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(54) **ELECTRIC CURRENT SENSING AND MANAGEMENT SYSTEM FOR ELECTROLYTIC PLANTS**

(71) Applicant: **HATCH ASSOCIATES PTY LIMITED**, Brisbane (AU)

(72) Inventors: **Chris Boon**, New Beith (AU); **Rob Fraser**, Indooroopilly (AU); **Jorge Garces Baron**, Santiago (CL); **Gerald Gill**, Myrtleford (AU); **Tim Johnston**, Keperra (AU); **Noel Johnston**, Beenleigh (AU); **John Yesberg**, Brookfield (AU); **Sebastian Nolet**, Belmont (AU)

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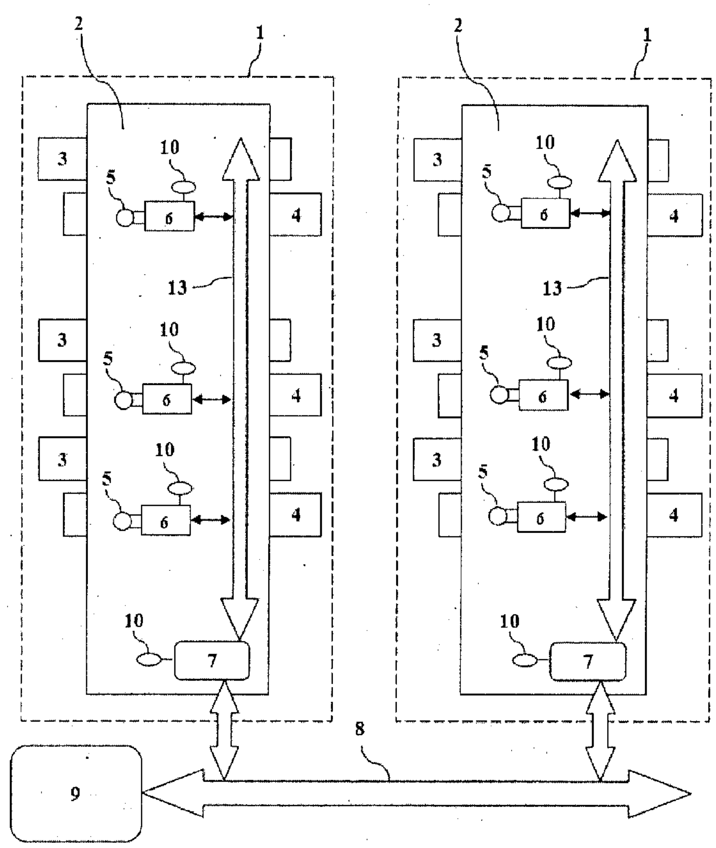
(57) **ABSTRACT**

The present invention relates to an electric current management (ECM) system and method comprising at least one electrolytic cell having at least two electrodes in contact with electrolyte media; a plurality of sensor means for measuring the current passing through one or more electrodes, said sensor means being located inside at least one ECM bar installed in one or more operating electrolytic cells; a support means for supporting at least one ECM bar in each cell; wherein the support means is adapted to avoid disruption to normal electrode movements and damage to the ECM bar. The present invention introduces improvements for minimizing the effects that several types of variables have on current measurement, such as magnetic field interference, cell geometry and contact configuration, in order to provide a reliable approximation of the current passing through each electrode. The present invention can be applied to real time monitoring of each cathode, or anode, constituting a metal electrowinning or electrorefining cell or other electrolytic cell.



