Title: REMOVAL OF METALS FROM SOLUTION

Abstract: An apparatus for removing metals from solution by electrowinning is described. It comprises a plurality of chambers in an endless annular array. Each chamber contains a plurality of submerged cells including a porous anode and cathode. A suction pump which draws solution from the chamber through the anode and then the cathode and discharges the solution back into the chamber. There are a valve controlled inlet to and a discharge from each chamber together with a valve controlled connector connecting the chambers to one another. The first chamber is filled with loaded solution and after treatment in the first chamber the solution is passed to the next chamber and so on around the annulus. By changing the valve settings the next chamber becomes the "first" chamber and this continued around the annulus. The metal adhering to the cathode is removed by flushing liquid or preferably by ultrasonic waves.
REMOVAL OF METALS FROM SOLUTION

Field of the Invention

This invention relates to the removal of metals from solution. In particular the invention relates to the method of removal of metals from solution by electrowinning. This process can be used for recovering noble or base metals from a solution formed as a result of treatment of an ore. The process can also be used for removing metal contaminants from waste solutions that are about to be discharged.

Background to the Invention

The electrowinning of metals is a well-known technique. An anode and a cathode are introduced into a solution and an electric current is applied thereto. The metal component of the solution will be drawn to the cathode and will adhere thereto. Initially the cathode was typically a plate but with developments more sophisticated cathodes have been proposed. Typical electrowinning plants are described as in International Patent WO 95/07375 (EA Technology Limited), South African Patent Specification No 98/11751 (Kemix Pty Ltd) and US Patents Nos 4,680,100 (Morin - American Cyanamid) and 6,017,4208 (Hill et al).

Where the electrowinning process is intended to remove (base) metal contaminants from a solution, the cathode is preferably a sacrificial member normally comprising porous carbon fibre material as is described in WO No 95/07375. The cathode can also be a sacrificial member especially where the electrowinning process is intended to remove noble metals from the solution. However in this case it is more usual for the cathode to be of the kind to which the metal would adhere, and from which the adherent metal is removed and which will be subsequently available for re-use. In this case, the cathode will be "permanent" and composed of a high surface area contacting material such as knitted stainless steel wool, titanium mesh, or reticulated nickel or nickel chrome alloy. In certain cases these materials may have a coating of iridium or other oxides or of chromium.
Statements of Invention

According to one aspect of the invention there is provided an electrowinning apparatus comprising a chamber for solution to be processed, an inlet to and an outlet from the chamber, a cell including an anode and a cathode, characterised in that a pump is provided connected to circulate solution from within the chamber through the cell and back into the chamber. According to another aspect of the invention there is provided an electrowinning apparatus comprising a chamber for solution to be processed, an inlet to and an outlet from the chamber, a cell including an anode and a porous vertical cylindrical cathode, and a pump connected to the interior of the cathode characterised in that the pump circulates solution from within the chamber through the cathode and back into the chamber.

The interior of the cathode is preferably connected, conveniently at its lower end, to the suction inlet of the pump which is preferably a suction pump. The upper end of the cathode is conveniently closed off to ensure that the solution will always pass through the cathode.

Although the anode may be provided within the cathode, preferably the anode surrounds the cathode. The anode is conveniently porous so that solution may pass through the anode to engage the cathode. In certain circumstances however, such as where the apparatus is intended to remove platinum from solution, a barrier member may be provided between the anode and the cathode dividing the cell into an anode chamber and a cathode chamber, the arrangement being such that in use the solution is circulated through the cathode chamber while an inert conducting liquid is passed through the anode chamber.

An internal pipe may be located within the cathode. This internal pipe may have electrical connections so that it will, in use, act as the anode or as an additional anode. Further or alternatively the pipe may be perforated and have hydraulic connections whereby it may be connected to a source of high pressure water which may pass therethrough to flush metal adhering to the cathode off the cathode.

A plurality of flushing pipes may be provided, preferably located outside the cathode and having hydraulic connections whereby they may be connected to a source of high pressure water which in use may pass therethrough to flush metal adhering to the cathode off the cathode.
Means may be provided for rotating the cathode during removal of the metal from the cathode and/or during electrodeposition. In addition there may be means for moving the cathode axially during flushing to improve the possibility of all the cathode being impinged by the flushing water.

According to a preferred option of the invention there may be provided ultra sonic means arranged to emit ultra sonic waves which in use will dislodge metal adhering to the cathode off the cathode. One or more ultra sonic means preferably are provided adjacent to the cathode. Alternatively the ultra-sonic means may comprise a transducer attached to a wall or the base of the chamber.

According to another feature of the invention the cathode or indeed the cathode assembly may be removably mounted in the cell.

The base of the cathode assembly conveniently rests on the lower mounting means closing a valve seat leading to a discharge pipe for metal dislodged from the cathode and means are provided for lifting the cathode assembly relative to the main cell arrangement so that the base will be spaced from the seat to enable solid matter in the cell about the cathode to pass between the base and seat into the pipe means. The base is preferably of frusto-conical shape as is the seat to facilitate the passage of the metal between the base and seat into the discharge pipe.

The discharge pipe which preferably is a continuation of the interior of the cathode preferably leads to collection means in which any metal falling off the cathode is collected. A sieve is desirably provided in the pipe means preventing any metal falling off the cathode travelling in the solution to the pump.

A surrounding sieve is preferably provided surrounding the cell. This surrounding sieve in use would prevent matter entrained in this solution from entering the cell and dislodged metal within it from entering the surrounding solution.

The pump may be a submersible pump that is contained within the chamber. Alternatively the pump may be located outside of and preferably below the chamber.
There are conveniently a plurality of cells in each chamber which are all connected to the pump suction inlet.

The chamber has first and second end walls and preferably a separating wall adjacent to the first end wall dividing the chamber into (a) a main chamber portion containing the cell/s and being closed by the second end wall and (b) an inlet portion which connects to the main chamber portion through an opening at the lower end of the separating wall and in that the chamber has an inlet to the upper part of the inlet portion and an outlet from the upper part of the main chamber portion. The electrowinning apparatus preferably comprises a number of chambers arranged in array with the second end wall of one of the chambers constituting the first end wall of the adjacent chamber and wherein flow connection means in the said second wall is arranged to permit solution in the said one chamber to pass thereover into to inlet chamber of the said adjacent chamber. The flow connection means may comprise an opening or weir provided in the second end wall preferably at or near the upper end thereof and a control valve is preferably provided for controlling the flow of solution through the opening.

The chambers are preferably arranged in an endless, preferably annular array of preferably six chambers having connections as mentioned in the preceding paragraph. This will permit the apparatus to operate automatically as a carousel. This can be effected by withdrawing the cathodes periodically and moving them to adjacent chambers and discharging the cells at appropriate times, normally when the loaded cathode is in a chamber containing demuded or substantially demuded solution. Preferably however each chamber has a solution inlet and discharge pipes all of which are connected respectively to inlet and discharge headers with suitable valve means therein, the control valves for the flow control means being arranged so that solution can be delivered to one chamber, passed by over the second wall to a second chamber from it to one or more other chambers and finally discharging through a discharge pipe of a chamber remote from the said one chamber and thereafter the valve settings can be altered to move the pattern of solution movement around the array. This lends itself to automatic control of the valves so that the apparatus can operate automatically. In addition to the advantages of automatic operation, this will inhibit or prevent theft of the laden solution and or the metal recovered therefrom. There is preferably also provided a common launder into which the collection means for all the cells discharge.
According to yet another aspect of the invention there is provided a method of electrowinning metal from a metal containing solution, the method utilising a chamber containing the solution and within which is a cell including an anode and a cathode and characterised by circulating the solution from within the chamber, through the cell and discharging the solution back into the chamber.

