object of the invention is believed to be attained by at least one embodiment of the invention, there is not necessarily any one embodiment of the invention that achieves all of the objects of the invention.

SUMMARY OF THE INVENTION

A continuous electrowinning system comprises, in accordance with some embodiments of the invention, a cell body configured to maintain electrolyte solution at a high pressure and/or temperature within the cell body; at least one anode; at least one cathode; an inlet configured for receiving an influent stream of electrolyte solution; a first outlet configured for discharging an effluent stream of spent electrolyte solution; a second outlet configured for removing cathode slime/sludge concentrate; and a residence chamber configured to dynamically and continuously transfer electrolyte solution from said inlet to said first outlet and increase residence time of said electrolyte solution between said at least one anode and said at least one cathode, the residence chamber comprising one or more channels which are configured to provide a forced flow of electrolyte solution therein which is strong enough to continuously dislodge and/or move cathode slime/sludge concentrate along and eventually out of said one or more channels.

According to some embodiments, the one or more channels may be defined between a cathode, an anode, and an insulator. In some embodiments, the one or more channels may comprise portions of a helix, spiral, coil, compound curve, 3D-spline curve, or serpentine. In some embodiments, cathodes or anodes may be configured as sleeves or portions thereof. In some embodiments, one or more insulators may be provided between anodes and cathodes. In some embodiments, one or more protuberances may extend from anodes and/or cathodes, wherein the one or more protuberances may extend in a helical path, spiral, coil, compound curve, 3D-spline curve, or serpentine path. The protuberances may extend radially-inwardly or radially-outwardly.

A continuous electrowinning process is also disclosed. In accordance with some embodiments of the invention, the process comprises the steps of: providing a continuous electrowinning system having a cell body configured to maintain electrolyte solution at a high pressure and/or temperature within the cell body; at least one anode; at least one cathode; an inlet configured for receiving an influent stream of electrolyte solution; a first outlet configured for discharging an effluent stream of spent electrolyte solution; a second outlet configured for removing cathode slime/sludge concentrate; and a residence chamber configured to dynamically and continuously transfer electrolyte solution from said inlet to said first outlet and increase residence time of said electrolyte solution between said at least one anode and said at least one cathode, the residence chamber comprising one or more channels which are configured to provide a forced flow of electrolyte solution therein which is strong enough to continuously dislodge and/or move cathode slime/sludge concentrate along and eventually out of said one or more channels; dynamically and continuously feeding electrolyte solution into said inlet; and dynamically and continuously removing spent electrolyte solution from said first outlet. The

process may further comprise the step of removing cathode slime/sludge concentrate from the system via said second outlet.

A continuous electrowinning cell is also disclosed, which, in accordance to some embodiments comprises at least one anode forming a portion of at least one channel; at least one cathode forming a portion of said at least one channel; and, at least one insulator forming a portion of said at least one channel; wherein said at least one channel is configured to increase the amount of residence time electrolyte solution spends between said at least one anode and said at least one cathode; and wherein said at least one channel is configured to dynamically and continuously provide a forced flow of electrolyte solution therein which is strong enough to continuously dislodge and/or move cathode slime/sludge concentrate along and eventually out of said at least one channel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a top plan view of a continuous electrowinning system according to some embodiments;

FIG. 2 is a vertical cutaway view of a continuous electrowinning system taken on line IIII in FIG. 1;

FIG. 3 is an isometric cutaway view of a continuous electrowinning system taken on line II-II of FIG. 1;

FIG. 4 is a detailed view of FIG. 3, showing the particulars of an inlet according to some embodiments;

FIG. 5 is a detailed view of FIG. 2, showing the particulars of an inlet according to some embodiments;

FIG. 6 is a side plan view of an electrowinning cell according to some embodiments;

FIG. 7 is a transverse cutaway view of an electrowinning cell along line VII-VII in FIG. 6;

FIG. 8 is a detailed cutaway view along line VIII-VIII in FIG. 1;

FIG. 9-11 schematically illustrate the forced flow function of one or more channels according to some embodiments;

FIG. 12 is a detailed view of a baffle according to some embodiments;

FIGS. 13-17 schematically illustrate cross-sectional profiles of channels according various embodiments; and,

FIG. 18 schematically illustrates a method of continuous electrowinning according to some embodiments.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1-8 show a continuous electrowinning system 100 according to some embodiments. The continuous electrowinning system 100 generally comprises a cell body 106 having a first end 140, a second end 180, one or more sidewalls 182 extending therebetween, a base 104 having one or more mounts 102, at least one inlet 110 for receiving a continuous influent stream 200 of a precious material-containing electrolyte, at least one first outlet 120 for providing egress of a continuous effluent stream 220 of spent electrolyte 216, and at least one second outlet 130 for providing egress of an effluent stream 240 of cathode slime/sludge concentrate 230 collected within the system 100. The second outlet 130 may be configured for continuous egress of said effluent stream 240, or the second outlet 130 may be configured for intermittent egress of said effluent stream 240. Within the cell body 106 is provided a first chamber 105, a second chamber 107, a third chamber 108, and a residence chamber 160 comprising one or more elongated channels 162. The channels 162 are configured to increase

residence time of the electrolyte and provide a forced flow 212 of electrolyte which is strong enough to dislodge and/or displace cathodic slime/sludge concentrate 204, 206 which may form and/or build up within the channels 162. The one or more channels 162 may comprise, for example, portions of a helix, double-helix, coil, spiral, serpentine, spline, compound curve, and may extend in curvilinear paths. In some embodiments, as shown, the residence chamber 160 may be concentrically situated between the third chamber 108 and the first chamber 105. The first chamber 105 may be configured to be devoid of electrolyte and/or cathodic slime/sludge concentrate during operation, and may generally serve as a space-filler bounded between first end 140, inner anode 177, and baffle 150. The space filling first chamber 105 generally provides channels 162 within the residence chamber 160 with a larger radius, thereby increasing the overall effective length of exposure of the channels 162 to electrolyte streams 212 contained within. The third chamber 108 serves to temporarily hold and/or transport spent electrolyte 216 from within the system 100 to one or more first outlets 120. In some embodiments, to reduce material costs, the first end 140 may be configured as an annular panel having a central opening exposing the first chamber 105, rather than as a solid continuous circular panel as shown. The one or more first outlets 120 may be provided at an upper portion of the system 100 where overflow is likely to be more clarified and free from precipitated concentrate 230.

Each channel 162 may be defined between at least one anode 174, at least one cathode 172, and one or more insulators 176 extending therebetween. In the particular embodiment shown, one or more anodes 174 and one or more cathodes 172 are provided as sleeve portions which alternate concentrically and radially, between an outer anode 179 and an inner anode 177. The anodes 174 and cathodes 172 are radially separated and maintain a uniform spacing by one or more spacing protuberances 173 projecting from said one or more cathodes 172. It should be understood, that while not shown, the one or more protuberances 173 may alternatively extend

from the anodes 174 alone, or may extend from both anodes 174 and cathodes 172 without limitation. However, by providing protuberances 173 on the one or more cathodes 172, a small amount of extra cathodic surface area is provided for precipitating cathodic sludge/slime concentrate 204, 206 out of the electrolyte stream 212 during electrolysis. The one or more insulators 176 prevent short circuit between the negatively charged anodes 174 and positively charged cathodes 172 and may serve as flexible, tolerance-compensating gaskets which delineate the cross-sectional boundary of each channel 162.

Each anode 174 may communicate with one or more anode terminals 142. Anode terminals 142 may comprise, for example and without limitation, a fastener 142a such as a pin or screw, a clamping member 142b such as a nut, flange, or head, a terminal lead 142c connected to a ground or power source, a conductive washer 142d or other clamping member, an insulative bushing 142e to prevent electrical currents from passing to surrounding portions of the system 100, a thread or equivalent securing feature 142f provided on said fastener 142a, a conductive support 142h comprising a complimentary thread or equivalent securing feature 142g for communicating with said thread or equivalent securing feature 142f, and a receiving portion 142i provided within the conductive support 142h for engaging and supporting one or more anodes 174. In the particular embodiment shown, anodes 174 are generally cylindrical/tubular sleeves and therefore, receiving portions 142i may be provided as small straight or generally arcuate slits. However, other equivalent interfaces are envisaged, particularly for non-cylindrical or non-tubular anodes 174 and cathodes 172. For example, instead of slits, receiving portion 142i may comprise a plurality of conductive clamps, spring clips, or pegs extending from the support 142h which straddle and secure an anode 174 thereto.

In some embodiments, the continuous electrowinning system 100 may be provided with a cylindrical cell body 106, a flat circular upper first end 140, and a generally frustoconical lower

second end 180. The frustoconical shape generally aids in channeling collected cathode slime/sludge concentrate 230 to the second outlet 130 for easy removal. The first end 140 may be secured to the cell body 106 via an annular flange 145 which may be electrically neutral or positively charged with the rest of cathodic cell body 106. The first end 140 may comprise a series of sandwiched panels, such as one or more ground or electrically-neutral panels 147, one or more anodic panels, 144, and one or more insulative panels 146. In some embodiments the one or more insulative panels 146 may comprise a gasket, such as a polytetrafluoroethylene (PTFE) insulating gasket. One or more fasteners 141 or adhesives may be provided to various portions of the first end 140 to secure the first end 140 to the body 106 and/or secure sandwiched panels 144, 146, 147 together. For example, a series of fasteners 141 may be provided around a perimeter of the first end 140 to secure the first end 140 to the flange 145. The fasteners 141 may be insulated, for example, with a sheath, coating, bushing, or washer of non-conductive material such as high molecular weight polyethylene (HMWPE), polyvinylidene fluoride (PVDF), polypropylene, or polyvinylchloride (PVC). Moreover, the fasteners 141 may provide a dual purpose of securing the first end 140 to the body 106 and securing sandwiched panels 144, 146, 147 together.