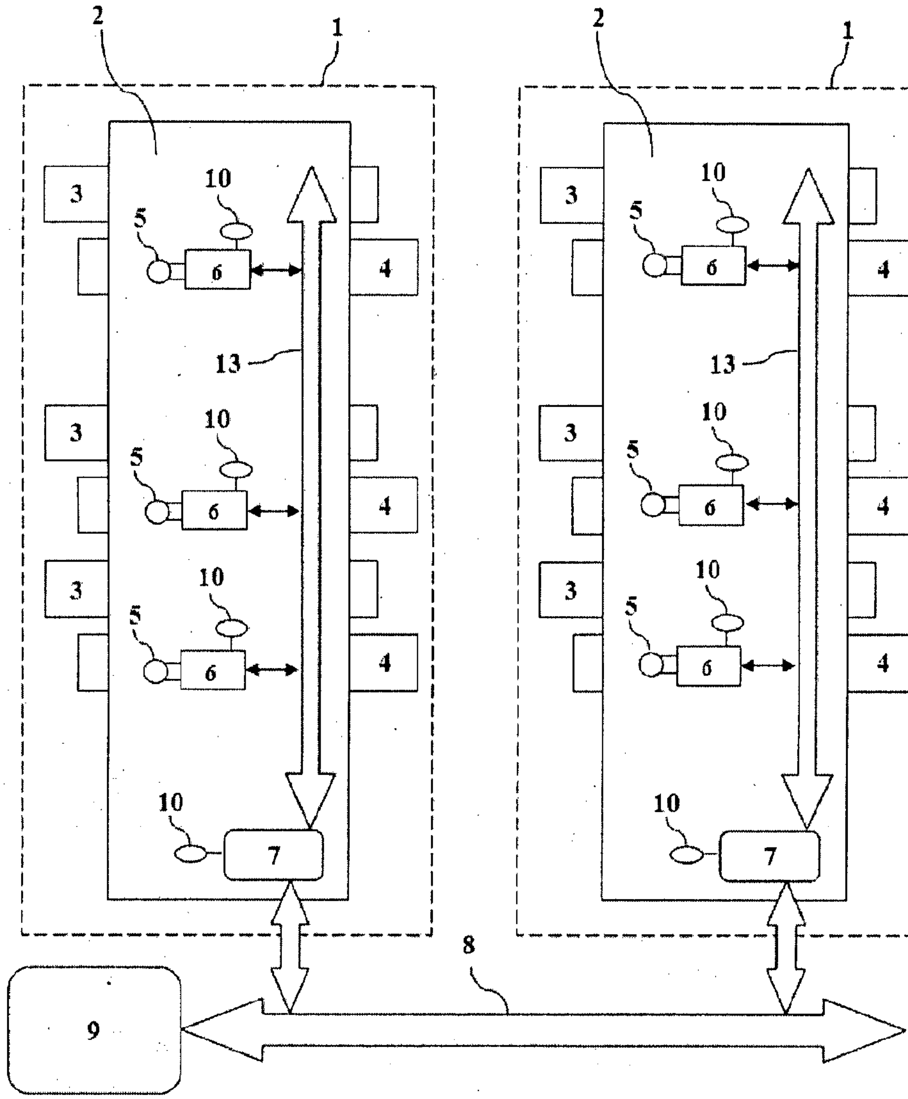


Figure 1

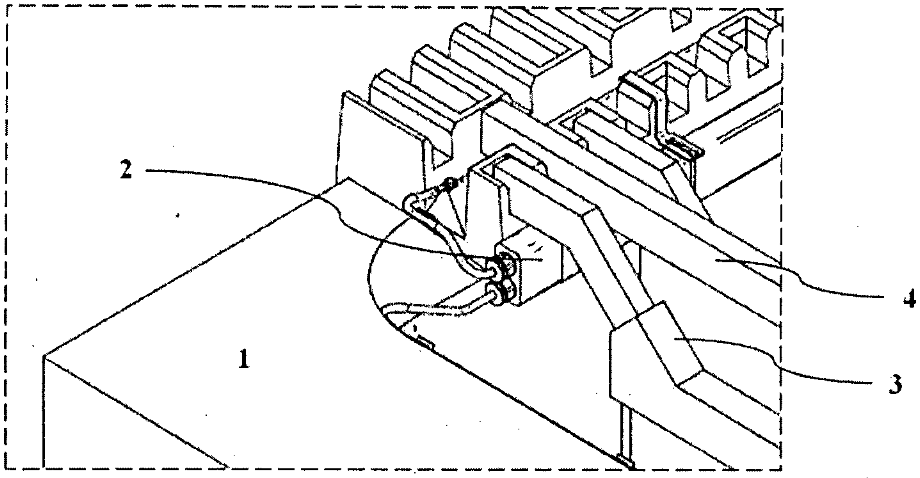


Figure 2

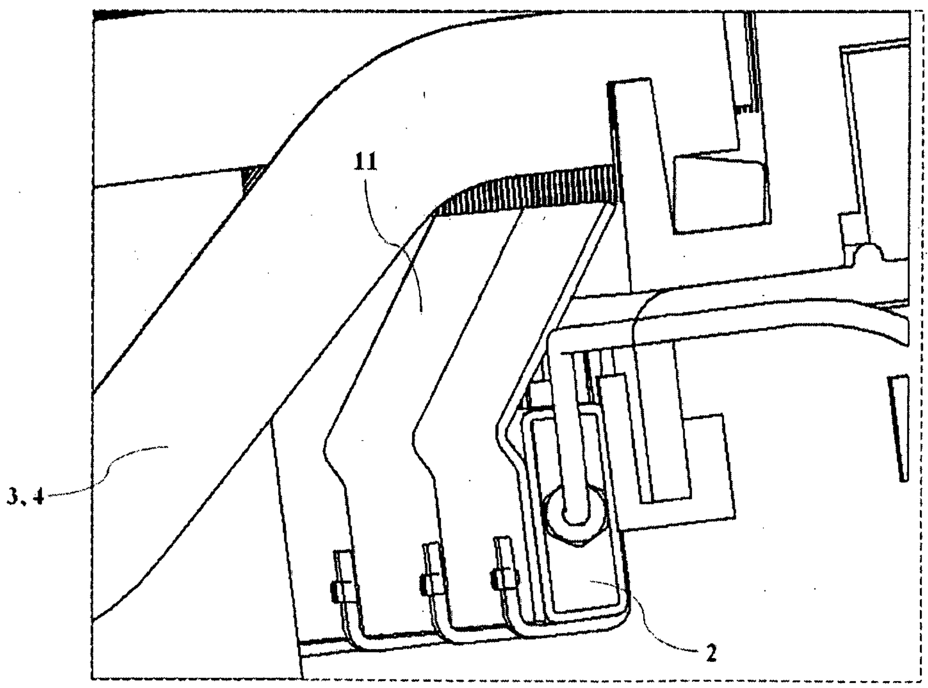


Figure 3

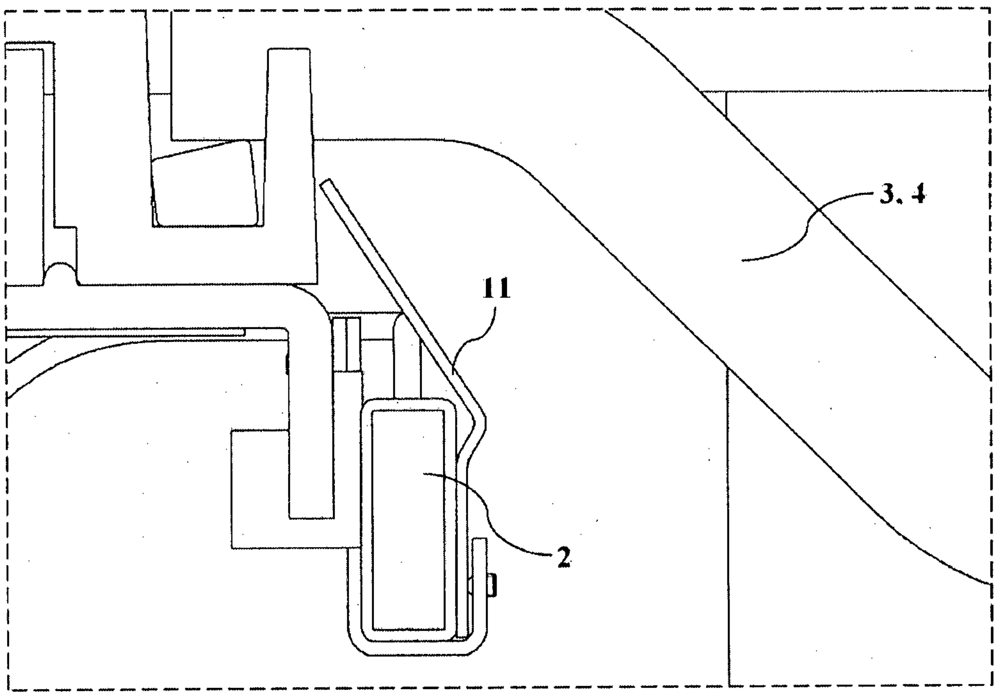


Figure 4

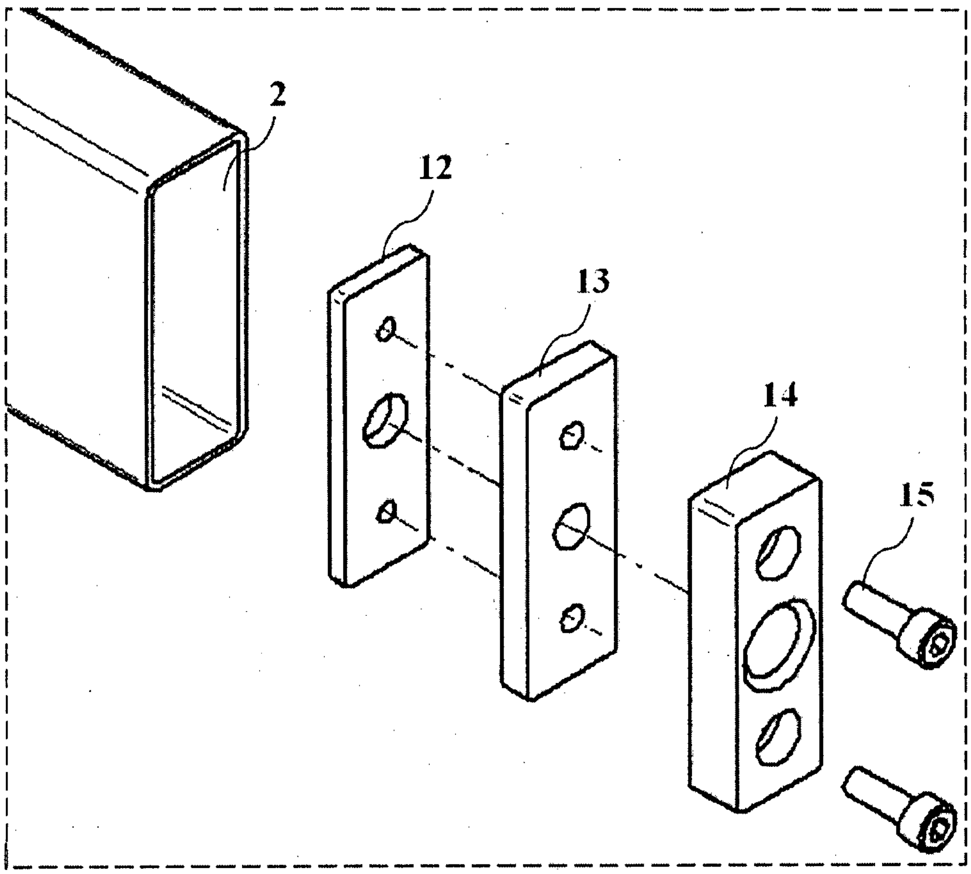


Figure 5

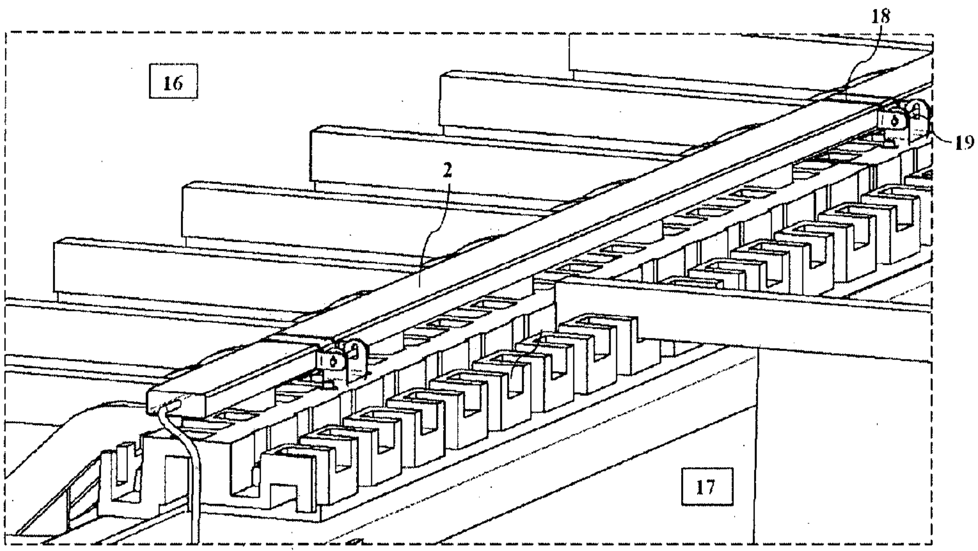


Figure 6

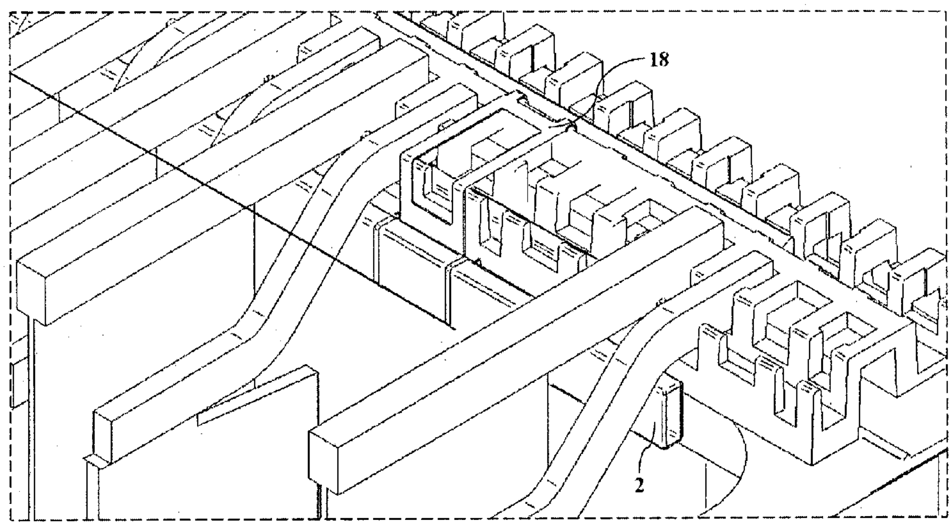


Figure 7

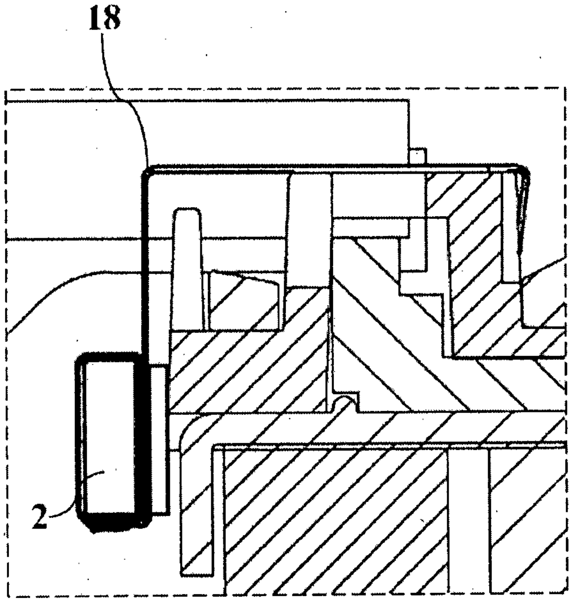


Figure 8

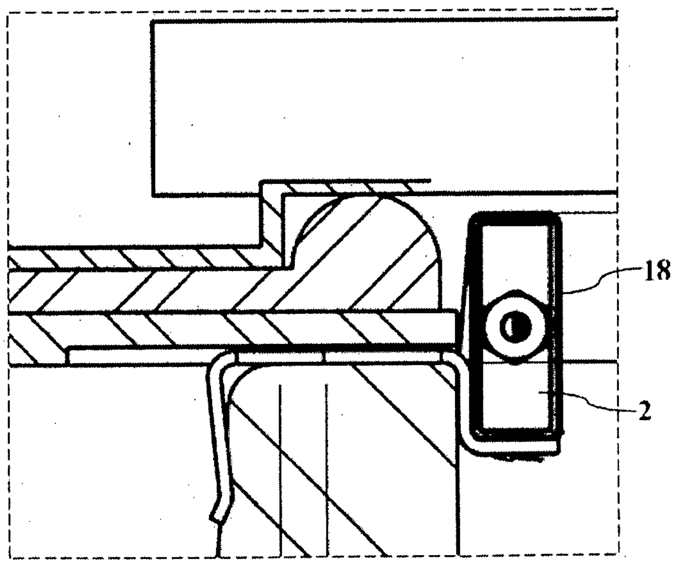


Figure 9

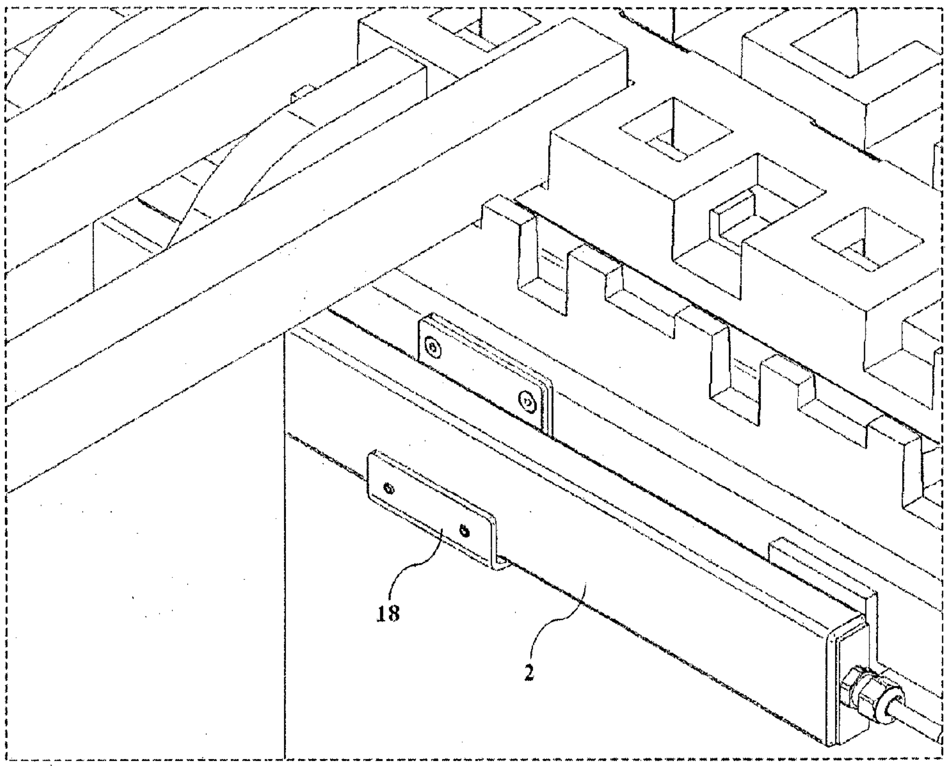


Figure 10

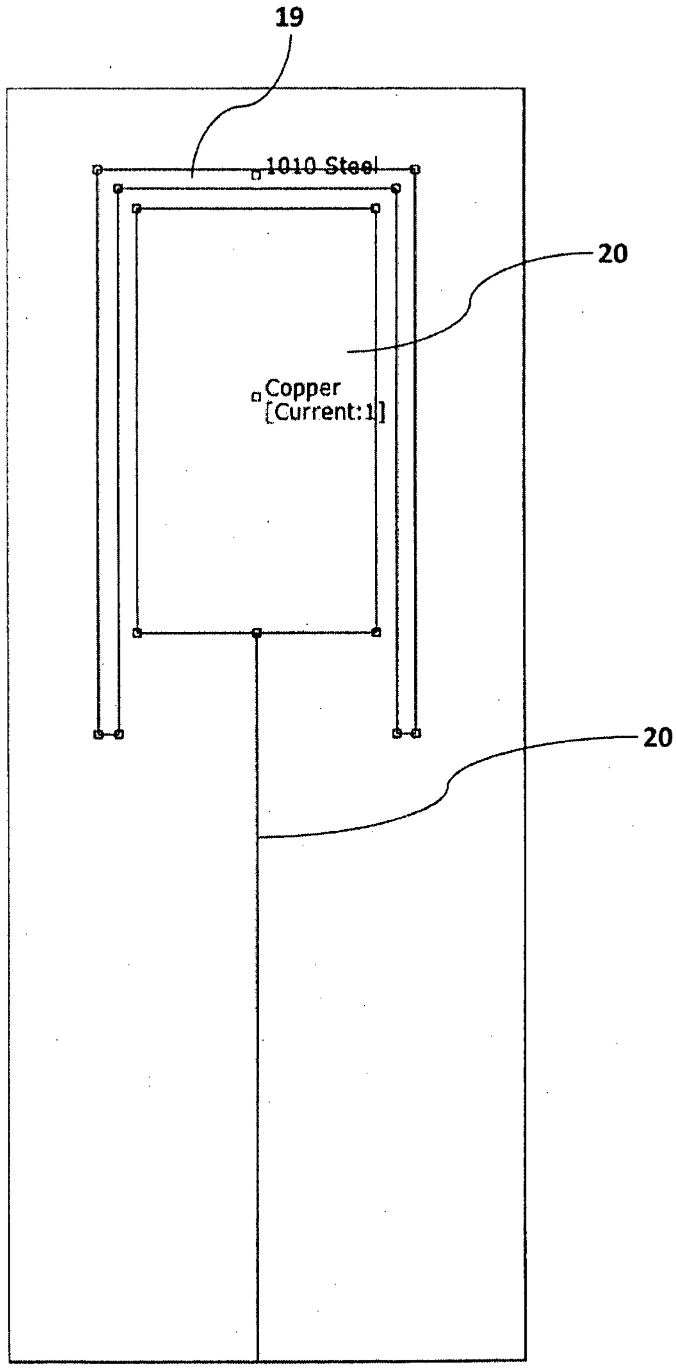


Figure 11

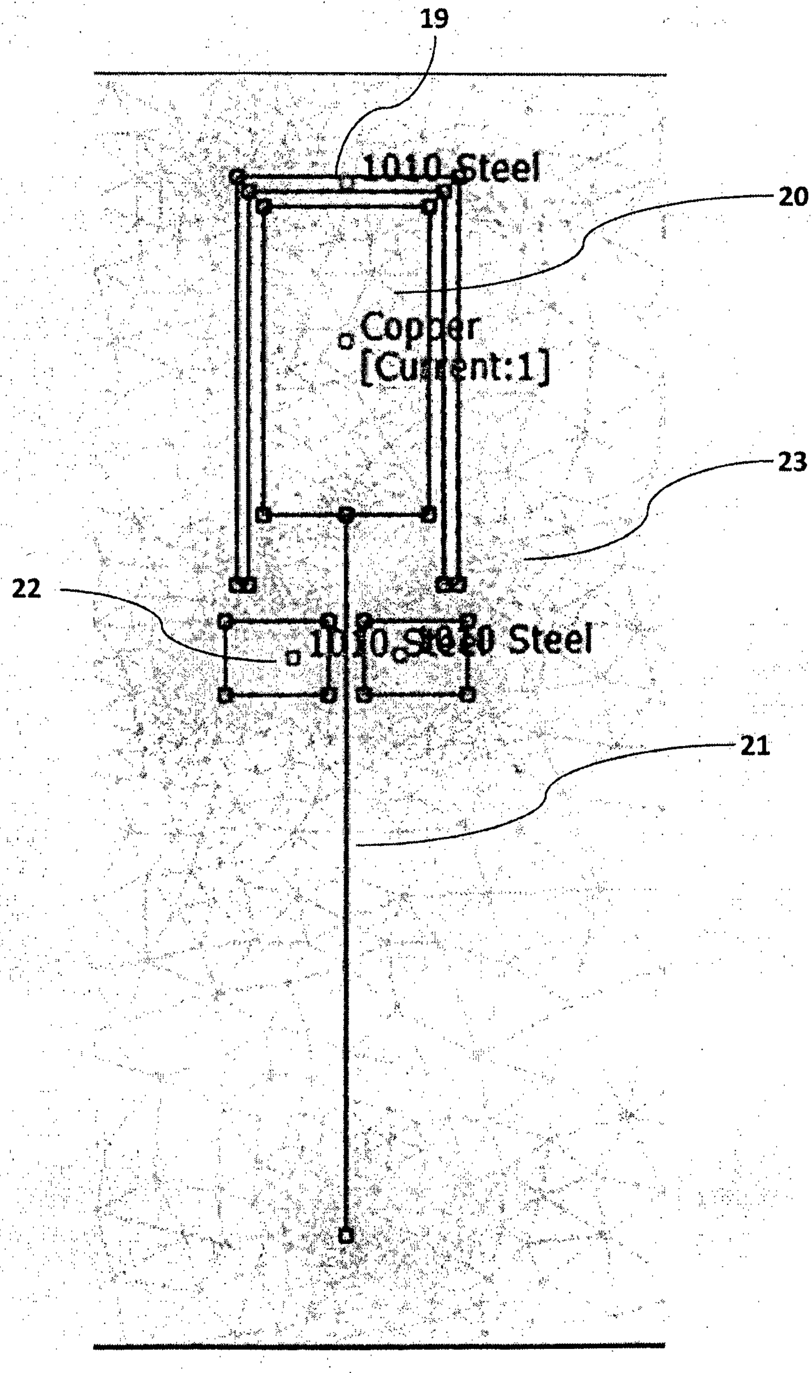

19
1010 Steel
20
Copper
[Current:1]
23
22
1010 Steel
1010 Steel
21

Figure 12

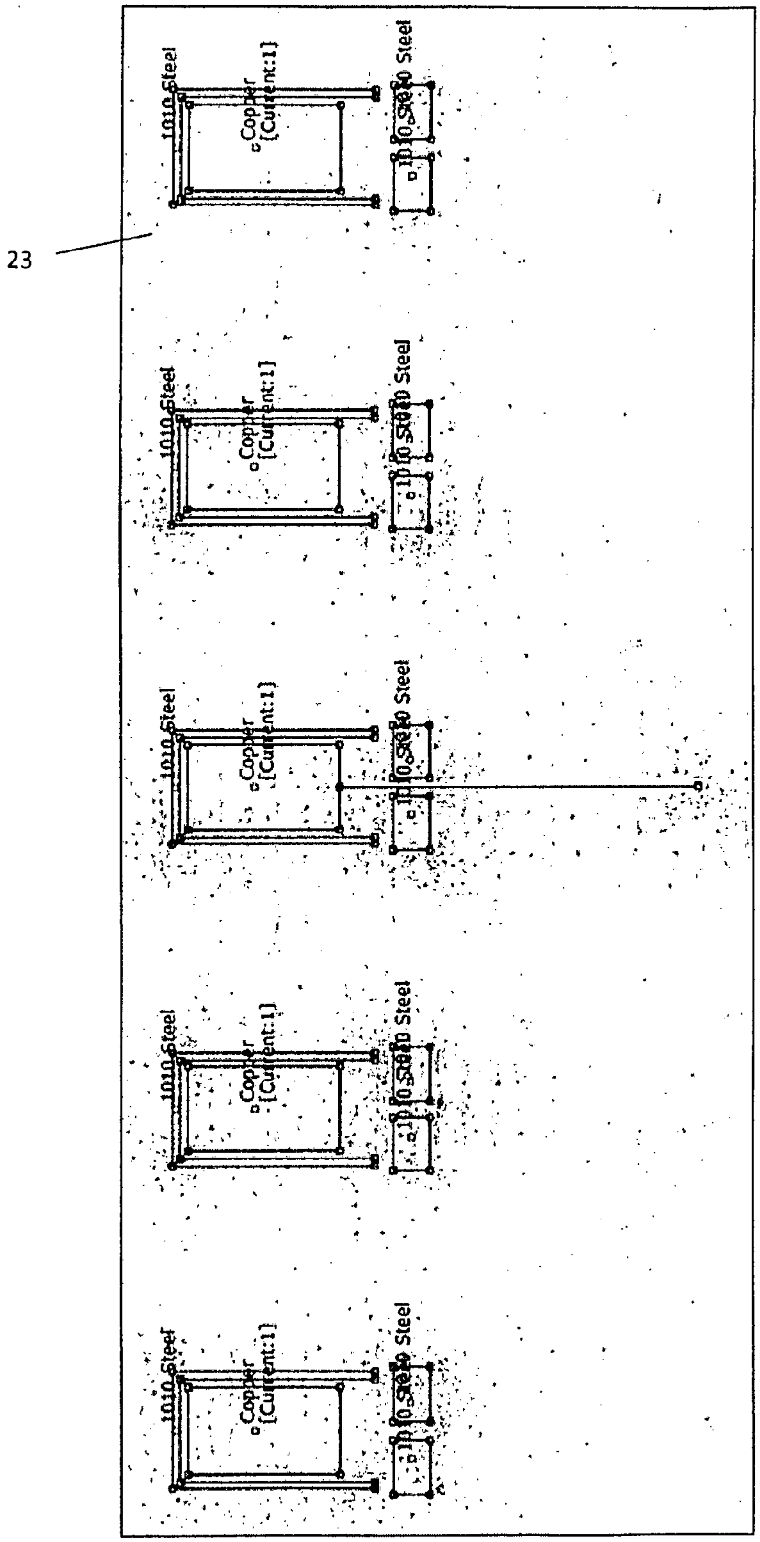


Figure 13

ELECTRIC CURRENT SENSING AND MANAGEMENT SYSTEM FOR ELECTROLYTIC PLANTS

FIELD OF APPLICATION

[0001] The present invention relates to metallurgical systems, especially electrometallurgical systems, and enhancement of electrolytic cell and/or tankhouse behaviour.

[0002] The present invention can be particularly applied to real time monitoring of each cathode, or anode, constituting a metal electrowinning or electrorefining cell or other electrolytic cell with parallel electrodes.

BACKGROUND

[0003] Metal extraction processes, such as those for copper, often include electrowinning or electrorefining recovery steps. With regard to these steps, it provides an advantage to monitor in real time each metal plate's performance in order to achieve optimum performance of the electrolytic plants.

[0004] Within the electrolysis process, a short circuit may occur if electrodes are arranged misaligned; when due to physical flaws metal growth is not uniform on a surface, which may be a result of operational issues such as impurities, higher than acceptable cathode currents, particulates in the electrolyte, damaged electrodes or peeling of electrodeposits that then touch the neighbouring electrode, among others. A low current situation may also occur when there is a poor electrical contact between anodes or cathodes and their current source, resulting in a reduction of the system efficiency. Both cases can lead to a low quality product, or as in the case of copper electrorefining, the desired purity is not achieved, wherein these cases can also lead to a reduction in current and power efficiency which can reduce plant production and increase costs. Within this context, controlling the current that passes through the electrodes of each electrolysis unit is important to improve processes, products and efficiency of systems that use the abovementioned procedure.