Preferably the pump draws the solution through the cathode under suction.

In a convenient embodiment of the method of the invention, there are provided a plurality of chambers connected together by flow connectors there being inlet port means to one of the chambers and outlet port means at an other of the chambers the method being characterised in that the solution is conveyed from the said one chamber to the said other chamber by the flow connectors in one direction only. In one arrangement, the cathodes of the cells may be moved periodically so that the less heavily loaded cathodes are moved to the chambers into which the richer solution is fed and vice versa. In a preferred arrangement, the chambers are arranged in an endless, preferably annular, array, control valves are provided in the flow connectors, each chamber has an inlet port means through which solution can be introduced thereto and outlet port means through which solution may be discharged, the method being characterised in that after a period during which the inlet means to the said one chamber is opened and the outlet port means of the said other chamber is opened and the control valves are so arranged as to permit flow from said one chamber to said other chamber in one direction only, the inlet means to the said one chamber and the outlet means from the said other chamber are closed and thereafter the inlet means to a first adjacent chamber which is adjacent to the said one chamber direction is opened and the outlet port means in a second adjacent chamber which is correspondingly adjacent to the said other chamber is opened and the connector valves being arranged so arranged as to permit flow from said first adjacent chamber to said second adjacent in one direction only and this process is continued moving continuously around the endless array. The various valves are preferably connected to a suitable control means and the operation of the apparatus takes place automatically.

The cells are preferably connected to a collector into which metal adhering to the cathodes can be discharged when removed from the cathodes, the metal being so discharged at appropriate times. The metal is conveniently discharged when the cathode is optimally loaded,
as can in practice be determined, as opposed to fully loaded. The discharge from the cathodes in a chamber preferably takes place when the solution in that chamber is denuded or substantially denuded of metal. If desired however the loaded cathodes when loaded may be removed from the chambers for further processing which may be recovering the metal adhering thereon or incineration of such metal usually with the cathode.

Preferably, ultrasonic means may be provided and the method comprises using ultrasonic waves to cause metal that adheres to the cathode to become free of the cathode.

Embodiments of this invention will now be described by way of example with reference to the accompanying drawings.

Short description of drawings

In the drawings:-
Figure 1 is a plan view of an electrowinning tank of the invention;
Figure 2 is an enlarged longitudinal section through the electrowinning cell of the invention;
Figure 3 is a transverse section through the electrowinning cell, the section being taken on line 3 - 3 of Figure 2;
Figure 4 is an enlarged detail of the upper portion of Figure 2 which is circled for clarity;
Figure 5 is a detail perspective view of a divider wall in the electrowinning cell;
Figure 6 is a side view of the tank showing feed and collection lines;
Figure 7 is a detail plan of a chamber of a modified tank of the invention (the second preferred embodiment);
Figure 8 is a section on line 8 - 8 of Figure 7;
Figure 9 is a longitudinal section through another tank of the invention (the fifth embodiment);
Figure 10 is a detail of a single chamber tank (the sixth embodiment);
Figure 11 is a view of an arrangement for electrowinning platinum from a platinic chloride solution (the seventh embodiment);
Figure 12 is an enlarged detail of the cell used in the arrangement of Figure 11,
Figure 13 is a view similar to Figure 1 of a further modified arrangement of the invention (the third preferred embodiment),
Figures 14 and 15 are detail perspective views of the outlet and inlet compartments of a chamber of the arrangement of Figure 13, and
Figure 16 is the plan of yet another arrangement of the invention (the eighth embodiment).

**Description of a first preferred embodiment**

Referring now to Figures 1 - 6 there is shown an electrowinning tank 100 supported off the ground by a robust welded steel formation (not shown). The tank 100 comprises inner and outer cylindrical walls 100a and 100b between which six chambers 102 are arranged in endless annular formation. The chambers 102 are separated from one another by radial separator wall arrangements 104. Within each chamber there is provided a pair of electrowinning cells 106 and a pump 108. There is an inlet pipe leading to each chamber and an outlet pipe leading therefrom as will be described below. In use the pumps 108 and cells 106 are submerged in the solution in the tank.

**The electrowinning cells**

Each cell 106 comprises a main section consisting of an insulating annular top cover 112 and an insulating cylindrical bottom member 114 between which is a cathode assembly 116.

The cathode assembly 116 comprises an insulating cylindrical top member 118, an insulating base 120 and a high surface area vertically disposed cylindrical cathode 122. The cathode 122 is wound on to an electrically conducting open mesh cathode support cylinder 124 in such a way that solution can be drawn through the cathode 122 i.e. the cathode is porous. This support cylinder 124 is mounted between the top member 118 and base 120. The cathode 122 is held in position on the cylinder 124 by means of surrounding plastic cable ties 126 at various positions along the length of the cathode 122. The lower end of the cylinder 124 is provided at its lower end with a machined electrically conductive connecting ring 128. The ring 128 fits tightly into a groove in the base 120 to provide a firm connection to the base 120 and also to provide good centring. The upper end of the support cylinder 124 is secured as is described below.

The top member 118 is slideably mounted within the central opening 130 of the annular top cover 112. The base 120 has a frusto conical lower portion 132 of Teflon® which seats on a correspondingly shaped seat 134 formed in the bottom member 114. At the smaller end of
the base 120 is a low annular rim 136 which can slide within the lower bore 138 of the bottom member 114. The cathode assembly 116 is capable of rotating and moving upwardly and downwardly relative to the top cover 112 and the bottom member 114 as will be described below.

A robust cylindrical outer anode 140 coaxially surrounds the cathode 122 and provides structural strength for the cell 106. It is carried between the top cover 112 and the bottom member 114 and is secured by two sets of four threaded rods 142 and 144 passing respectively through the top cover 112 and bottom member 114. The upper end of one of the rods 142 is connected by means of an insulated electrical cable indicated at 146 to the positive terminal of an D.C. power supply. The anode comprises expanded metal mesh forming a pattern of openings 148 in the anode 140 (see Figure 3) which make the anode porous and through which solution may pass radially through the cell 106 as will be described.

An electrically conductive inner tube 150 is coaxially located within the cathode 122. The lower end 152 of the inner tube 150 is carried by three radial support rods 154 that engage the bottom member 114. This inner tube 150 serves as an internal anode and a spray tube as will be described below.

An electrically conductive connector tube 156 extends beside the cell 106 from the upper end of the cell and is supported near its upper end by a bracket 157. At its lower end, the connector tube 156 passes through the bottom member 114 and leads to the lower end 152 of the inner tube 150.

The exposed surfaces of the electrically conductive members are insulated from the solution 160. The connector tube 156 is covered by insulating shrink fit tubing 156a. The ends of the rods 142 and 144 are insulated by a silicone sealant or adhesive indicated at 143.

The upper end of the connector tube 156 is connected to a source of high pressure water, there being a valve 158 which controls water flow to the inner tube 150. The connector tube 156 is also connected at 161 to the positive terminal of a source of high D.C. current.
Four equi-spaced axially extending outer flushing tubes 162 extend between the top cover 112 and bottom member 114, being located in the annular space 163 between the anode 140 and the cathode 122 (as best shown in Figure 3). An internal annular header conduit 164 which is formed in the top cover 112 is connected to the top ends of the flushing tubes 162. A connection 166 to a source of high pressure water controlled by a valve 168 leads to the header 164.