In use, an influent stream 200 of electrolyte at a higher-than-ambient pressure and temperature continuously enters the system 100 via inlet 110. The electrolyte may contain a dissolved mineral, metal, or precious material such as copper, gold, silver, platinum, lead, aluminum, or uranium, without limitation. The electrowinning system 100 is preferably maintained at a higher-than-ambient temperature (e.g., around 88 degrees Celsius) and/or pressure. The influent stream 200 may come from an upstream electrolyte holding tank, an elution/carbon stripping system, or a combination thereof. In some embodiments, the inlet 110 may be formed from a portion of a pipe or tubing having one or more sidewalls 112 and may

further comprise an inlet mount 114 having a flange, seal, valve, pipe fitting, or equivalent connector for integration with a larger plant system. Inlet 110 comprises one or more openings 113 (e.g., through said one or more sidewalls 112), which are configured to feed said one or more channels 162 of the residence chamber 160 with incoming electrolyte 200. Though not shown, a plurality of openings 113 may be provided per channel 162. In the event multiple channels 162 are employed as shown, the influent stream 200 of electrolyte will generally be split into a plurality of dispersed influent streams 202, each entering different channels 162. Alternatively, while not shown, a separate inlet 110 may be provided for each channel 162. The openings 113 may be configured to allow uniform or non-uniform flow rates or similar residence times for each of the channels 162. As clearly shown in FIG. 5, one or more insulators 117 (e.g., an insulation pad) may be placed between the one or more sidewalls 112 of the inlet 110 and the first end 140 of the cell body 160. The one or more insulators 117 may encircle the one or more openings 113 to ensure that incoming electrolyte from dispersed streams 202 does not form, plate, or sludge within the openings 113 adjacent cathodes 172.

In some embodiments, channels 162 may be configured to allow the dispersed influent streams 202 of electrolyte to flow 212 through the channels 162 in a uniform helical or spiral path as shown. However, the channels 162 may also be configured to direct the dispersed influent streams 202 along serpentine paths, compound curve paths, or complex 3D-spline curve paths so long as they can support a forced flow of electrolyte therein, and provide sufficient residence time of electrolyte between an anode 174 and cathode 172. Channels 162 may shrink or grow in circumference or change in overall or cross-sectional shape and/or size as they extend within the residence chamber 160; however, it is preferred that channels 162 remain uniform in cross-section, path/direction, and/or anode-cathode spacing throughout their entire length. While not shown, since channels 162 located at greater radial distances from the center of the system

100 are longer and will generally have higher residence times than inner channels 162, the overall height of inner channels 162 (e.g., channels adjacent inner anode 177 and first chamber 105) may be made greater than the overall height of outer channels 162 (e.g., channels more proximate the outer anode 179 and third chamber 108) in order to lengthen the effective length of said inner channels. Portions of baffle 150 are generally open so as to allow channels 162 to continuously deliver streams of electrolyte 212 and cathodic slime/sludge concentrate 204, 206 formed in said channels 162 to second chamber 107 where a mass 230 of it is collected.

As shown in FIG. 12, baffle 150 may comprise an anodic layer 152, a middle electrically-neutral insulator 154 to support said one or more anodes 174 and cathodes 172, and a support structure 156 for supporting the insulator 154. The insulator 154 may be made of a material such as ultra-high molecular weight polyethylene (UHMWPE) and may be cruciform in shape as shown. A plurality of receiving portions 158 such as notches may be provided to the insulator 154 to hold, space, insulate, and support the one or more anodes 174 and cathodes 172; however, other holding means such as pegs, spring clips, or clamps may be provided. The insulator 154 may be connected to the support structure 156 with one or more fasteners, adhesives, or other connecting means, and the support structure 156 may be connected to the body 106 by conventional means such as bolting, forming, adhering, or welding. The anodic layer 152 may serve to close off the first chamber 105 and prevent electrolyte from entering said first chamber 105. In some embodiments, the support structure 156 may be a lattice structure such as a low mesh screen or supporting member such as a crossbar which spans a width of the cell body 106, but does not inhibit electrolyte flow 212 or passing of slime/sludge concentrate 204, 206 to the second chamber 107 from the channels 162.

As schematically illustrated in FIGS. 9-11, when electrolyte streams 212 flow through the one or more channels 162 in the residence chamber 160, a large electric potential is placed

between the one or more anodes 174 and one or more cathodes 172 in order to effectively “plate-out” slime/sludge 204 onto the one or more cathodes 172. However, by varying operating parameters such as residence time, electric current, electrolyte flow rate, temperature, pressure, electrolyte concentration/composition, and/or smoothness/material/coating of each cathode(s) 172, the channels 162 may be configured such that cathodic slime/sludge concentrate 204 initially forming on or adjacent to the one or more cathodes 172 will not actually bond or “plate” to the cathodes 172 and will instead wash down the channels 162 suspended by electrolyte streams 212. Any slime/sludge concentrate 204 that may settle to bottom of a channel 162 may also be washed down and eventually out of the channels 162 and into second chamber 107 by the forced flow of electrolyte streams 212. Concentrate 204, 206 may be flushed out of the one or more channels 162 by virtue of: gravitational forces acting on inclined surfaces, high flow rates of electrolyte streams 212 passing through the one or more narrow channels 162, increased turbulence within each channel 162, and/or by virtue of small cross-sectional areas provided to each channel.

After the electrolyte streams 212 pass through the one or more channels 162, the outflow 214 of the residence chamber 160 will generally comprise a liquid carrier component of spent electrolyte 216 (i.e., “barren” solution) relatively free of dissolved precious material, and a solid precipitate component comprising cathodic slime/sludge concentrate 204, 206 which has been discharged from the channels 162 by forced electrolyte flow 212. The solids may follow a sludge precipitate stream 218 before settling in mass 230 adjacent the second end 180. Spent electrolyte 216 (i.e., “barren” solution) travels into the third chamber 108 before leaving the system 100. Thereafter, the spent electrolyte 216 continuously leaves the system 100 through the first outlet 120. In embodiments where the cell body 106 is cathodic, some residual plating or cathodic slime/sludge concentrate 204, 206 formation may occur within the third chamber 108

(for example, on or around inner portions of cathodic sidewall(s) 182). Cathodic slime/sludge concentrate 204 formed within the third chamber 108 will typically settle and eventually end up in second chamber 107 with the rest of the collected slime/sludge concentrate 230.

The first outlet 120 may be formed from a portion of a pipe or tubing having one or more sidewalls 122 and may further comprise a first outlet mount 124 having a flange, seal, valve, pipe fitting, or equivalent connector for integration with a larger plant system. When in use, an effluent stream 220 of spent electrolyte 216 continuously leaves the cell body 106 through said first outlet 120 at which point it may enter a barren solution holding tank (not shown), be discarded, return to an elution system, or undergo further processing.

Captured concentrate 230 may be removed from the system 100 intermittently or continuously via second outlet 130. The underflow 240 of removed slime/sludge may proceed to a holding tank, be pumped away for further refining, or may be dumped into a container and transported to a smelter. In some embodiments, the second outlet 130 may be formed from a portion of a pipe or tube having one or more sidewalls 132 and may further comprise a second outlet mount 134 having a flange, seal, valve, pipe fitting, nozzle, tap, or equivalent connector for integration with a larger plant system.

FIGS. 12-17 schematically illustrate cross-sectional views of residence chambers 360, 460, 560, 660, 760 according to various alternative embodiments. Each residence chamber comprises one or more channels 362, 462, 562, 662, 762 formed between one or more anodes 374, 474, 574, 674, 774 and one or more cathodes 372, 472, 572, 672, 772 which are separated from each other by one or more insulators 376, 476, 576, 676, 776. Channels may extend linearly, helically, in a cascade of connected horizontally arranged and vertically-displaced “figure-8s”, or in any continuous path in 3-D space which is configured to provide a forced flow of electrolyte solution. In order to assist with outgassing of air which could get caught in the

channels 362, 462, 562, 662, 762 and also prevent the backup of precipitated slime/sludge concentrate within the channels 362, 462, 562, 662, 762, it is preferred that the continuous path the channels follow in 3-D space be free of sharp bends, abrupt turns, overhangs, high spots, and/or tightly wound corners which may be prone to air capture and clogging. In some embodiments, residence chambers 360, 460, 560, 660, 760 according and channels 362, 462, 562, 662, 762 within may simply extend as long straight pipe sections tilted at an angle with respect to horizontal.