[0005] The problem of monitoring each electrolysis unit is described in patent CL 44,909 (J. Garcés Baron). In this patent, a monitoring system of the electric current passing through each cathode forming a set of electrodes is described, such monitoring system comprising a plurality of proximity electric current sensors connected to communications means, and wherein such communication means communicate with a processing and control unit having graphical user interface means. Such proximity sensors measure the electric current passing through an electrode by measuring the strength of the magnetic flux density generated by such passing current.

[0006] U.S. Pat. No. 7,445,696 (Eugene You et al.) also describes the basis behind a current sensing system for electrowinning and electrorefining cells and describes theoretical methods for compensating for magnetic fields generated by neighbouring electrodes. This patent does not describe the essential practical aspects of constructing a sensor bar including means of sealing the bar, electrical noise avoidance, practical calibration considerations, limitations on geometry of a sensor bar that will fit inside many cell systems, and supporting such a bar in a cell. In particular, the presence of the current sensing systems of the prior art can cause difficulties with electrode removal/replacement in a cell, due to the propensity of the electrodes to knock the sensor system as they are being lowered into the cell, causing damage to sensor systems and interfering with efficient loading of electrodes into the cell. Neither patent CL 44,909 nor U.S. Pat. No. 7,445,696 address the problem of impeded movement of the electrodes in the cell due to the presence of the sensor system, or a means for preserving the integrity of the sensors. The crane bale and strong back electrode hooks used to pick up cathodes and anodes may in themselves provide means for damage to the sensor system. U.S. Pat. No. 7,445,969 also describe methods for overcoming interferences from neighbouring electrodes. Such a system does not yield a reliable measurement of the electric current passing through an electrode, as "ideal" theoretical scenarios rarely occur in practice. Thus, the prior art method based on theoretical calculation does not cater for additional magnetic field contributions. Additionally, the solution proposed in the prior art does not consider the external effects of the measurement, such as temperature, which affects both the behaviour of magnetic fields and the electric current measured.