The flushing tubes 162 and the inner tube 150 have ports 162a and 150a therein. These ports 162a and 150a are so arranged so that when flushing liquid is supplied to them, high pressure jets of water are directed through the ports 162a and 150a against the cathode 122 for the purpose which will be described.

An electrically conducting cathode connecting shaft 170 is provided. The lower end 172 of the shaft 170 is turned down to a smaller diameter, there being a radial shoulder 171 (best shown in Figure 4) where the shaft 170 is turned down. This end 172 is externally screw threaded. It passes freely through a central bore 174 in the top member 118. The lower end 172 is threaded into a threaded central opening in an electrically conductive cathode connecting disc 178. The disc 178 is in turn welded to the upper end of the cathode support cylinder 124 and hence is electrically connected to the cathode 122. The lower end 172 of the shaft 170 also threadedly engages in a central blind bore 180 in an insulating Teflon® shield 182, the outside of which is slideable within the cathode support cylinder 124. The shield 182 has a central conical centring device 184 on its underside. The centring device 184 is received within a conical recess 186 in a cylindrical closure 188 for the inner tube 150.

In the under surface of the shield 182 are a pair of blind bores 190. These bores 190 can be engaged by noses on a key device (not shown) used to tighten the shield on to the shaft 170. The key is longer than the axial length of the cathode 122. It is inserted into the cathode when the cathode assembly has been removed from the cell until the noses engage the bores 190. On rotation of the key device, the shield 182 is rotated on the threaded end 172 of the shaft 170 to be removed therefrom. The cathode 122 and the support 124 can now be removed from the top member 118 for use as then appropriate.
The upper end 192 of the connecting shaft 170 is also of reduced diameter. A moving device (shown diagrammatically at 194) is connected to the upper end 192. This device 194 is capable of rotating the connecting shaft 170 and also moving this member axially through a short distance of, say, 10 mm. The main body of the shaft 172, which is exposed to the solution 160 in the chamber 102 is covered by insulating shrink fit tubing (not shown). A rotary and axially sliding electrical connector indicated at 198 is provided at the upper end 192 above the body of the connector shaft 170. This connector 198 is connected to the negative terminal of a D.C. power supply.

It will be noted that the cathode assembly 116 seats on the bottom member 114 under gravity.

The suction and discharge connections from the cell

Fitted into the lower end of the bore 138 is a discharge pipe 200 (see Figure 2). The lower end 202 of the pipe is conical. It fits into a discharge cone 204 passing through and being secured to the base 206 of this cell chamber 102. Below the base 206 the discharge cone 204 is connected through a valve 208 (see Figure 6) to a collector pipe 210 as will be described below. Four internal brackets 212 support each discharge cone 204.

A suction arm 214 is teed upwardly off the pipe 200 above its conical end 202. The suction arm 214 has a flanged connector 216 to a flexible in-tank suction pipe 218 leading to the pump connector manifold 250 (see Figure 1) that connects to the pump 108. A polypropylene sieve 222 is provided between the flanges of the connector 216.

The filter sleeve

A surrounding polypropylene filter sleeve 224 is wound about the cell 106. It is connected at its upper and lower portions to the top cover 112 and bottom member 114 which fit into these ends and to which it is secured by means of plastic cable ties 226. This sleeve 224 serves two main purposes. First, it prevents any suspended matter that may be present in the incoming solution from passing into the cell. Second, it prevents the metal particles that have
been dislodged from the cathode (as will be described later) from being returned to the body of the solution 160 in the tank.

The separator wall arrangements

The separator wall arrangements 104 each comprise an end wall 428 and a separating wall 4130 adjacent thereto (see Figure 5). The separator wall 430 divides the chambers 102 each into a main chamber portion 432 containing the cells 106 and pump 108 and a much smaller inlet portion 434. The inlet portion 434 is connected to the main chamber portion 432 through an underflow passage 436 at the bottom end of the second separating wall 430.

Each end wall 428 has a flow connector connecting the adjacent chambers. The flow connector is formed by a rectangular weir opening 438 at its upper edge 440. The flow connector has a control valve in the form of a Teflon™ plate or gate 442 which is slideable in a housing 244 between (a) a lower position in which it shuts off the weir opening 438 and (b) an upper position spaced from the weir 438 to permit solution to pass through the weir opening 438.

When the gate 442 is open the solution overflows from the main chamber portion 432 of an adjacent chamber 102 through the weir opening 438 into the inlet portion 434 and then through the underflow passage 436 into the main chamber portion 432 of the next chamber 102. The movement of the plate 442 is controlled by a lifting mechanism (not shown).

The inlet pipe 238 also opens into the upper end of the inner chamber portion 434.

It will be seen therefore that solution delivered to the upper part of the inner chamber portion 434 thus follows a serpentine path in moving to the main chamber portion 432. It also follows a similar serpentine path in moving to the next chamber.

Ultra sonic transducers

On either side of each cell 106 are opposing banks of ultrasonic transducers 235 (see Figures 2 and 3) equispaced from the cathode 122. These transducers 235 are arranged to emit ultra sonic waves which cause the adhesion between the electro-deposited material and the surface
of the cathode 122 to decrease, so that metal deposited thereon will shake free and fall off the cathode.

Other arrangements of ultrasonic transducers may be provided. For example only a single transducer module may be provided for each chamber. Further the ultrasonic transducer module/s may be mounted either inside or outside the chamber e.g. on the inner or outer curved walls or on the base of the chamber. In Figure 6, the transducers 235a are shown mounted on the inner curved wall 100a of each chamber.

All these transducer modules may be connected to a single power supply unit and the transducers for each chamber can be selectively actuated.

**Solution flow**

The flow of solution to the electrowinning tank 100 will now be described with reference to Figure 6. As shown herein an inlet pipe 234 leads to an annular header pipe 236. Six inlet pipes 238 lead from the header pipe 236 to the upper parts of the inlet1 chamber portions 234 of the six chambers 102 respectively. Valves 240 respectively control flow through the inlet pipes 238.

A discharge header 242 is provided below the tank 100. Six outlet pipes 244 open at the level of the solution 160 and somewhat above the lower level of the weir opening 438 of each chamber 102. These outlet pipes 244 lead into the discharge header 242 for discharging spent solution. Valves 246 control the outlet pipes 244.

The collector pipes 210 lead to a closed launder 248 which conveys matter discharged through the lower end of the pipe 200 for further treatment.

The flexible suction pipe 218 is connected into a manifold 250 which leads to the suction inlet of the pump 108.
The pump

The pump 108 is a submersible suction pump having an adjustable flow rate. It has a very high flow capacity relative to the power of the motor 252 which drives it (see Figure 10). The pump 108 has a throttle valve 256 for controlling the flow and a submerged outlet pipe 254 discharging into the chamber 102 which consequently causes agitation in the chamber. The second cell in the chamber 102 is also connected to this pump 108 as shown in Figure 1.