FIG. 18 schematically illustrates a method 1000 of continuous electrowinning according to some embodiments. The method 1000 comprises the step of providing 1002 an electrolyte solution. The electrolyte solution may be produced from a conventional elution/carbon stripping process and may comprise water, cyanide, caustic, and a dissolved precious material (e.g., gold, copper, silver, platinum, aluminum, or uranium) therein. The electrolyte solution is continuously fed 1004 (e.g., at one or more predetermined flow rates) into an electrolytic cell which is preferably maintained 1006 at a higher-than-ambient temperature and/or pressure. In some embodiments, the cell may comprise a series of nested anode sleeves and cathode sleeves, wherein adjacent sleeves have a different electrical potential or charge. In a preferred embodiment, the sleeves are spaced concentrically and radially evenly with respect to each other so that any two neighboring sleeves hold an opposite charge 1008. One or more insulators may be placed between the anodes and cathodes to define a plurality of channels (e.g., helical channels) and simultaneously prevent arcing between the anodes and cathodes. The method 1000 further comprises the step of subjecting the electrolyte solution to a longer residence time within a continuous electrowinning cell 1010. This may be achieved by providing one or more elongated channels between the anode and cathode sleeves, which extend in a smooth, continuous and uninterrupted helical path. Electrolyte solution maintained within the channels

may be forced along the channels and walls thereof by small pressure differentials between the inlet 110 and the first 120 and/or second 130 outlet. As the electrolyte solution moves through the channels, cathodic slime/sludge concentrate precipitates out of the solution adjacent the cathodes until the electrolyte solution becomes weaker in concentration and eventually substantially barren 1012 of precious material. Precipitated concentrate is collected continuously 1014, but may be extracted 1018 continuously or intermittently or a combination thereof. Used electrolyte solution (which is substantially barren of precious material) is continuously extracted 1016 from the system and may be re-used as a strip solution for an upstream elution process.

A contractor or other entity may provide a continuous electrowinning system 100 in part or in whole as shown and described. For instance, the contractor may receive a bid request for a project related to designing a continuous electrowinning system 100 for extracting a solid concentrate from an electrolyte loaded with a dissolved precious material (e.g., gold), or the contractor may offer to design such a system 100 for a client. The contractor may then provide, for example, any one or more of the devices or features thereof shown and/or described in the embodiments discussed above. The contractor may provide such devices by selling those devices or by offering to sell those devices. The contractor may provide various embodiments that are sized, shaped, and/or otherwise configured to meet the design criteria of a particular client or customer. The contractor may subcontract the fabrication, delivery, sale, or installation of a component of the devices or of other devices used to provide such devices. The contractor may also survey a site and design or designate one or more storage areas for stacking the material used to manufacture the devices. The contractor may also maintain, modify, or upgrade the provided devices. The contractor may provide such maintenance or modifications by subcontracting such services or by directly providing those services or components needed for said maintenance or modifications, and in some cases, the contractor may modify an existing

electrowinning system with a “retrofit kit” to arrive at a modified system comprising one or more devices or features of the systems 100 and processes 1000 discussed herein.

Although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without departing from the spirit of or exceeding the scope of the claimed invention. For example, electrolyte solutions described herein may utilize reagents other than water, cyanide, and caustic in lieu of or in addition to what is disclosed. Furthermore, the disclosed systems 100 and processes 1000 may be used with electrolytes containing numerous types of precious materials/metals including, but not limited to copper, gold, silver, platinum, uranium, lead, zinc, aluminum, chromium, cobalt, manganese, rare-earth and alkali metals, etc.

Accordingly, it is to be understood that the drawings and descriptions herein are proffered by way of example to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

Reference numeral identifiers

100 System	176 One or more insulators
102 Mount	177 Inner anode
104 Base	179 Outer anode
105 First chamber	180 Second end
106 Cell body	182 One or more sidewalls
107 Second chamber	200 Influent stream
108 Third chamber	202 Dispersed influent stream
110 Inlet	204 Semi-plated slime/sludge concentrate
112 One or more inlet sidewalls	206 Loose slime/sludge concentrate
113 One or more openings	212 Electrolyte stream
114 Inlet mount	214 Residence chamber outflow
117 One or more insulators	216 Spent electrolyte stream
120 First outlet	218 Slime/sludge precipitate stream
122 One or more first outlet sidewalls	220 Effluent stream
124 First outlet mount	230 Collected slime/sludge concentrate
130 Second outlet	240 Sludge removal stream
132 One or more second outlet sidewalls	304 Semi-plated slime/sludge concentrate
134 Second outlet mount	360 Residence chamber
140 First end	362 One or more channels
141 Fastener	372, 472, 572, 672, 772 Cathode
142 Anode terminal	374, 474, 574, 674, 774 Anode
142a Fastener	376 One or more insulators
142b Clamp	404 Semi-plated slime/sludge concentrate
142c Terminal lead	460 Residence chamber
142d Conductive washer	462 One or more channels
142e Insulative bushing	476 One or more insulators
142f Thread or equivalent securing feature	504 Semi-plated slime/sludge concentrate
142g Complimentary thread or securing feature	560 Residence chamber
142h Conductive support	562 One or more channels
142i Receiving portion	576 One or more insulators
144 Anodic panel	604 Semi-plated slime/sludge concentrate
145 Cathodic flange	660 Residence chamber
146 Insulative panel	662 One or more channels
147 Anodic panel	676 One or more insulators
150 Baffle	704 Semi-plated slime/sludge concentrate
152 Anodic panel	760 Residence chamber
154 Anode/Cathode insulator	762 One or more channels
156 Anode/Cathode insulator support	776 One or more insulators
158 One or more receiving portions	1000 Method of continuous electrowinning
160 Residence chamber	1002-1018 Method steps
162 One or more channels	
172 Cathode	
173 One or more protuberances	
174 Anode	

WHAT IS CLAIMED IS:

1. A continuous electrowinning system [100] comprising:
 - a cell body [106] configured to maintain electrolyte solution at a high pressure and/or temperature within the cell body [106];
 - at least one anode [174];
 - at least one cathode [172];
 - an inlet [110] configured for continuously receiving an influent stream [200] of electrolyte solution;
 - a first outlet [120] configured for continuously discharging an effluent stream [220] of spent electrolyte solution;
 - a second outlet [130] configured for removing collected cathode slime/sludge concentrate [230];
 - and
 - a residence chamber [160] configured to dynamically and continuously transfer electrolyte solution from said inlet [110] to said first outlet [120] and increase residence time of said electrolyte solution between said at least one anode [174] and said at least one cathode [172], the residence chamber [160] comprising one or more channels [162] which are configured to provide a forced flow of electrolyte solution therein which is strong enough to continuously dislodge and/or move cathode slime/sludge concentrate [204; 206] along and eventually out of said one or more channels [162].
2. The system according to claim 1, wherein said one or more channels [162] are defined between said at least one cathode [172], said at least one anode [174], and at least one insulator [176].

3. The system according to claim 1, wherein said one or more channels [162] comprise one or more portions of a helix, spiral, coil, compound curve, 3D-spline curve, or serpentine.
4. The system according to claim 1, wherein the at least one anode [174] or the at least one cathode [172] is configured as a portion of a sleeve.
5. The system according to claim 1, wherein at least one insulator is provided between the at least one anode [174] and the at least one cathode [172].
6. The system according to claim 1, wherein one or more protuberances [173] extend from the at least one anode [174] and/or the at least one cathode [172].
7. The system according to claim 6, wherein the one or more protuberances [173] extend in a helical path, spiral, coil, compound curve, 3D-spline curve, or serpentine path.
8. The system according to claim 6, wherein the one or more protuberances [173] extend radially-inwardly or radially-outwardly.
9. A method of continuous electrowinning comprising the steps of:
providing an electrowinning system [100] comprising a cell body [106] configured to maintain electrolyte solution at a high pressure and/or temperature within the cell body [106]; at least one anode [174]; at least one cathode [172]; an inlet [110] configured for receiving an influent stream [200] of electrolyte solution; a first outlet [120] configured for discharging an

effluent stream [220] of spent electrolyte solution; a second outlet [130] configured for removing collected cathode slime/sludge concentrate [230]; and a residence chamber [160] configured to dynamically and continuously transfer electrolyte solution from said inlet [110] to said first outlet [120] and increase residence time of said electrolyte solution between said at least one anode [174] and said at least one cathode [172], the residence chamber [160] comprising one or more channels [162] which are configured to provide a forced flow of electrolyte solution therein which is strong enough to continuously dislodge and/or move cathode slime/sludge concentrate [204; 206] along and eventually out of said one or more channels [162];

dynamically and continuously feeding electrolyte solution into said inlet [110]; and
dynamically and continuously removing spent electrolyte solution from said first outlet [120].

10. The method according to claim 9, wherein said one or more channels [162] are defined between said at least one cathode [172], said at least one anode [174], and at least one insulator [176].

11. The method according to claim 9, wherein said one or more channels [162] comprise one or more portions of a helix, spiral, coil, compound curve, 3D-spline curve, or serpentine.

12. The method according to claim 9, wherein the at least one anode [174] or the at least one cathode [172] is configured as a portion of a sleeve.

13. The method according to claim 9, wherein at least one insulator [176] is provided between the at least one anode [174] and the at least one cathode [172].