[0007] In addition, conditions within electrowinning and electrorefining cells are very harsh. This includes chemical conditions with general high acidity of electrolyte, acid mist droplets and perhaps halogens being present in the air space above the electrolyte. As serious as this is, the physical environment with the frequent process of removing and replacing electrodes give many opportunities for damage to the sensors and for impeding of the movement of the electrodes by the sensors. The versions described in the prior art are not robust to said conditions which would result in frequent failure.

[0008] The humid and chemically corrosive conditions above the cell electrolyte necessitate that sensors must be fully sealed inside a housing. As an additional constraint, in many cell systems a bar with round profile will not fit beneath the electrode header bars due to the thickness of its profile impeding the path of electrodes as they are lowered into the cell and electrode lifting hooks as they may be lowered beneath the header bars to lift the electrodes by their header bars. Thus non-round profiles are desirable since are more practically used and allow closer placement of the sensors to the header bars improving accuracy of sensor readings. The prior art is silent on this issue.

[0009] Then, there is no clearly defined prior art for sealing a non-round section of non-round profile tubes in a manner that is suitable for this application. The known standardised methods available in the art such as flanges and threaded end caps, are geometrically prohibitive for a non-round profile. Internal methods of sealing such as o-rings are not practical due to the tight radius bends that may be present in the corner or corners of non-round profile tubes. Gluing, epoxy resin and bonding a plug in the end of the tube were attempted by the Applicant but failed, due to what was understood to be differences in thermal expansion between the bonding material and the tube housing.