Electronic control means

All the valves 158, 168, 208, 240 and 246 as well as the lifting and rotating motor 194 and the means for lifting the weir gates 442 are connected to automatic control means which controls the operation of the apparatus. Similarly the various electrical connections are connected to this automatic control means. These include provision for controlling the amplitude of the current from the rectifiers to the cells and also for reversing the current to the electrodes when surface passivation of the cathodes is required (as will be described below). To this end, metal concentration sensors may be provided in each chamber and the amplitude of the current to that chamber may be varied in accordance with the metal concentration in that chamber. Thus there will be savings of electrical energy.

The control means also includes provision for controlled automatic switching of power to the ultrasonic modules 235 of each chamber 102.

Method of Operation of Apparatus

The operation of the apparatus 100 will now be described.

In the description which follows each chamber and its parts are indicated by the suffix .1 to .6 respectively.

The tank is filled with water. The weir gates 442 in all the separating wall arrangements are opened except for that in the wall between the first chamber 102.1 and the last chamber 102.6 (i.e. the chamber adjacent thereto having the wall 428.6 as its end wall). The outlet valves 246
(except for valve 246.6) are all closed as are all the inlet valves 240 except for inlet valve 240.1. Electronic power is now supplied to the anodes 140 and 150 and cathodes 122 of all the cells 106 and also to all the pumps 108. The solution is fed into the header pipe 236 and then delivered into the inlet chamber 234.1 of the first chamber 102.1 from whence it passes through the opening 236 into the main chamber portion 432.1. The solution displaces the water in the main chamber portion 432.1 which passes over the weir into the second chamber 102.2. The filling of the chambers with solution is repeated for all chambers. The excess liquid, which is initially water but subsequently treated solution escapes through the outlet pipe 244.6.

It will be seen that the solution moves in a serpentine or labyrinthine fashion passing through all the chambers. When the solution reaches the appropriate height in the chamber 102.6 it overflows the inlet to the outlet standpipe 244.6. At this stage the solution has been stripped or substantially stripped of its metal content. The solution may be passed to waste or if desired recycled.

The pumps 108 draw the solution 160 into the associated cells 106 through the porous filter sleeves 224 and then through the openings 148 in the anodes 140, it being noted that the top member 118 prevents or inhibits the solution being drawn through the upper end of the cathode. The solution is then drawn radially through the cathodes 122. The solution is discharged back into the chamber 102. It will be seen that there will be movement of solution through the cells which is not dependent upon the movement, if any, of solution into and out of the chamber. This movement of solution through the cells is maintained at a high velocity so as to increase the kinetics of electrodeposition.

During this operation, the metal in the solution is now deposited on to the cathodes 122 of the cells 106.

It will be appreciated that the solution in the "first" chamber 102.1 will (after the solution is flowing through the arrangement) be richer in metal than the subsequent chambers which contain sequentially more dilute solutions. Therefore the cathode of the cells in the first chamber will become more heavily loaded than the subsequent cathodes. The metal is recovered from the cathode assembly as will be described below.
After an appropriate time the operation of the system is altered. The valves 240.1 and 246.6 are closed and the inlet valve 240.6 and outlet valve 246.5 are opened. The gate 442.5 is closed and the gate 442.6 is opened. The operating process continues. Now the richly loaded solution will be delivered to the chamber 102.6 and after passing through the chambers 102.1 to 102.4 the diluted solution is discharged from the chamber 102.5. The procedure is repeated with the first operative chamber rotating about the annulus in a direction opposite to the direction of solution flow.

In due time the cells 106.1 will be optimally loaded (this may take place during the period when the chamber is first supplied with the richest solution or may be after one or more circuits or parts of circuits have been completed). The metal is then removed from the cells 106.1 as will be described. Similarly the further cells will become optimally loaded and the metal removed from them from time to time sequentially so that there is a continuous lodging of metal on the cathodes and the dislodgement of the metal therefrom.

**Metal Recovery**

The metal is recovered from the cells 106 of a chamber 102 as follows:- The electric power to the pump 108, the cathode assembly 116 and the anodes 140 and 150 is disconnected. The ultrasonic transducer 235 is activated so that the cathode 122 is subjected to the ultrasonic waves and this serves to dislodge the metal from the cathode 122. The valves 158, 168 and 208 are opened. Flushing water is discharged in jets from the central tube 150 and from the flushing tubes 162. These jets strike the cathode 122 also to dislodge the metal therefrom. During this time the cathode assembly 116 will be rotated and oscillated vertically to ensure that all of the parts of the cathode 122 are impinged upon by the flushing liquid.

Some of the dislodged metal powder or sludge travels into the annular space 163 between the cathode 122 and the anode 140. The cathode assembly 116 is lifted and maintained in a raised position of approximately 10 mm by the moving device 194. Thus the base 120 will be spaced from the seat 134. The metal powder or sludge will fall from the annular space 163 through the passage between the base 120 and the seat 134 into the pipe 200 where it meets the metal powder or sludge that fell into the passage way 252 between the support cylinder 124 and
central anode 150. The metal falls into the connector pipe 200 through the valve 208 which has been opened and thence into the launder 248 wherefrom it is directed for further treatment.

The discharge operation for a particular chamber 102 would desirably be timed to take place when the concentration of metal in solution in that chamber is at a minimum.

The abovementioned valves are now closed and power is reconnected to the various parts. The cathode assembly 116 is allowed to fall back to its lower position in which the base 120 seats on the seat 134 in the bottom member 114. The electrowinning process is now continued.

It will be noted that the sieve 222 prevents or inhibits any dislodged metal or powder or sludge from being drawn into the pump 108.

The suction arrangement

It will be noted that because the solution is drawn through the cell by suction, the cathode assembly can easily be removed without unscrewing or other disconnection. The suction holds the cathode assembly firmly in its seating position. Furthermore the dislodged metal will be able to move in the same direction as the solution is drawn through the cell as is described herein.

In addition, for maintenance, the entire cell can easily be removed from the tank by simply pulling it out of the discharge cone.

Second preferred embodiment

Reference is now made to Figures 7 and 8 wherein is shown the chamber 262 of a modified electrowinning tank 260 of the invention. Once again the tank 260 comprises six chambers 262 arranged in annular endless format, is mounted on a steel stand and is generally similar to the first described embodiment except as is described below.
Within each chamber 262 there are eight cells 264 which (although shown in a simplified manner in Figure 8) are identical to cells 106. The outlets of metal sludge discharge pipes 266 from the cells 264 pass through the base 268 of the tank. Below each chamber 262 the metal sludge discharge pipes 266 lead to a central discharge hopper 270, there being eight inlet ports 272 to the hopper 270 to which the pipes 266 are respectively connected. A single discharge valve 274 is provided to connect the hopper 270 of each chamber 262 to the collection manifold (not shown). Off-take pipes 276 are teed off the pipes 266 below the tank 260. These off-take pipes 276 are connected through a flange arrangement 278 to the suction pipe 280 of a pump 282 located below the tank 260. The pump 282 discharges the solution through an apertured header pipe 284 within the chamber 262 below the cells 264. Sieves (not shown) are carried between the flanges 278 as in the first embodiment.

Each chamber 262 is provided with a fixed security cover or lid 285. There are access openings 287 for maintenance purposes. These are covered by smaller lids 288 which have openings 290 through which the cathode shafts 292 pass.

With this arrangement, the extra cells 264 provide a better use of the tank space and considerably greater processing ability. Furthermore a single pump 282 is provided for a large number of cells in each chamber 262 providing for more efficient circulation of solution. In addition by having the off-take pipes and pump below the tank, the space within the chamber can be more efficiently packed with cells.