14. The method according to claim 9, wherein one or more protuberances [173] extend from the at least one anode [174] and/or the at least one cathode [172].
15. The method according to claim 14, wherein the one or more protuberances [173] extend in a helical path, spiral, coil, compound curve, 3D-spline curve, or serpentine path.
16. The method according to claim 14, wherein the one or more protuberances [173] extend radially-inwardly or radially-outwardly.
17. The method according to claim 9, further comprising the step of removing collected cathode slime/sludge concentrate [230] from the system via said second outlet [130].
18. A continuous electrowinning cell comprising:
- at least one anode [174] forming a portion of at least one channel [162];
 - at least one cathode [172] forming a portion of said at least one channel [162]; and,
 - at least one insulator [176] forming a portion of said at least one channel [162];
- wherein said at least one channel [162] is configured to increase the amount of residence time electrolyte solution spends between said at least one anode [174] and said at least one cathode [172]; and
- wherein said at least one channel [162] is configured to dynamically and continuously provide a forced flow of electrolyte solution therein which is strong enough to continuously dislodge and/or move cathode slime/sludge concentrate [204; 206] along and eventually out of said at least one channel [162].

[1/11]

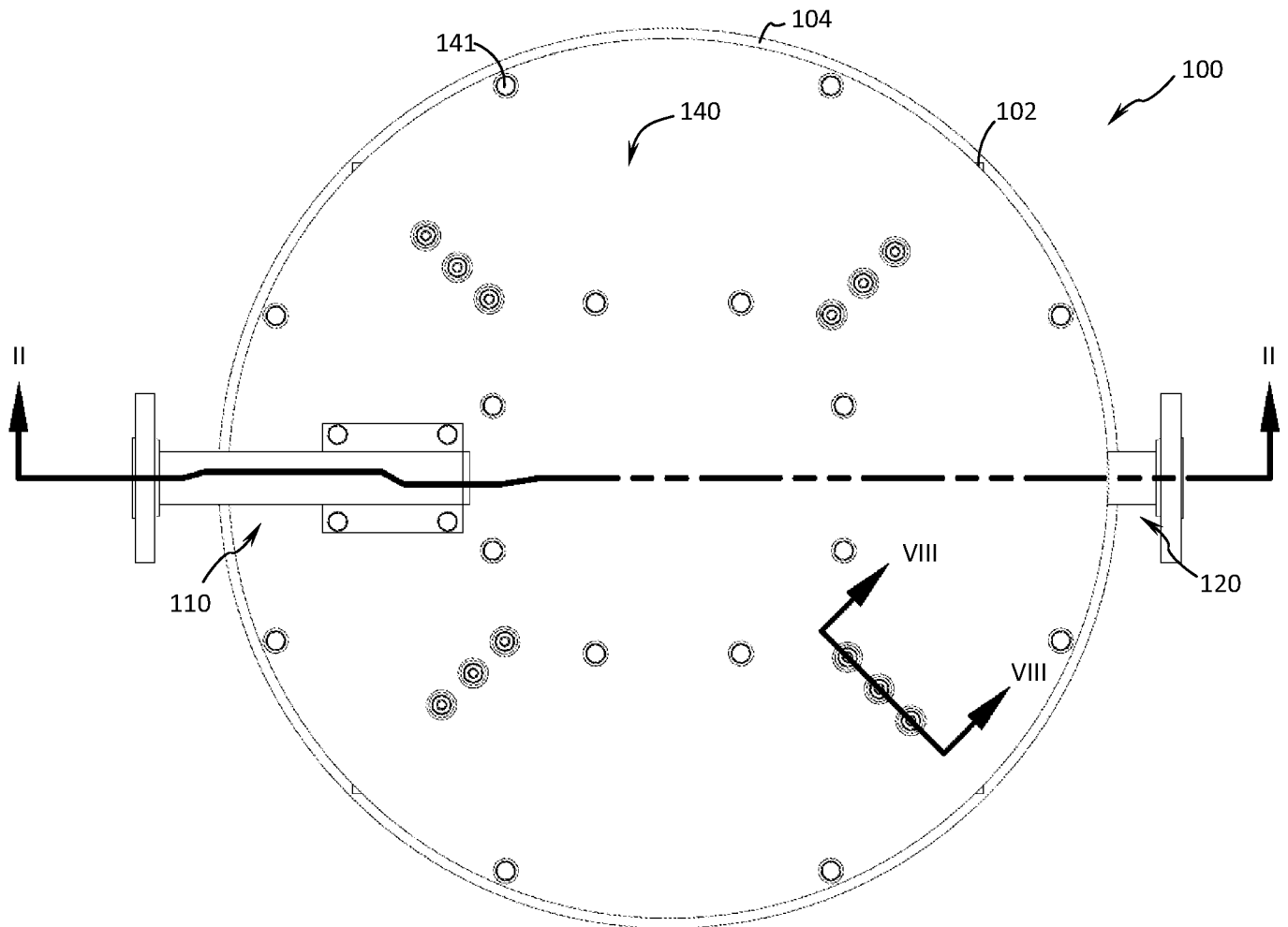
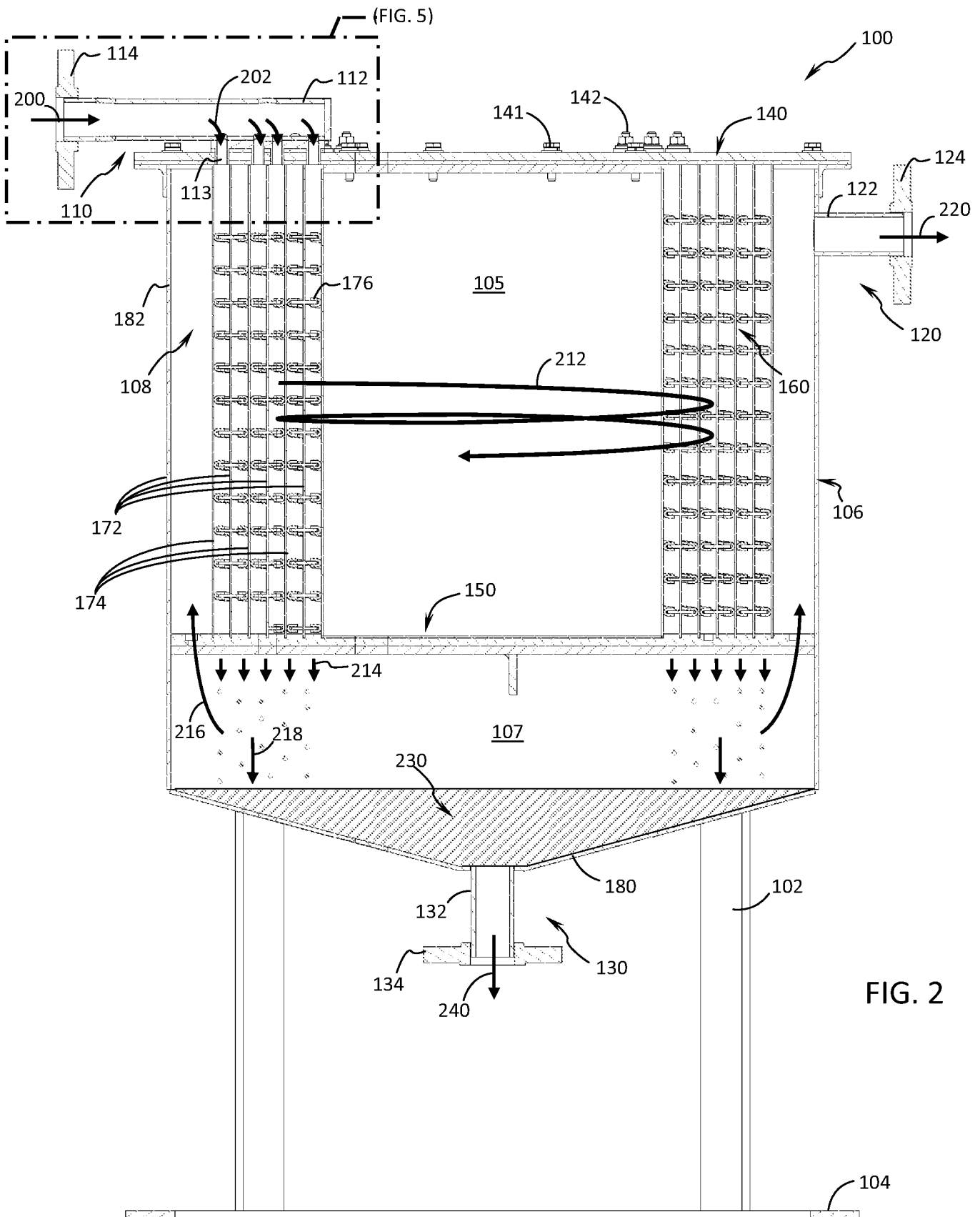
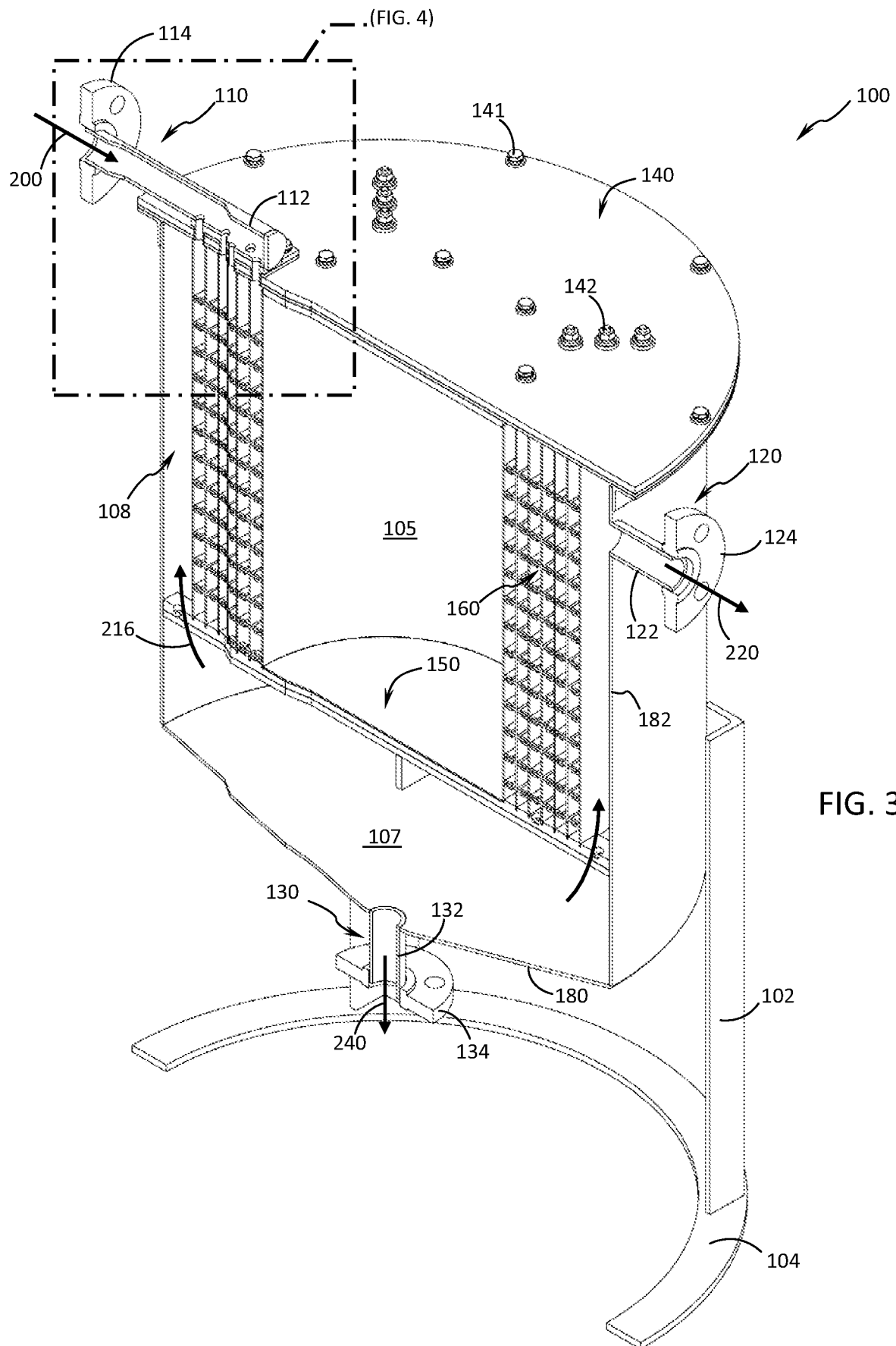