[0010] Regarding the operation within electrolytic plants, the management of harvesting cycles (also known as stripping cycles) in electrowinning or electrorefining plants is usually undertaken utilising written or computer driven schedules to identify which cells need to be harvested at which time. Such systems necessarily rely on paper or manually entered computer records for when cells are to be harvested. It is desirable to know the exact deposition period of a particular cells to enable the accurate determination of current efficiency which requires customised software systems and recording rigour by operators to ensure that data is correct. It is also valuable in times when current settings change in the tankhouse to be able to know and to adjust deposition times according to amp hours passed but this requires additional calculations for each cell. In addition, in the event of human error such that data is not recorded correctly and cells are not harvested within an acceptable band of time periods, inconsistent cathode weights, poor morphology, short circuits, damaged anodes and reduced current efficiency can result.

[0011] Where plants have fully automatic cranes these cranes can record the exact time that cells are harvested but such systems are expensive and most tankhouses do not have these cranes.

[0012] Thus, the invention described in the present application is intended to overcome one or more of the aforementioned problems of the prior art, by providing a reliable current measurement which enables optimizing processes in relation thereto, through a hardware reliable solution.

SUMMARY OF THE INVENTION

[0013] The present invention relates to improvements in metallurgical systems, especially electrometallurgical systems, related to enhancement of the electrolytic cell and/or tankhouse behaviour by improving one or more of the functionality, adaptability, control and human-interface of said systems, wherein the electric current management, i.e. its measurement and control, is a key factor.

[0014] The present invention relates to an electric current management (ECM) system comprising at least one electrolytic cell having at least two electrodes in contact with electrolyte media; a plurality of sensor means for measuring the current passing through one or more electrodes, said sensor means being located inside at least one ECM bar installed in one or more operating electrolytic cells; a support means for supporting at least one ECM bar in each cell; wherein the support means is adapted to avoid disruption to normal electrode movements and damage to the ECM bar.