The operation of this embodiment is entirely analogous to the operation of the first described embodiment.
Third preferred embodiment

Reference is now made to Figures 13, 14 and 15. The apparatus 450 herein shown is very similar to the arrangement as shown in Figures 7 and 8 save as described below. The apparatus 450 embodies a simpler wall arrangement 452 between the chambers 454. Each wall arrangement 452 comprises a plain radial wall 456 extending between the inner and outer cylindrical walls 458a and 458b. Near the outer cylindrical wall 458b a pair of inclined walls 460 and 462 extend outwardly from the wall 456. Each chamber 454 has a main chamber portion or operative space 464 defined by a pair of walls 456, the inner and outer cylindrical walls 458a and 458b and the inclined walls 460 and 462. This space 464 is generally hexagonal in plan.

Within the space 464 there are eight cells 466 in a generally circular array. (In the centre of the cells 466 there is a vertical ultrasonic transducer 468. The cells 466 are connected to a pump (not shown) provided below the apparatus in a similar manner to that of the preceding embodiment. The pump returns the solution to the chamber 454 via a vertical recirculation distributor pipe 470 near the outer wall 458b of the chamber 454.

The walls 460 and 462 together with the end of the wall 456 and the outer cylindrical wall 458b form two triangular compartments 472 and 474. The compartment 472 (partly formed by wall 460) is an inlet compartment into the upper part of which an inlet pipe 476 discharges (see Figure 15). The under edge of the wall 460 is castellated or notched to provide an underflow passage 476 so that solution will be delivered from the inlet compartment to the main chamber portion 464.

The compartment 474 is an outlet compartment. The wall 462 is slightly lower than the wall 456 and its upper edge is notched at 476 (see Figure 14) to serve as an overflow weir. A flow connector formed by a rectangular weir opening 478 having a valve 480 similar to that described above at the upper edge of the radial wall 456 connects the adjacent compartments 472 and 474. There is an outlet pipe 482 leading from the base of compartment 474.

The operation of this apparatus will be self-evident when considered in the light of the prior description. It will be noted too that when the outlet pipe 482 is opened (i.e. when the chamber is the "last" chamber through which the solution circulates) the compartment 474 will
quickly drain and the solution will merely cascade over the overflow weir to escape through the outlet pipe 482.

The single ultrasonic transducer 468 serves to cause the cathodes in all the cells to be effected by the ultrasonic waves to dislodge the metal adhering to them. Because of its central location this provides an very efficient use of the transducer. Indeed the ultrasonic waves will reflect off the walls to improve their operation.

It will be noted too that the walls 470 and 472 will provide structural support for the end of the radial wall 456 and the outer cylindrical wall 458b in the manner of gusset plates.

**Fourth preferred embodiment**

In this embodiment (which is not illustrated) the cell is substantially identical to the cell 106 save that the flushing tubes 162 are omitted and the inner anode pipe 150 may be a solid rod but in any case does not have flushing apertures. The means for rotating the cathode may also be omitted. The dislodgement of the metal from the cathode is effected solely by the ultrasonic means. Some small amount of flushing water may be provided to convey the metal or sludge to the discharge pipes, if flow of the barren solution inwards through the porous sleeve 224 is insufficient.

It will be noted that this arrangement has a number of significant advantages. First it will not be necessary to have a source of high pressure water. Second, the solution is not diluted during dislodgement of the metal as will occur when high pressure flushing water is used so that the problem of increased volume of solution does not occur. Third, the cell is less expensive than the first described embodiment. Fourth, rotation the cathode is not required.

**The cathode**

The embodiments above described can with advantage be used for the recovery of gold or other noble metal from eluate or leach solutions. For this purpose the cathode has a high surface area (HSA). It may be made of any suitable "permanent" material including knitted stainless steel wool, titanium gauze, reticulated stainless steel or titanium or reticulated nickel
chrome alloy. These materials may also be coated with various materials, e.g. chromium, iridium oxide and other oxides. Such coating may make the cathode longer wearing and may improve the release characteristics of the cathode.

Sacrificial materials such as carbon or graphite felt or reticulated vitreous carbon may also be used as discussed below. Thus the embodiments can also be used to recover metal contaminants which are often found in very low concentrations in waste solutions resulting from production processes. In such arrangements, the cathode 122 may comprise carbon felt or graphite felt which have a higher surface area than those described previously. It, the cathode 122, is in these circumstances fully loaded with metal before removal. The cathode cartridge may be removed from the cell manually, or robotically. By snipping the cable ties, the felt may be unrolled from the cathode holder and sent for smelting in toto. Again solution flow and current manipulation, as described for the first embodiment, may be applied.

Passivation of the cathode

The surface of a metal cathode is desirably passivated to ensure that the metal does not adhere too strongly thereto. This may be effected initially by filling the tank with a dilute sodium hydroxide solution (instead of water as described above) and reversing the polarity of the electrodes for a short period say one minute at a suitable current density.

Further passivation using current reversal may take place immediately after the metal has been dislodged from the cathodes in a particular chamber and removed therefrom and prior to the next loading cycle beginning. The electronic control means may be arranged to implement this automatically.

The anode

The anode is as described preferably an open mesh anode. It may comprise stainless steel, titanium, tantalum or similar material. It may be coated with a suitable coating such as iridium oxide or tantalum oxide, the coatings being optimised for the characteristics of the metal-containing solution. This will maximise the time between replacement and may well reduce electrical energy consumption.
A fifth embodiment

Reference is now made to Figure 9 which is a longitudinal section through a tank 300 comprising three consecutive chambers 302. In each chamber there are cells and a pump as described in the first described embodiment. Certain details are not shown in the interest of clarity. The tank 300 has an inlet 304 at one wall 306 at its upper portion and an outlet 308 at the other tank wall 310. Between the first and second chambers 302.1 and 302.2 and the second and third chambers 302.2 and 302.3 there are separator wall arrangements 312. Each wall arrangement comprises an end wall 314 and a separator wall 316 adjacent thereto. There is a separator wall 318 at the wall 306 of the tank 300 through which the inlet 304 enters and an end wall 320 at the third chamber 302.3 close to the wall 310 of the tank and from which the outlet 308 is drawn.

The height of the separator walls 316 is greater than that of the end walls 314. There is thus a flow connector over the end walls between adjacent compartments. The first chamber 302.1 extends between the wall 306 of the tank 300 and the end wall 314.1. The first chamber 302.1 is divided into an inlet chamber portion 318.1 and a main chamber portion 302.1 by the separator wall 318, the portions being connected by an under flow passage 322 at the bottom of the separator wall 318. The second and third chambers are similarly constructed. An outlet chamber portion 324 is formed between the end wall 320 of the third chambers 302.3 and the end wall 310 of the tank 300.

It will be seen that solution delivered to the inlet portion 318.1 by the inlet pipe 304 will move through the under flow passage 322.1 into the main chamber portion 302.1. The solution will then pass over the top edge of the end wall 322.1 into the inlet chamber portion 302.1 of the second chamber 302.2. The solution will continue its serpentine or labyrinthine flow until it is received in the outlet chamber portion 324 from which it exits through the outlet 308. From there it may be discharged to waste. Alternatively it may be recycled by a pump (not shown) into the first chamber for re-treatment. Each chamber 302 is fitted with a discharge cone 304, as for the first embodiment, and a flanged outlet 307. These may be closed off (if "sacrificial" cathodes are used) or connected via valves to a discharge launder as described in the first embodiment if "permanent" cathodes are used.
The tank 300 may be used for handling much smaller solution flow rates as compared to the first three embodiments. Flow manipulation as discussed previously is not possible, but the cathode cartridges in each chamber may be transported counter currently to adjacent chambers for greater efficiency, if desired. Thus fully loaded "sacrificial" cathodes would be removed from chamber 302.1 as new cathodes are placed into chamber 302.3.