FIG. 1

[2/11]





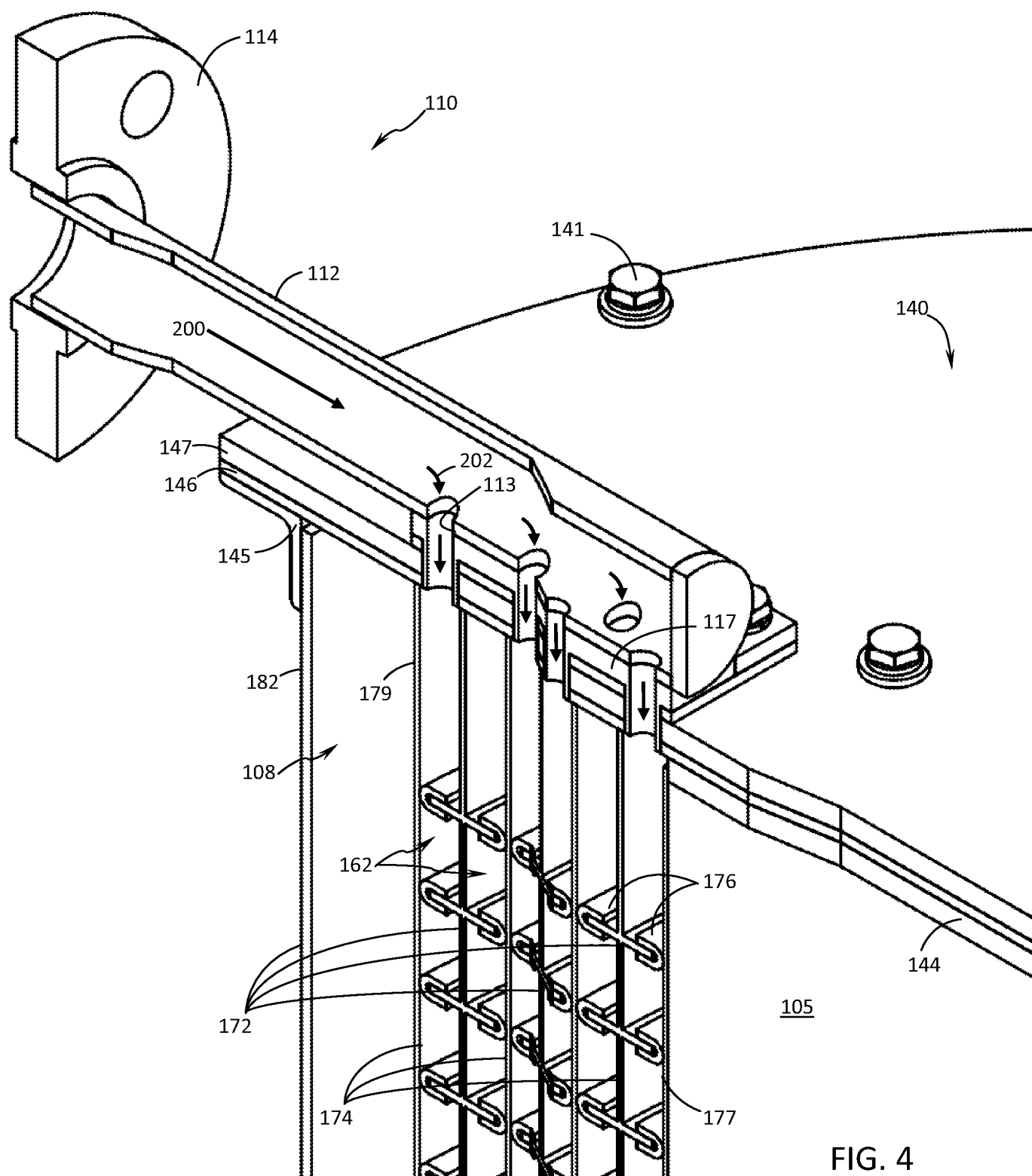


FIG. 4

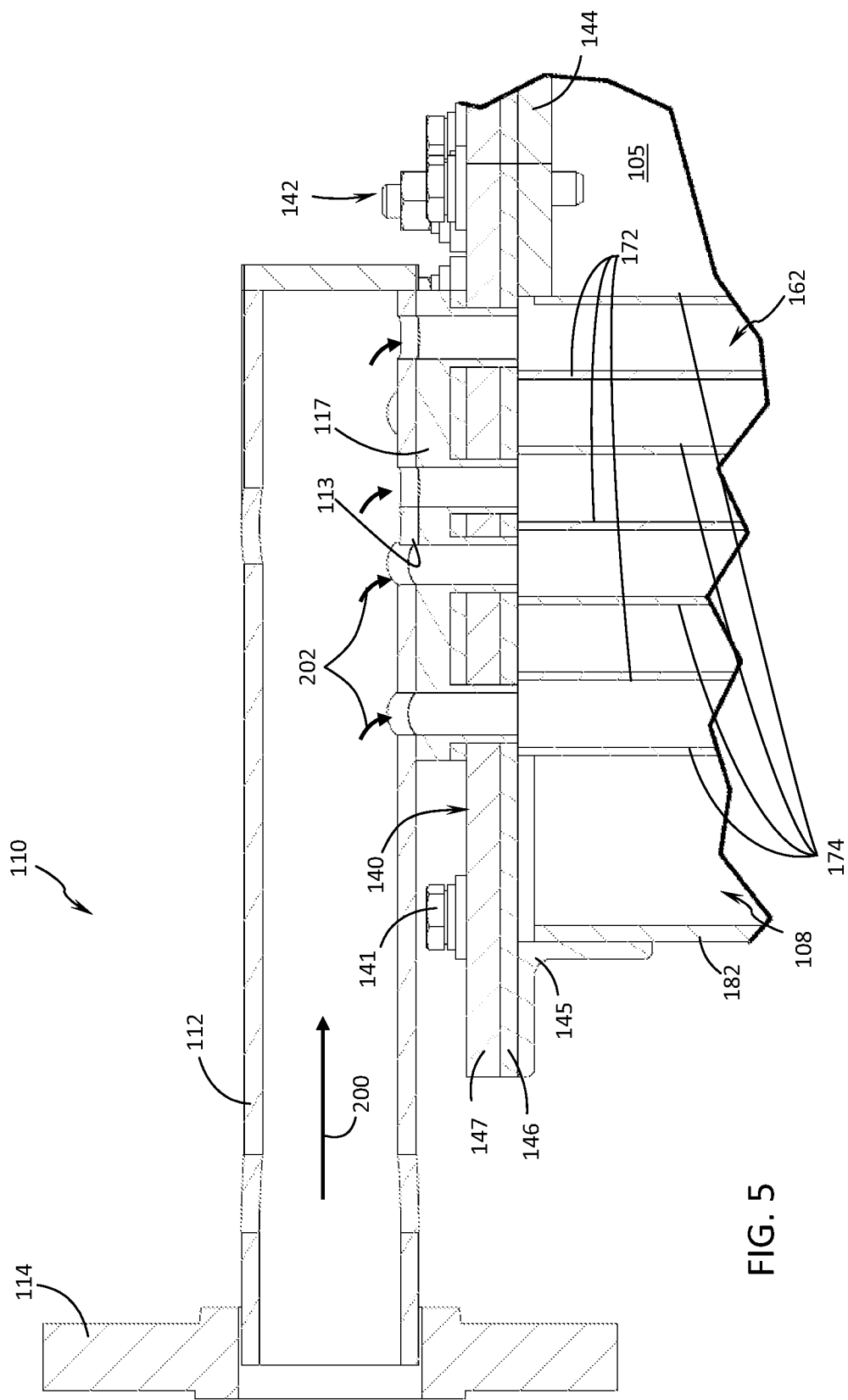


FIG. 5

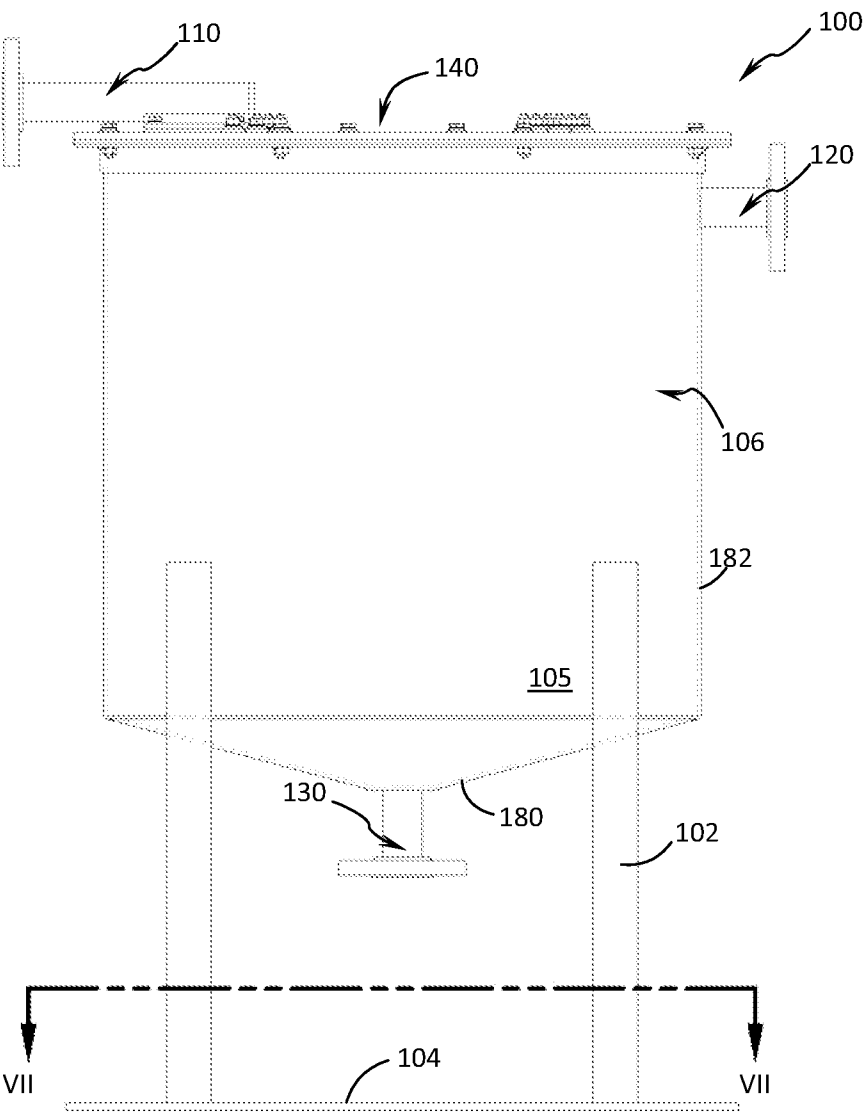
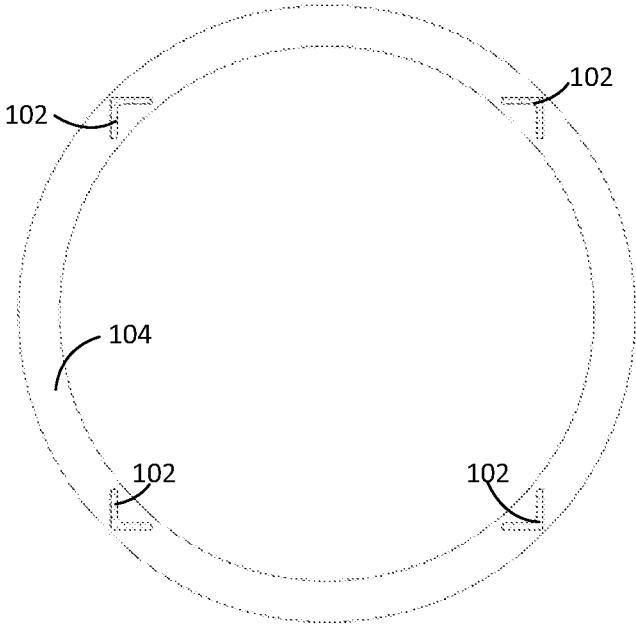


FIG. 7



[7/11]