[0015] Hence, the invention relates to a system for improving the monitoring, in real time, of the electric current that passes through each one of a plurality of single cathodes or anodes forming an electrolytic cell. In this context, the present invention also introduces improvements to different electric current measurement systems, which measure the electric current passing through an electrode or a plurality of electrodes within an electrolytic cell. Said improvements comprise means for minimizing the effects that several types of variables have on current measurement, such as magnetic field interference, cell geometry and contact configuration, in order to provide a reliable approximation of the current passing through each electrode. Then, the above referred improvements are related to maximizing the device functionality, adaptability and control, providing a full enhancement of metallurgical systems wherein it is important to provide a reliable management of the electric current passing through the electrodes. Accordingly, the present invention can be particularly applied to real time monitoring of each cathode, or anode, constituting a metal electrowinning or electrorefining cell or other electrolytic cell with parallel electrodes.

[0016] As indicated above, the present invention is particularly related to improving systems in which the electric current management (ECM) is a key factor. In this context, the invention allows to provide a reliable and optimized system for measurement in real time of the electric current and/or provide improvements to existing measurement devices. This explains the adaptability of the invention, offering solutions widely adaptable to different systems and devices that may be in use, development/fabrication and/or which have not yet been designed.

[0017] Considering the above, the system of the invention comprises a plurality of current sensor means, which preferably correspond to Hall Effect sensors. Such sensors are located in a sensor bar, or electrode current management bar, which can incorporate means for processing and improving the current measurement, in particular means for minimizing the effects that background magnetic fields have on current measurement. Furthermore, in one embodiment, such sensors are also in data-communication with central units, which preferably corresponds to at least one pre-processing unit, wherein such pre-processing units are in data-communication with a head controller unit which in turn is in data communication with a central server unit comprising a user interface. Said units, and any other type of devices used for processing, controlling and visualizing data would be referred as central units and displaying devices, respectively.

[0018] The present invention also describes a method that enables a more accurate measurement and management of the current of each electrode within the electrolytic cell (cathode or anode) by using a ferromagnetic device on either side of the sensors to channel the magnetic flux in order to direct and concentrate the effects of magnetic fields over the sensor means.

[0019] The invention also describes a method for sealing a hollowed bar using an end seal arrangement comprising a backing plate, a gasket, an end cap and fastening means, Once assembled, the arrangement compresses a flexible seal (gasket) between the end cap and the backing plate through the tensioning of fasteners that pass from the end cap through the gasket and the end cap.

[0020] Preferably, the end cap may have threaded holes for these fasteners, nuts or other means of fastening.

[0021] The invention also describes an ECM system having a means for detection of metal harvesting cycles in order to improve tank house management. The harvesting cycles can be determined by pattern recognition since harvesting in each tankhouse follows a specific pattern of electrode position lifting. Since the system measures the currents of each electrode it can detect the positions of the electrodes that are lifted at the same time and can compare this with the pattern preprogrammed for the tankhouse.

[0022] Preferably, the ECM system includes a specific arrangement of one or more sensors to provide for automatic detection of misalignment of electrodes and corresponding adjustment to calculations of current flow.

[0023] The ECM system preferably is configured to work with a double contact system, wherein at least one balance bar is included to improve current distribution along the length of the cell.

[0024] Preferably, the ECM system monitors cell voltage for each individual cell.

[0025] Preferably, the ECM system includes a monitoring system for predicting poor contact and/or short circuit conditions.

[0026] Preferably, the ECM system automatically adjusts current thresholds according to real cell conditions, to prevent false indications of short circuiting and bad contacts.

[0027] Still preferably, the ECM system comprises a means for prioritizing maintenance and repair of shorts and poor contacts according to, for example, age and severity of short circuits.

[0028] Preferably, the support means for the ECM bar includes protection means which may be a deflector.

[0029] The deflector serves a two-fold purpose to prevent damage to the ECM bar as a result of electrode removal/replacement, and also to guide electrodes into correct alignment.

[0030] Alternatively, the support means for the ECM bar is in the form of a hinged support means located on top of the electrolytic cell.

[0031] The hinged support means allows the ECM bar to be rotated out of the path of electrodes as they are being harvested or replaced in the cell. In one embodiment the hinge system rotates the bar over the ICCB of an electrolytic cell and positions it near the header bars in the adjacent cell for measurement of the adjacent cell.

[0032] Still preferably, the hinged support means is attachable to any of the existing cell features, including cell furniture, cell walls or intercell contact bar (ICCB).

[0033] The support means for the ECM bar is preferably adapted to be retrofitted to an existing cell. Alternatively, the support means is in the form of a permanent fixture of the cell furniture.

[0034] Alternatively the support means for the ECM bar may be attached to the cathode ventilation hoods that rest on top of the cells or to flaps that may be attached to the side of such hoods. In this embodiment the ECM bar or bars would be lifted off the cell with the ventilation hood when cells are to be harvested.

[0035] Preferably, the ECM system comprises controllers for relaying information from the ECM bars to a central server.

[0036] Still preferably, each controller can communicate with one or more ECM bars.

[0037] The ECM system preferably comprises additional sensors for monitoring further parameters including, but not limited to, pH, electrolyte media concentration and temperature.

[0038] Preferably, the ECM system calculates an overall cell performance relative to the variety of parameters monitored.

[0039] Preferably, the ECM bar is formed from any one or more of metallic or non-metallic materials. Where the ECM bar is formed from metallic material, the ECM bar preferably also comprises a coating of insulation material. The insulation material acts to make it safe to transport the bar in the cell house and also to prevent undesired electric shorts when the bar is installed.

[0040] The ECM system preferably comprises an electrode tracking system.

[0041] A tracking system helps an operator to track the performance of the metal growing on a certain electrode from the cell through the harvesting process, through quality assessment and weighing and current efficiency determination allowing identification of consistent issues with specific cathodes blanks, cells, and cathode positions in a cell. Still preferably, the electrode tracking system includes but is not limited to, radio-frequency identification (RFID) tags.

[0042] The tracking system preferably further includes a visual status identification. Visual status identification can be employed in addition to electronic status, to enable an operator in the plant immediately determine the status of an electrode, for example, by the colour of an LED (normal, high current, low current).

[0043] The ECM system preferably comprises energy saving features wherein during the time interval between successive sensor readings a portion of the electronic circuit can be disabled or configured into a low power mode which allows that only one sensor within the overall bar is operated in full power mode at any time, reducing both the peak and average power requirements.

[0044] The ECM system preferably includes an alarm system. The alarm system is preferably automatically generated when an operational problem is detected.

DESCRIPTION OF THE DRAWINGS

[0045] Further aspects of the invention will be better understood from the following detailed description of its preferred embodiments, given by way of example only, with reference to the accompanying drawings, in which:

[0046] FIG. **1** depicts a schematic representation of an electrolytic cell including the main devices according to an embodiment of the invention.

[0047] FIG. **2** depicts a schematic view of an electrolytic cell showing the ECM bar according to an embodiment of the invention.

[0048] FIG. **3** depicts a schematic perspective view of an ECM bar protected with a deflector device according to an embodiment of the invention.

[0049] FIG. **4** depicts a schematic cross sectional view of the deflector device according to FIG. **3**.

[0050] FIG. **5** depicts an exploded view of the end seal arrangement at one end of an ECM bar according to an embodiment of the invention.

[0051] FIG. **6** depicts a schematic perspective view of a rotating ECM bar installed on top of two adjacent electrolytic cells according to an embodiment of the invention.

[0052] FIG. **7** depicts a schematic view of a first embodiment of the ECM bar support means.

[0053] FIG. **8** depicts a schematic cross sectional view detailing the support means according to FIG. **7**.

[0054] FIG. **9** depicts a schematic cross sectional view detailing a second embodiment of the ECM bar support means.

[0055] FIG. **10** depicts a schematic view detailing a third embodiment of the ECM bar support means.

[0056] FIG. **11** depicts a schematic view of an embodiment of the invention disclosing a channelling device or electrode current measuring system applied over a cathode or anode header bar.

[0057] FIG. **12** depicts a schematic view of an embodiment of the invention disclosing the channelling device or electrode current measuring device applied over a cathode or anode header bar and over an anode or cathode blade, wherein the grid represents a mesh used for computational simulation.

[0058] FIG. **13** depicts a schematic view of a group of cathodes or anodes with the channelling device or electrode current measuring device according to an embodiment of the invention, wherein the grid represents a mesh used for computational simulation.