**A sixth embodiment**

In a sixth embodiment shown in Figure 10, the tank 330 comprises a single chamber in which a pair of cells 332 (only one shown) is provided. Each cell 332 is of simplified construction. It comprises a support arm 334 connected to one wall 335 of the tank having a circular opening therein. The cell 332 further comprises a cylindrical unit consisting of a top member 336 and a base 338 fitted with a surrounding filter sleeve 339. An anode 340 extends between the top member 336 and the base 338. A cathode assembly 342 which may be generally similar to the cathode assembly 116 is carried on a top piece 344 which is slideably received in the top member 336. A handle/flushing tube/cathode connection 346 projects from the top piece 344 above the solution 348 whereby the cathode assembly 342 may be lifted out of the cell for further processing of the cathode, including incineration.

A collection pipe 350 extends from the interior of the cathode 342 leading to a collection device similar to that described with respect to the first embodiment. A suction arm 352 is teed upwardly off the pipe 350 leading to the flexible pump connector pipe 218 that connects to a manifold 250 leading to the inlet of a pump 108. The second cell connects to the other end of manifold 250. As in the first described embodiment, a polypropylene sieve (not shown) is provided between the pipe 350 and the pump connector pipe 218.

The tank has an inlet and an outlet (both not shown) for delivery and removal of the solution.

The operation of this arrangement is self evident after consideration of the previous description. In particular it will be noted that the solution will circulate through the cathodes irrespective of flow through the tank from inlet to outlet.
This arrangement could be used with advantage as a drag out tank in an electroplating system.

**A seventh embodiment**

A cell 360 for use in electrowinning platinum group metals is shown in Figures 11 and 12. It is substantially the same as the cell 106 except as described below.

The cell 360 is submerged in the metal containing solution. It is surrounded by an insulating cylinder 362 which is fitted with an inlet port 364 at its lower end and an outlet port 366 at its upper end. It is sealed at the top and bottom to the insulating annular top cover 368 of the cell 360 and to the insulated cylindrical base member 370, respectively, by means of "O"-rings 372. The cylindrical anode 374 is contained within the cylinder 362 and surrounds the cathode 363. A cylindrical ion exchange membrane such as "Nafion 450" (Du Pont Trademark) 376 is provided in the annular space 378 between the anode 374 and the cathode 363 so as to divide the cylinder into an anode chamber 380 and a cathode chamber 382.

A plurality of inlet holes 384 are formed in the cylindrical top member 386 of the cathode assembly opening into the top of the annular space 382 surrounding the cathode. These holes 384 are covered by an annular-shaped filter 388 which is clamped in position by means of a perforated plate 390, fixed to the top member 386 by means of cap screws 392.

A separate pump 393, reservoir 394, flow meter 395 and connecting pipes 396 are connected to the inlet port 364 and to the outlet port 366 of the anode chamber 380. This provides a separate circuit of an "inert" electrically conducting liquid which can be circulated through the anode chamber 380 during the electrowinning operation. This liquid is necessary to complete the conducting path between anode and cathode. A suitable example of such inert liquid is 1 molar sodium sulphate solution.

The metal containing solution is sucked by means of the suction pump 352 through the cell and passes through the cathode 363. This occurs in the same way as discussed previously, except that the metal-containing solution only passes through the cathode chamber, and not through the anode at all.
The presence of a cation exchange membrane prevents the passage of anions, for example, chloride ions in the case of a platinum solution, from reaching the anode, where they would be oxidised to chlorine. In the absence of a membrane this gas could in turn inhibit the reduction of metal ions at the cathode, causing a drop in efficiency.

It will appreciated too that more sophisticated materials of construction may be required in place of stainless steel for example, tantalum.

The inner tube 394 will now not function as an internal anode. It can, however, still serve as a flushing device and can act as a centring pivot if rotation is employed during electrowinning. As before, the Teflon® base 340 acts as a bearing for the cathode and can rotate on the cone seats 342.

In the present case rotation could become more important during electrowinning from a kinetic point of view, as it is no longer possible to suck the metal-containing solution in radially through the anode 374.

**An eighth embodiment**

In this embodiment (shown in Figure 16) there is shown a different form of endless array 490 of chambers 492 which may be more space saving than the annular arrays described above. In this arrangement, the chambers 492 are rectangular or square in plan and are arranged side by side in columns and rows.

**Advantages**

The arrangements described have a number of advantages to some of which allusion has been made above.

The gold or noble metal recovery system described with reference to Figures 1 to 8 and 13 to 16 lends itself to long term automatic use. The arrangement is a substantially completely "hands-free" gold electrowinning system that can be operated on a large scale for prolonged periods and with minimum maintenance. This implies, among other things, that the
cathodes need not normally be removed from the electrowinning cells, as is the case at present; rather the gold can be removed from them in situ. Furthermore, these cathodes must be “permanent” so as to be able to operate unattended for long periods during which time the gold is loaded on to them and then removed in a cyclical manner. As will have been seen the cells and cathodes do not have to be removed from the chambers to remove the gold from the cathode. Indeed all the gold and/or gold sludge is removed automatically and is conveyed by the launder to a treatment source. It is extremely difficult for there to be unauthorised access to the heavily loaded liquid conveyance. This advantage of good security is of great importance because, although not generally known, theft of gold in major gold mines, especially in South Africa, results in losses in revenue amounting to millions of Rands annually. A very substantial amount of such losses will be prevented by using the arrangements of automatic gold electrowinning described herein.

By removing the adhering gold by ultra sonic waves, rather than by flushing operations, the liquid in the chambers will not be diluted and the amount of liquid that will have to be treated will not be increased.

In the third embodiment the effective operative solution space 464, being hexagonal is of the most effective shape thereby minimising the ultrasonic power required.

Furthermore where the surface of the cathode is pre-treated by means of anodic passivation the gold or gold sludge may more easily be dislodged from the cathode.

By using suction to draw the solution through the cell, it is extremely easy to disconnect the cell from the pump in order to perform another action thereon such as maintenance. Furthermore if one requires to remove the cathode, this can be effected with a minimum of steps. In addition the cathode can seat on the base member by gravity, which simplifies the manufacture of the parts.

By circulating the solution through the cells independently of the solution flow through the chamber, the solution can pass through the cells for treatment an optimum number of times. Furthermore the kinetic energy of the solution engaging the cathode can be optimised for the most satisfactory deposition of the metal on the cathode. Thus the solution can be stripped most
efficiently of metal. The annular arrangement of chambers also ensures that the solution, which is ultimately discharged, may be wholly or substantially wholly stripped of metal. Similarly if the electro-winning apparatus is being used to remove metal contaminants from a solution that is to be released into atmosphere, the discharged liquid will be so treated that substantially all the contaminants e.g. down to about or below 1 p.p.m. are removed before the liquid can be discharged.