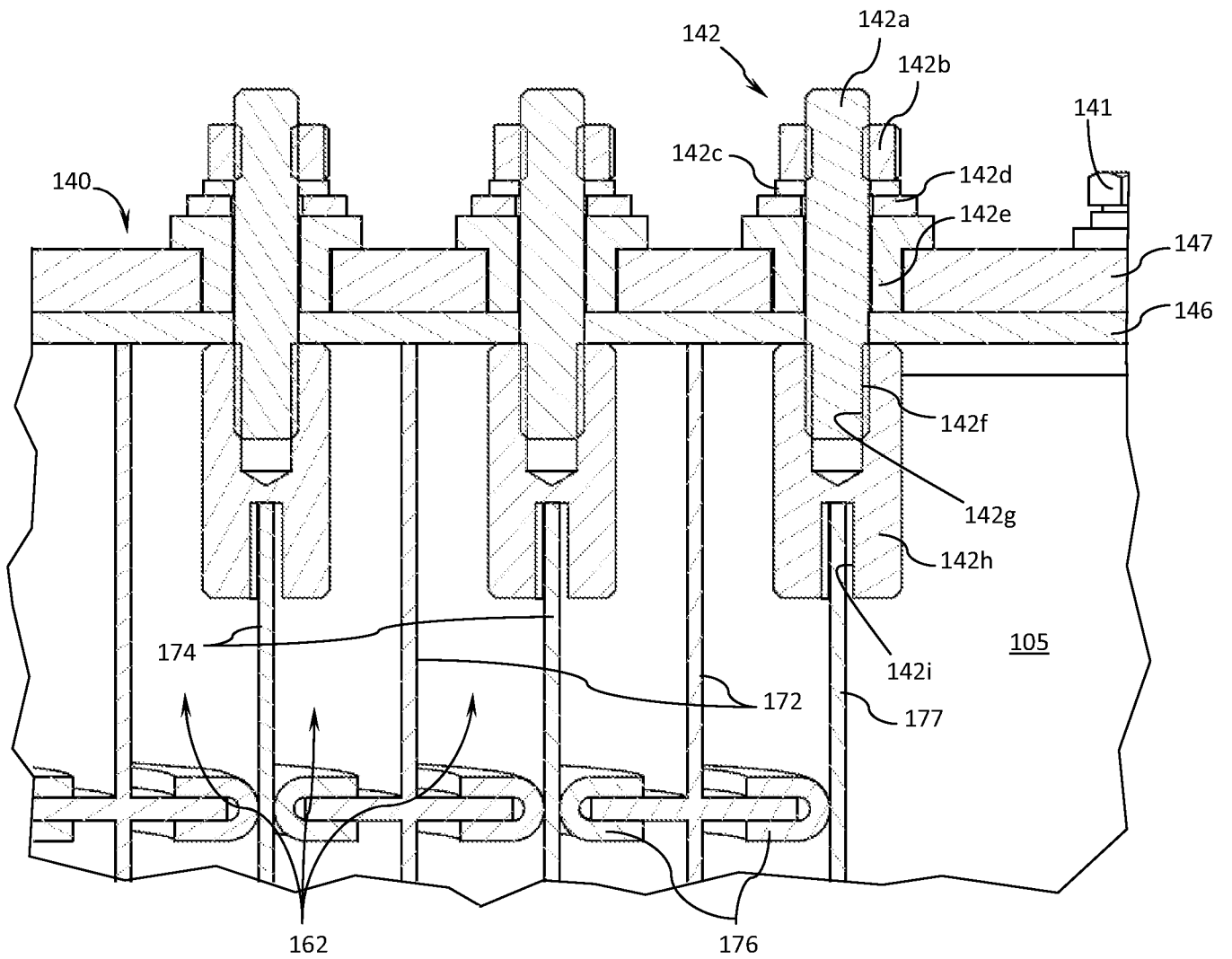


FIG. 8

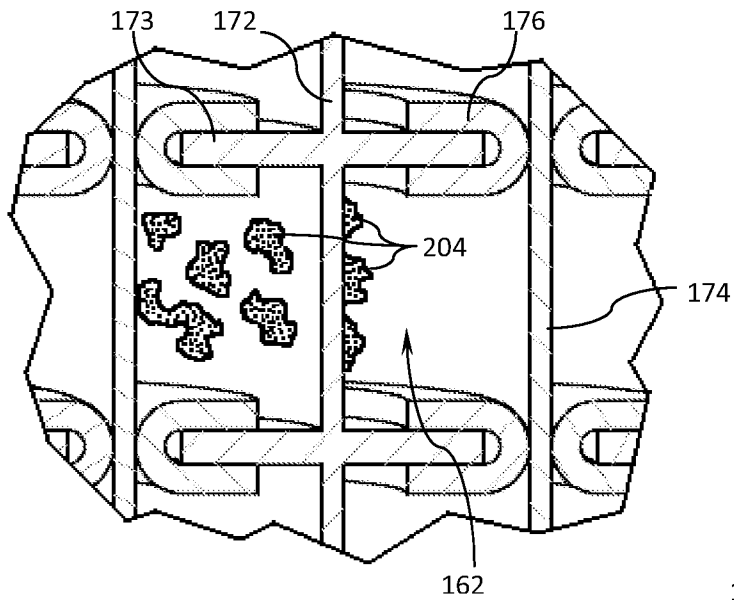


FIG. 9

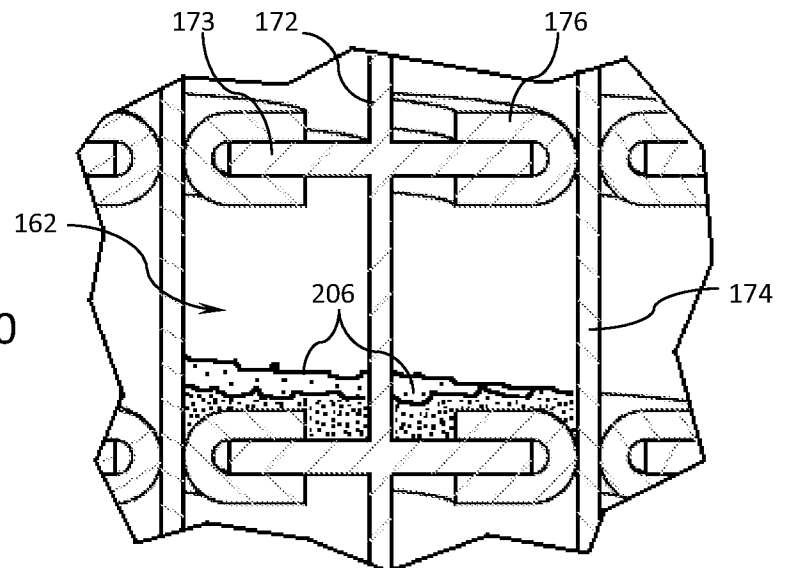


FIG. 10

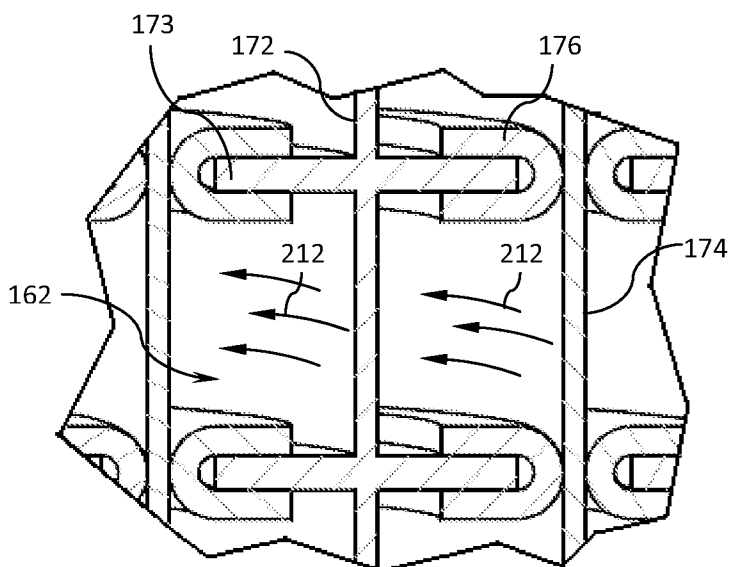


FIG. 11

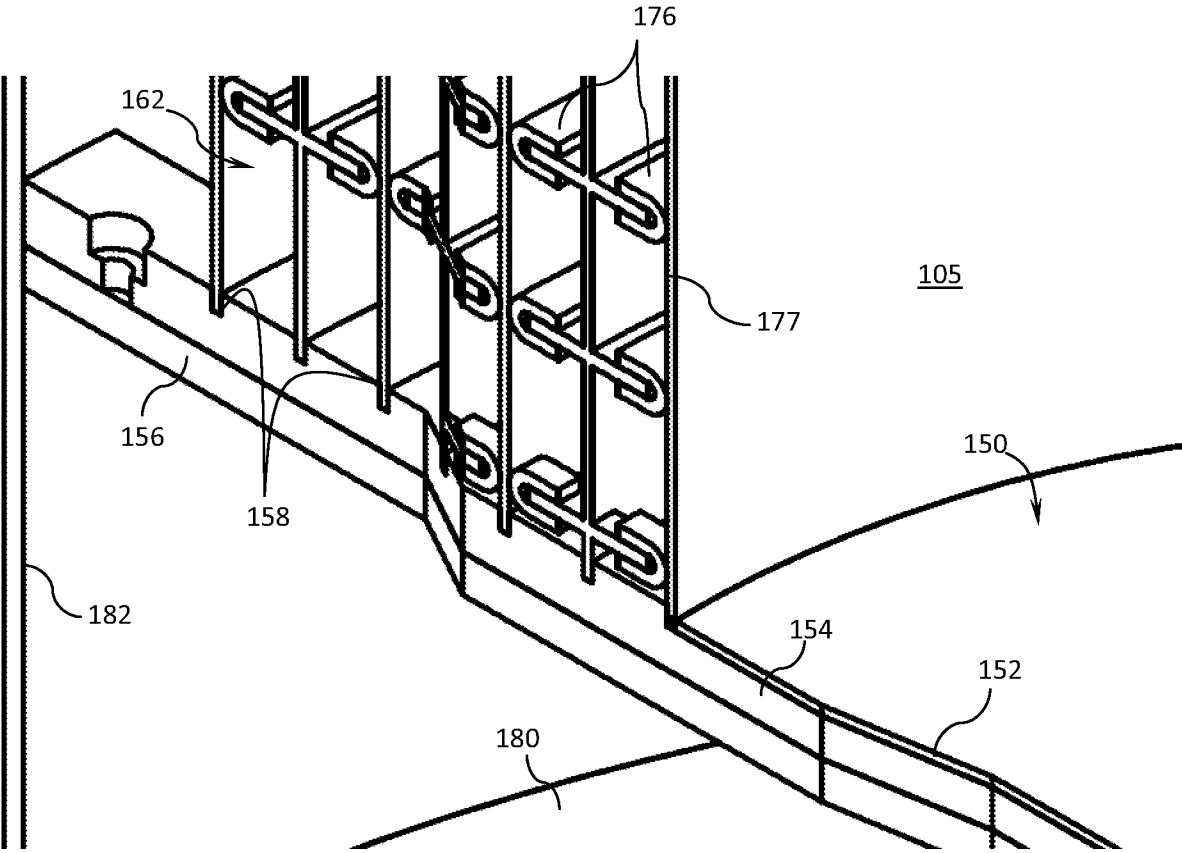
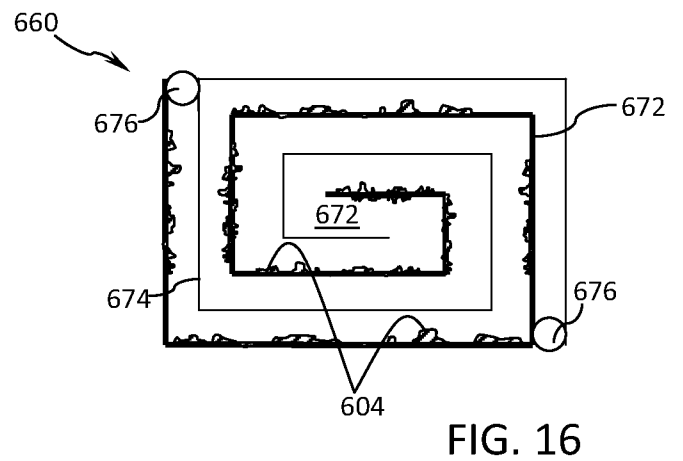
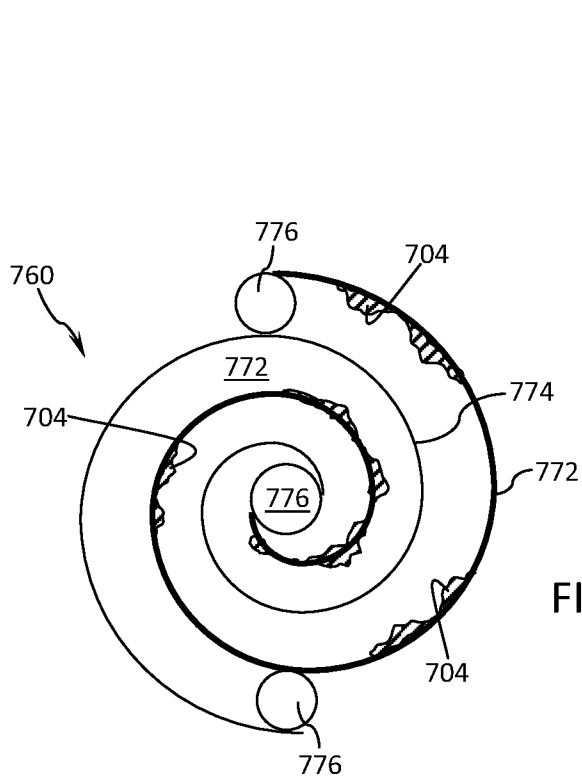
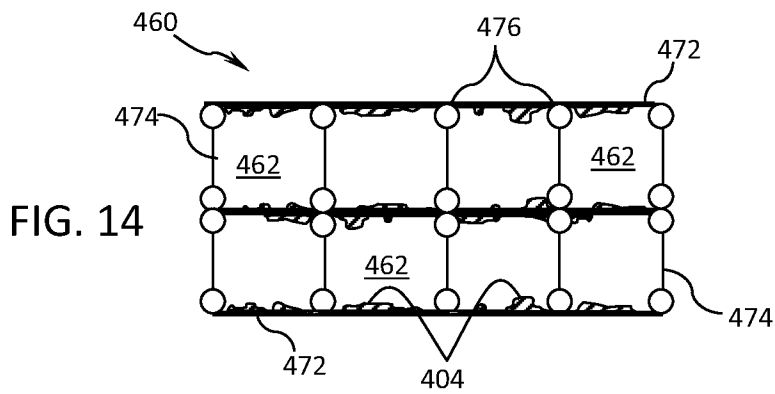
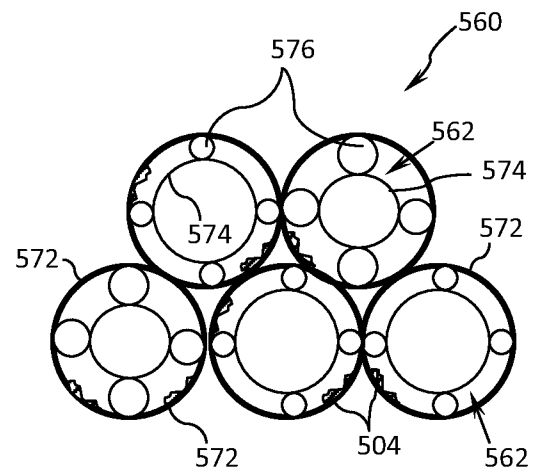
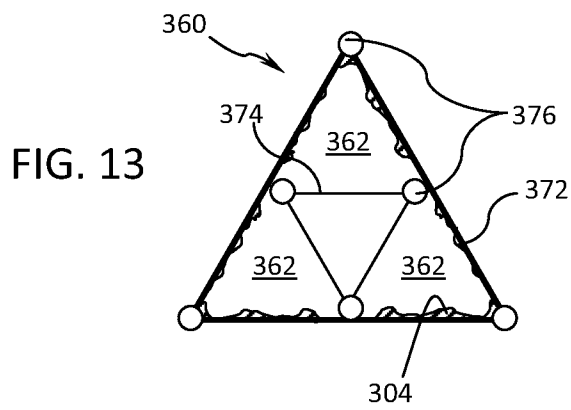
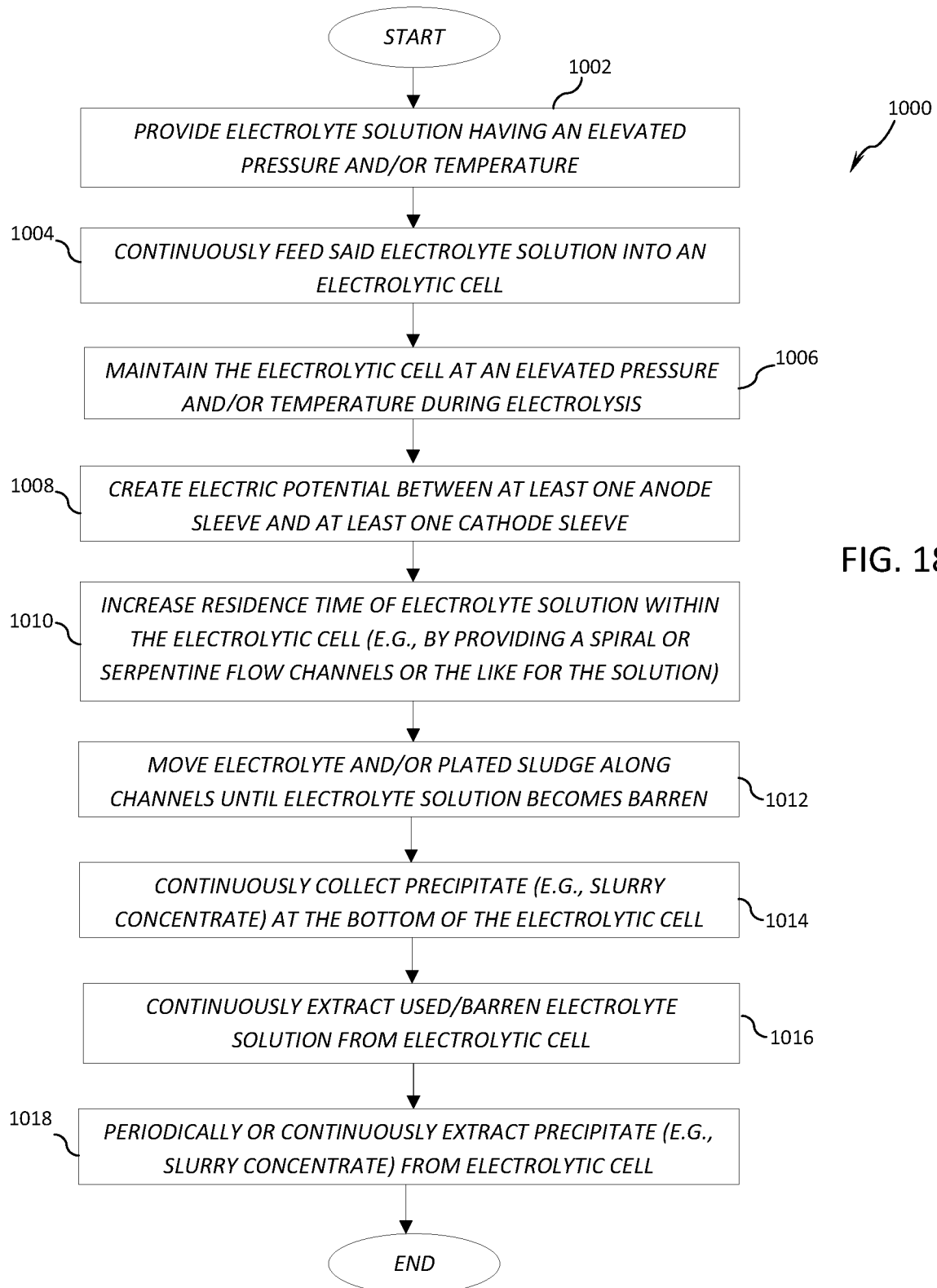


FIG. 12



[11/11]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 11/63762

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C25C 7/08, 7/00, 7/02 (2012.01)

USPC - 204/281; 204/216

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)

USPC: 204/281; 204/216

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

USPC: 205/74 (text search - see terms below)

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

PubWEST(USPT,PGPB,EPAB,JPAB); Google

Search Terms: electrowinning, channel, flow, helical, helix, spiral, circular, high, temperature, pressure, metal, sludge, precipitate, outlet, compartment

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,090,927 A (FRESNEL et al.) 23 May 1978 (23.05.1978), entire document especially Abstract; Fig 1; col 4, ln 65-col 5, ln 28; col 7, lns 8-26; col 8, ln 69- col 9, ln 7	1-18
Y	US 3,860,509 A (EMMETT, JR.) 14 January 1975 (14.01.1975), entire document especially col 1, lns 57-66; Col 87, lns 18-26	1-18
A	US 2,216,167 A (FISHER) 01 October 1940 (01.10.1940), entire document especially Figs 1-2; pg 2, col 2, lns 3-15	1-18

☐ Further documents are listed in the continuation of Box C.


* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

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"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search

04 April 2012 (04.04.2012)

Date of mailing of the international search report

20 APR 2012

Name and mailing address of the ISA/US

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