DETAILED DESCRIPTION OF THE INVENTION

[0059] As shown in FIG. **1**, an embodiment of the invention comprises an electrolysis cell (**1**) comprising a plurality of cathodes (**4**) and anodes (**3**) within an electrolyte media, arranged in an alternating manner relative to each other. In the case of the invention, cathodes (**4**) and anodes (**3**) correspond to plates which are arranged parallel to each other. In the vicinity of each plate, preferably, of each one of the cathode plates, sensor means (**5**) are arranged on a sensor bar (**2**) or ECM bar. Such sensor bar, that is part of the ECM system of the invention, is located in the vicinity of the current bar output (or input) from (or to) the cathode (or anode) plate. Such sensor bar and such sensor means need not be in direct contact with the electrodes. Additionally, the ECM bar (**2**) may be located in one of many places of the electrolytic cell (**1**) such as within cell wall, within cell (as shown in FIGS. **2** to **10**), within cell top furniture/insulators, attached to electrodes or others. The sensor bar geometry, specially its housing, may take on different shapes including a rectangular hollow section (RHS) that is approximately the length of the cell, pipe or other. In an embodiment of the invention the sensor bar may be located within the cell using one of the following possible support means, as shown in FIGS. **6** to **10**:

[0060] Using hooks that are attached to the bar by means of stainless steel or plastic zip ties attached over the top of the cell wall under the intercell bus bar, intercell capping board or intercell furniture. These hooks may be glued in place to stop them from moving. This may include the relieving of the capping board or cell furniture to allow for the hooks to pass under.

[0061] Using specially formed brackets that are glued to the inside surface of the cell which allow for the sensor housing to be removed/replaced without replacing the supporting brackets. Brackets may also be bolted in to the cell wall or the cell capping board or cell top insulator block or other components of cell top equipment.

[0062] The hooks or brackets may be made of stainless steel, plastic, aluminium or other appropriate material

[0063] The electrolytic cells may be replaced or manufactured new with a support means such as a specific ledge, slotted groove or holder that provides built-in support and locating features. This design overcomes the issues identified with the prior art by removing the possibility for the ECM bar to be directly impacted by the electrodes, crane bale or other mechanical items as they are positioned or removed from the cell.

[0064] These arrangements are advantageous over the prior art because the design:

[0065] allows for a reduction in the impact load required to be supported by the attachments to cell

[0066] assists the operator in the location of the electrodes into the cell

[0067] allows the bar to be located closer to the electrode header bars improving the accuracy of the system,

[0068] can be installed with minimum down time for the cell/operation

[0069] All embodiments of the fixing methodology identified have been designed to avoid damage of the sensing devices located within the ECM bar.

[0070] The support brackets have been designed to allow for the permanent fixture of an ECM bar to an electrolytic cell. The design provides the physical strength sufficient to sustain the mechanical impacts associated with electrodes moving in and out of the cell whilst maintaining a narrow profile as to avoid restricting the placement/removal of electrodes. Key to the design of the support brackets is a means for maintaining alignment between the sensors in the bar and the predetermined electrode positions. This is achieved with a friction connection between the support brackets and the ECM bar. In some embodiments this also includes the fitment of deflectors used to protect the bar from physical damage whilst assisting the operators with the positioning of electrodes.

[0071] As shown in FIG. **1**, in a preferred embodiment the sensor means (**5**) are connected with pre-processing units (**6**) in order to improve the quality of the signal and to facilitate it reading and interpretation in the following units of the system, preferably such pre-processing unit (**6**) is a microprocessor unit. Then, it may be possible for each individual sensor unit (which comprises one or more sensor devices (**5**) and a pre-processor unit (**6**)) to communicate directly with the central server unit. However, is preferable to have individual sensors within one sensor bar communicating data to a single head controller unit in that bar. The head controller unit (**7**) can then communicate the whole bar's data to the central server unit (**9**). If communication to the central server unit (**9**) is wireless (e.g. WiFi), then this would reduce the number of relatively expensive wireless interfaces by a factor of approximately 60. Other parts of the sensor circuits that can be shared, such as voltage regulators, may also be located in the head controller unit (**7**) for cost advantages. Finally, in a preferred embodiment of the invention it is useful to have one or more locations in the cell house at which all the electrode currents can be monitored. This helps an operator to see immediately which electrode in which cell may have either a low current or a high current, and therefore to rectify the condition quickly. Information can be transmitted from each cell (typically, but not necessarily from the head controller unit—it could be from every sensor) to a central computing device where the information is displayed.

[0072] If the information is received by a central computing device for display, it can also be stored for further subsequent analysis. This analysis can provide historical trend information which can help the operator to identify sources of variance which reduce overall manufacturing quality. By detecting when cell deposition cycles commence (by detecting the removal of one-third of the electrodes at harvesting time), it can also help the operator to identify when a given electrode (and hence cell) has passed enough charge (amp-hours) to be ready for harvesting. The system can maintain a table showing the preferred order in which cells should be harvested. The system can also tell how long it has been since a cell was cleaned, and hence provide a recommendation for the time and order for cells to be cleaned. Therefore, the system of the invention not only treats with the electric current management, but also improves different operative areas involved in electrolytic systems.

[0073] Regarding the main parts of the system, each one of the sensor means (**5**) is in data-communication with the corresponding pre-processing unit (**6**), which in turn is in data-communication with a communication channel, such as a sensor data bus (**13**), whose signals are received by a head controller unit (**7**), located in each one of sensor bars (**2**). The above mentioned data communication may be achieved through many different means including optical, cable or bus. Additionally, signals from each head controller unit (**7**) are received by a communication channel, which may be a main data bus (**8**), which is in data-communication with a central server unit (**9**). The main function of this head controller unit (**7**) is to control communications between the central server unit (**9**) and each one of the pre-processing units (**6**). In this context, the communication from the device, i.e. between the sensors (**5**) and the head controller unit (**7**), to the central server unit (**9**) may be achieved through many different means either wirelessly which may include WIFI or Bluetooth or licensed spectrum and hard wired in the case of LAN. The above mentioned arrangement for data communication is a preferably embodiment, being possible to utilize any combination of the components for other embodiments of the invention. In this sense, there may be a variety of bus, star, ring, mesh, or other communication topologies that could be used, as well as a variety of processing methods and equipments. Then, those skilled in the art will recognise that there are many options for either centralisation or distribution of computation elements, and that communications may be analog or digital, raw or encoded. In particular, any known or unknown communication and processing means can be applied to the present invention. For that reason, the pre-processing unit (**6**), head control unit (**7**) and central server unit (**6**) will be generally mentioned as central units, which interact with each other using any available communication means.

[0074] The sensor means (**5**) comprise electric current sensors and any other type of sensor used for measuring the behaviour of the process and electrodes within the electrolytic cell. Preferably, electric current sensors are magnetic sensors, known as Hall Effect sensors, or any other sensor having a calibratable response within the operating range of electrolytic cells (**1**). In one embodiment of the invention is possible to include other types of sensor means to monitor the condition of each individual cell for electrolyte temperature, acid concentration, pH, ion concentration and conductivity, among other properties. While the ECM bar (**2**) may not be in contact with the electrolyte, it may have probes that extend into the electrolyte to perform such measurements. These probes may have appropriate mechanical support and protection mechanisms in order to improve the sensor response. In another embodiment of the invention, the sensor bar may be able to measure and report the cell voltage, perhaps using wires connected between the adjacent busbars.

[0075] Additionally, in order to be protected, sensor means (**5**), and preferably the pre-processing units (**6**) and any other required electronic equipment of the invention, may be encapsulated in a corrosion resistant material housing. This encapsulation is part of the aforementioned sensor bar or ECM bar (**2**). In this context, a feature of the invention is its resilience to damage associated with acidic electrolyte and acid mist. To achieve this feature the electronics are housed within either a stainless steel, aluminium, FRP or other sealed corrosion resistant material housing. In a preferred embodiment one end of the housing is welded shut and at the other a moulded PVC component is glued onto the housing. This PVC component is where the wireless communications are located (they cannot transmit through a metallic housing). When a metallic housing is used this may be protected by a non-conductive protective sleeve that may be formed (for example, using electrical heat shrink) over the entire length of the bar. This provides some corrosion protection for the electrode current measuring means as well as electrical insulation to stop accidentally forming short within the cell or during installation (safety). In an alternate embodiment the wireless communications equipment may be located external to the housing.