Because the cathode and cathode assembly can be removed from and replaced in the cells, the operation of the cells can be varied as desired, for example the cathode may be changed from a "permanent" cathode to a "sacrificial" cathode. This means that the tank can be used for different electrowinning processes e.g. the winning of desirable metals, such as noble metals, and then with a minimum of modification, i.e. changing the cathodes, can be used for removing metal contaminants from solution. Obviously different "permanent" or "sacrificial" cathodes may be used depending upon the metal being won from the solution.

The interchangeability of "permanent" and "sacrificial" cathodes provides greater versatility of application which can be further enhanced by the use of a divided cell.

By removing gold from the optimally loaded (as opposed to fully loaded) cathode not only is dislodgment easier but "gold lock-up" is minimized i.e. the time that the gold is in the apparatus is minimized.

By seating the cathode on a converging and preferably conical base and then lifting the cathode when the metal or metal sludge has been shaken loose, at least some of which is in the annular space about the cathode, this latter metal can easily escape therefrom into the discharge pipe for delivery to the launder. This discharge operation can take place without any interruption of the overall flow through the tank.

In passing it should be mentioned that the term launder" often means an open conduit. As used herein the term includes and in the embodiment the part to which the term is applied is a closed conduit.
Dimensions

In the embodiment of Figures 1 to 3 the electro-winning plant preferably comprises six chambers of 500 litres capacity each. It has an outer diameter of 2.4 metres and an inner diameter of 1 metre. Its depth is 1.2 metres and its weir and discharge pipe are arranged so that in use there will be a freeboard of 100 mm above the solution. The cell has an outside diameter of 150 mm and an axial height of 700 mm. The anode diameter is 120 mm. and its length 600 mm. The cathode outer diameter is 85 mm and inner diameter is 51 mm. The current provided would be 45 Amps applied in parallel to both cells in each chamber. The solution flow through the apparatus is 1 500 (fifteen hundred) litres per hour and up to 10 000 litres (ten kilolitres) per hour through each cell. The solution has a residence time in the tank of two hours.

Caveats and modifications

The invention is not limited to the precise constructional details hereinbefore described and illustrated in the drawings. For example in operating this process where subsequent treatment apparatus may be unavailable, the noble metal may be loaded on to a carbon or graphite felt cathode. This may be removed periodically and sent in a suitable security carrier to a smelter or other treatment device remote from the electrowinning plant.

The solution discharged into the header 242 may be recycled if desired.

The various dimensions mentioned above and the numbers of chambers and cells in the chambers etc may be varied as desired.

Where the discharge pipes lead to a hopper (as in the embodiment illustrated in Figures 7 and 8) the pump inlet may be connected to the top of the hopper (rather than through the separate discharge pipes). With this arrangement, a single large filter disc may be provided to simplify the protection of the pump.

In the endless annular array there may be two or more sets of solution movement, e.g. the inlets may be to chambers 1 and 4 and the outlets from chambers 3 and 6. Obviously if there
are more than six chambers, more sets of solution movement may be provided. This may will provide a more efficient usage of the apparatus.

Instead of the ultra sonic transducers being located on opposite sides of the cathode as described above, these transducers may with advantage rather be arranged at ninety degrees to each other so that the waves generated by them will enhance one another.

If desired small flushing jets may be provided to clean the sieves 222 of trapped material. Similarly internal jets may also be provided to clean the filter sleeve 224 periodically. Rotation of the cathode may take place during metal deposition.

Instead of the Nafion ion exchange membrane, there may be provided a porous membrane such as polypropylene to separate the anode and cathode chambers of the cell.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments may also be provided in combination in a single embodiment. Conversely various features of the invention which are for brevity described in the context of a single embodiment may also be provided separately or in any suitable combination.

Other flow arrangements about the annulus are possible. For example the rich solution may be introduced into chamber 102.1 and the demuded solution discharged from chamber 102.4. In due time the rich solution will be fed into chamber 102.2 and discharged from chamber 102.5. This continues around the annulus.
CLAIMS

1. Electrowinning apparatus comprising
   a chamber for solution to be processed,
   an inlet to and an outlet from the chamber,
   a cell including an anode and a cathode,
   characterised in that a pump is provided connected to circulate solution from within the
   chamber through the cell and back into the chamber.

2. Apparatus as claimed in claim 1 characterised in that the cathode is porous and hollow,
   and in that the interior of the cathode is connected to the pump.

3. Apparatus as claimed in claim 2 characterised in that the interior of the cathode is
   connected by suction to the inlet of the pump.

4. Electrowinning apparatus comprising
   a chamber for solution to be processed,
   an inlet to and an outlet from the chamber
   a cell including an anode and a porous vertical cylindrical cathode, and
   a pump connected to the interior of the cathode
   characterised in that the pump circulates solution from within the chamber through the
   cathode and back into the chamber.

5. Apparatus as claimed in claim 4 characterised in that the interior of the cathode is
   connected, conveniently at its lower end, to the suction inlet of the pump which is preferably a
   suction pump.

6. Apparatus as claimed in claim 5 characterised in that the upper end of the cathode is
   closed off.

7. Apparatus as claimed in any one of the preceding claims characterised in that the anode
   is provided within the cathode.
8 Apparatus as claimed in any one of claims 1 to 6 characterised in that the anode surrounds the cathode.

9 Apparatus as claimed in claim 8 characterised in that the anode is porous so that solution may pass through the anode to engage the cathode.

10 Apparatus as claimed in any one of the preceding claims characterised in that a barrier member is provided between the anode and the cathode dividing the cell into an anode chamber and a cathode chamber, the arrangement being such that in use the solution is circulated through the cathode chamber while an inert conducting liquid is passed through the anode chamber.

11 Apparatus as claimed in any one of the preceding claims characterised in that an internal pipe is located within the cathode.

12 Apparatus as claimed in claim 11 characterised in that the internal pipe has electrical connections so that it will, in use, act as the anode or as an additional anode.

13 Apparatus as claimed in claim 11 or 12 characterised in that the pipe is perforated and has hydraulic connections whereby it may be connected to a source of high pressure water which may pass therethrough to flush metal adhering to the cathode off the cathode.

14 Apparatus as claimed in any one of the preceding claims characterised in that a plurality of flushing pipes, preferably located outside the cathode, having hydraulic connections whereby they may be connected to a source of high pressure water which in use may pass therethrough to flush metal adhering to the cathode off the cathode.

15 Apparatus as claimed in any one of the preceding claims characterised in that means provided for rotating the cathode during removal or the metal from the cathode and/or during electrodeposition.

16 Apparatus as claimed in any one of the preceding claims characterised in that means for moving the cathode axially during flushing.
17 Apparatus as claimed in any one of the preceding claims characterised in that there is provided ultra sonic means arranged to emit ultra sonic waves which in use will dislodge metal adhering to the cathode off the cathode.

18 Apparatus as claimed in claim 17 characterised in that one or more ultra sonic means are provided adjacent the cathode.

19 Apparatus as claimed in claim 18 characterised in that the ultra sonic means are provided within a ring of cells.

20 Apparatus as claimed in claim 17 or 18 characterised in that the ultra-sonic means comprises transducer means attached to a wall or the base of the chamber.

21 Apparatus as claimed in any one of the preceding claims characterised in that the cathode is removably mounted in the cell.

22 Apparatus as claimed in any one of the preceding claims in which the cathode forms part of an assembly including a base, characterised in that the base rests on lower mounting means closing a valve seat leading to a discharge pipe for metal dislodged from the cathode and in that means are provided for lifting the cathode assembly relative to the seat so that the base will be spaced from the seat to enable solid matter in the cell about the cathode to pass between the base and seat into the pipe means.

23 Apparatus as claimed in claim 22 characterised in that the base is of frusto-conical shape as is the seat to facilitate the passage of the metal between the base and seat into the discharge pipe.

24 Apparatus as claimed in claim 23 when dependant directly or indirectly upon claim 2 or claim 5 characterised in that the discharge pipe is a continuation of the interior of the cathode.

25 Apparatus as claimed in claim 24 the discharge pipe leads to collection means in which any metal falling off the cathode is collected.
26  Apparatus as claimed in claim 24 or 25 characterised in that a sieve is provided in the pipe means preventing any metal falling off the cathode travelling in the solution to the pump.

27  Apparatus as claimed in any one of the preceding claims characterised in that a surrounding sieve is provided surrounding the cell.

28  Apparatus as claimed in any one of the preceding claims characterised in that the pump is a submersible pump that is contained within the chamber.

29  Apparatus as claimed in claim 1 to 27 characterised in that the pump is located outside of and preferably below the chamber.

30  Apparatus as claimed in any one of the preceding claims characterised in that there are a plurality of cells in each chamber which are all connected to the pump suction inlet.

31  Apparatus as claimed in any one of the preceding claims in which the chamber has first and second end walls characterised in that there is a separating wall adjacent to the first end wall dividing the chamber into

(a) a main chamber portion containing the cell/s and being closed by the second end wall and

(b) an inlet portion which connects to the main chamber portion through an opening at the lower end of the separating wall

and in that the chamber has an inlet to the upper part of the inlet portion and an outlet from the upper part of the main chamber portion.

32  Apparatus as claimed in claim 31 characterised in that it comprises a number of chambers arranged in array with the second end wall of one of the chambers constituting the first end wall of the adjacent chamber and wherein flow connector means in the said second wall is arranged to permit solution in the said one chamber to pass thereover into to inlet chamber of the said adjacent chamber.

33  Apparatus as claimed in claim 31, 32 or 33 characterised in that the chambers are arranged in an endless, preferably annular, array of preferably six chambers.
Apparatus as claimed in any one of the preceding claims 1 to 29 characterised in that it comprises a number of chambers arranged in an endless annular array with inner and outer cylindrical walls defining an annular space and end walls separating the space into the chambers and in that separating walls are provided dividing the chambers into
(a) a main chamber portion containing the cell/s and being defined by the end and separating walls,
(b) an inlet portion between an end wall and the first separating wall, which inlet portion connects to the main chamber portion through an opening at the lower end of the separating wall, and which has a solution inlet opening thereto,
(c) an outlet portion between the other end wall and the second separating wall, which outlet portion connects to the main chamber portion by flow connection means and which has a solution outlet therefrom,
and in that flow connector means is provided in an end wall between the inlet and outlet portions of adjacent chambers on either side of the said end wall to permit solution in the said one chamber to pass therethrough from the outlet portion into the inlet portion.

Apparatus as claimed in claim 32, 33 or 34 characterised in that the flow connection means comprises an opening or weir provided in the second end wall preferably at or near the upper end thereof and a control valve is provided for controlling the flow of solution through the opening.

Apparatus as claimed in any one of claims 31 to 35 characterised in that each chamber has a solution inlet and discharge pipes all of which are connected respectively to inlet and discharge headers with suitable valve means therein, the control valves for the flow control means being arranged so that solution can be delivered to one chamber, passed by over the second wall to a second chamber from it to one or more other chambers and finally discharging through a discharge pipe of a chamber remote from the said one chamber and thereafter the valve settings can be altered to move the pattern of solution movement around the array.

Apparatus as claimed in claim 31 to 35 characterised in that there is provided a common launder into which the collection means for all the cells discharge.
38 A method of electrowinning metal from a metal containing solution, the method utilising a chamber containing the solution and within which is a cell including an anode and a cathode, the method being characterised by circulating the solution by a pump from within the chamber, through the cell and discharging the solution back into the chamber.

39 A method as claimed in claim 38 characterised in that the pump draws the solution through the cathode under suction.

40 A method as claimed in claim 38 or 39 in which there are provided a plurality of chambers connected together by flow connectors there being inlet port means to one of the chambers and outlet port means at another of the chambers the method being characterised in that the solution is conveyed from the said one chamber to the said other chamber by the flow connectors in one direction only.

41 A method as claimed in claim 40 characterised in that the cathodes of the cells are moved periodically so that the less heavily loaded cathodes are moved to the chambers into which the richer solution is fed.

42 A method as claimed in claim 40 in which the chambers are arranged in an endless, preferably annular, array, control valves are provided in the flow connectors, each chamber has an inlet port means through which solution can be introduced thereto and outlet port means through which solution may be discharged, the method being characterised in that after a period during which (i) the inlet means to the said one chamber is opened, (ii) the outlet port means of the said other chamber is opened and (iii) the control valves are so arranged as to permit flow from said one chamber to said other chamber in one direction only, the inlet means to the said one chamber and the outlet means from the said other chamber are closed and thereafter the inlet means to a first adjacent chamber which is adjacent to the said one chamber direction is opened at the outlet port means in a second adjacent chamber which is correspondingly adjacent to the said other chamber is opened and the connector valves being arranged so arranged as to permit flow from said first adjacent chamber to said second adjacent in one direction only, and this process is continued moving continuously around the endless array.
A method as claimed in any one of claims 40 to 42 in which the various valves are connected to a suitable control means characterised in that the operation of the apparatus takes place automatically.

A method as claimed in any one of claims 40 to 43 in which the cells are connected to a collector into which metal adhering to the cathodes can be discharged when removed from the cathodes, characterised in that the metal is removed from the cathodes and so discharged at appropriate times.

A method as claimed in claim 44 characterised in that the metal is discharged when the cathode is optimally loaded.

A method as claimed in claim 44 or 45 characterised in that the discharge from the cathode/s in a chamber takes place when the solution in that chamber is denuded or substantially denuded of metal.

A method as claimed in claim 45 or 46 characterised in that the cathodes when loaded are removed from the chambers for further processing.

A method as claimed in any one of claims 40 to 46 characterised in that ultra sonic waves are used to cause metal that adheres to the cathode to become free of the cathode.

A method as claimed in any one of claims 40 to 46 or 48 characterised in that jets of flushing water are used to cause metal that adheres to the cathode to become free of the cathode.

Electrowinning apparatus having parts arranged and operating substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 6 of the drawings.

Electrowinning apparatus having parts arranged and operating substantially as hereinbefore described with reference to and as illustrated in Figures 7 and 8 of the drawings.

Electrowinning apparatus having parts arranged and operating substantially as hereinbefore described with reference to and as illustrated in Figure 9 of the drawings.
53 Electrowinning apparatus having parts arranged and operating substantially as hereinbefore described with reference to and as illustrated in Figure 10 of the drawings.

54 Electrowinning apparatus having parts arranged and operating substantially as hereinbefore described with reference to and as illustrated in Figures 11 and 12, Figures 13 to 15 or Figure 16 of the drawings.

55 A method of removing metal from solution comprising the steps described with reference to Figures 1 to 6, Figures 7 and 8, Figure 9, Figure 10 or Figures 11 and 12 of the drawings.