[0076] In this context, other embodiment of the invention includes a magnetic channeling device, which directs and concentrates the desirable magnetic flux over the desirable sensor means, allows reduction of measurement interference, thus getting more accurate data as it increases the signal to noise ratio.

[0077] There are multiple potential arrangements of the channelling device for the channelling of the magnetic flux. In this context it is possible to apply two pieces of ferritic material, paint or any other kind of material related to direct and concentrate magnetic flux, one on either side of the Hall Effect sensors. An alternate arrangement to this includes a ferritic (or similar) ring or horseshoe (**19**) of material that encapsulates three of the four sides of the cathode header bar (**20**) for the purposes of directing and concentrating the magnetic field to sensors beneath the open side of the horseshoe (**19**), as shown in FIG. **11**. In this sense, FIG. **12** shown an embodiment of the channelling device wherein a ferritic device (**22**) is used for channelling the magnetic field over the electrode blade (**21**). In addition, FIGS. **12** and **13** shows a grid (**23**) that represent the mesh used for simulating the behaviour of the channelling device, wherein FIG. **13** shows multiples header bars in representation of multiples electrodes using said device. As mentioned above, by having these devices at each of the cathodes it is possible to significantly reduce the noise associated with the magnetic flux produced by the neighbouring cathode as it stops the extension of the magnetic flux beyond the ferritic material. In a preferred embodiment, the ferritic ring or horseshoe type ring around the header bar would be encapsulated in a corrosion resistant material such as PVC.

[0078] Accordingly, within the housing it is essential that all the sensors (**5**) be spaced at the correct spacing to correspond with the spacing of the electrodes within the electrolytic cell (**1**). In a preferred embodiment, this is achieved with an extruded PVC "carrier" that holds all the Printed Circuit Boards (PCBs) along the length, in which sensors along with other electronics components are mounted. The carrier has pin holes that are at the correct spacing which locates the individual sensor boards. The carrier is then located along the length of the housing.

[0079] There may be environmental variables such as power supply voltage or RF interference that affect the sensor measurements. In a preferred embodiment, the sensor bar comprises means for detecting these environmental variables, and compensate for the effect to ensure that the resulting values are as accurate as possible.

[0080] According to the current measurement, the state of each electric unit, particularly, of each cathode with regard to pre-established threshold values, may correspond to any of the following three states:

[0081] (a) Current below lower threshold, a situation of cathode isolation or high contact resistance.

[0082] (b) Current between lower and upper thresholds or a situation of cathode normal functioning; or

[0083] (c) Current above the upper threshold or a situation of over current.

[0084] For the above described states it can be useful to provide a tracking system for the total charge passed through a particular electrode during a deposition cycle, and to compare this against the mass of the product that is eventually harvested from the electrode. This comparison yields the current efficiency of the electrode, which is traditionally only able to be calculated as an aggregate across the whole tankhouse or cell unit. But detecting problems with individual electrodes (such as poor contacts), or individual electrolytic cells would be desirable. This means that is necessary to record the charge for a given electrode, and track the mass of the product from that same electrode. This requires the ability to identify a specific electrode. In this sense, it is possible that a given electrode may be used in different positions in different cells throughout its life

[0085] To enable the operator to accurately locate anomalies detected by the system, the preferred embodiment provides cathode state and cell state indicators (**10**) within each pre-processing unit (**6**) as well as within each head controller unit (**7**), which in a preferred embodiment of the present invention can be luminous indicators such LEDs, with several colours, associated to each one of the aforementioned cathode functioning states. Consequently, besides an indication of the cathode state which may be displayed on a screen of the central server unit (**9**), a local visual indication for each cathode is generated through cathode state indicators (**10**), and in front of each electrolytic cell (**1**), through cell state indicators.

[0086] In the case of the cell state indication, the indication strategy of the aforementioned embodiment consists of:

[0087] "Normal cathode" indication, if every cathode is under this normal condition; or

[0088] "Low current" indication, if at least one of the cathodes is under this condition (low current) and the rest of the cathodes are under normal conditions (one activated colour); or

[0089] "High current" indication, if at least one of the cathodes is in this condition (high current) one activated colour; or finally

[0090] "Low current and high current" indication, if the current in one or more cathodes is below the lower threshold, and also if the current in one or more cathodes is above the upper threshold (two activated colours).

[0091] In other embodiment of the invention the identification of the cathodes may be achieved with Radio Frequency Identification (RFID) tags but may also include visual indicators such as coloured or raised bands along the devices housing (such as the above mentioned luminous indicators), numbers or other similar written markings on the device, on the cell or on the cell furniture (insulator bars). Also, it is desirable to help an operator find a particular cathode in a particular cell. For example, the system may identify that cathode **47** in cell **36** has a high current. The operator needs to find this cathode, then counting from 1 to 47 may be a tedious process, and it may be advantageous if there were a way to identify quickly which electrode had the problem. Additionally, the housing could also include RFID tags that can be read from above but also by the device below for the purposes of identifying individual cathodes/anodes.

[0092] Information from the server about the progress of deposition cycles on each cathode and each cell with respect to time and amp hours passed will help to inform the operators of the most appropriate sequence for harvesting the plated material from the electrodes. It can also be used to record, automatically, when cells were cleaned (by sensing zero current through electrodes), and hence to recommend a sequence and timings for future cell cleaning activities. It can also provide information about the total inventory of plated product in the tankhouse at any time.

[0093] Once main components of the present invention have been defined, considering both the components from prior art and the ones being the subject matter of the present patent application, it is possible to define the method used by the novel electric current management system. In this context, it is important to mention that because of measuring each cathode current in a cell, by measuring the cathode current of two cathodes (**4**) adjacent to a single anode (**3**) it is possible to infer the amount of current that is passing through that specific anode (**3**). The advantage of doing this is it makes it possible to detect poor anode contacts or anodes that are not operating at the current level that would normally be expected.

[0094] In a preferred embodiment, the outputs from the sensors are conditioned and sampled by the pre-processing units. This includes amplification, correction for power supply effects, filtering and analog to digital conversion.

[0095] In relation to the power supply means of the system, there is a variety of sources such as batteries, separate power connection (whether mains or other), power over Ethernet, connection to the busbars on either side of the cell, connection to busbars associated with other cells, connection to busbars between which there are multiple cells (this will provide a higher voltage which may assist the operation of the device, and provide for the device to continue operation if required even when the local cell voltage is insufficient—such as when that cell is being cleaned), photovoltaic, thermoelectric, piezoelectric, induction if the DC isn't perfectly smooth, induction through a non-metallic section of the bar housing, or any other convenient power source.

[0096] According to an embodiment of the method, in a preferred embodiment the pre-processing unit (**6**) receive the data from the sensor units and performs corrections to the data signal in order to provide an optimal signal transmission through the data communication channel to the following units and corrections to the current measurement caused by the effect of external variables for which the above mentioned compensations can be carried out based on magnetic field fluctuations.

[0097] It may be necessary to apply a transformation step to compensate for several possible variations in the magnetic field sensor, amplifier, reference voltage, and digital to analog conversions. These variations may arise due to the effects of power supply, stray currents, earth's magnetic field, manufacturing and installation tolerances, geometrical arrangements of the cell, magnetic fields from electrode currents in neighbouring cells, intercell contact bar magnetic fields, misaligned electrodes, bent header bars and other effects.

[0098] The prior art includes calculations describing how to make magnetic field corrections for neighbouring electrodes and cells based on theory. The preferred embodiment involves such calculations as are known in the art. A skilled person would understand that parameters of calculations will change with individual cell characteristics. In practice, cells need to be modelled and calculations adjusted.

[0099] Another source of variation that can arise is that electrodes may not always be placed (by the crane) in exactly the correct horizontal location on the cell busbars. If the electrode is not directly above the sensor, the contribution to that sensor's field will be lower than it should be. In a preferred embodiment, there is not a single sensor (pair), but a linear array of magnetic field sensors or pairs. The outputs from these sensors can be compared to find the sensor with the highest reading (after correcting for perhaps higher contributions from neighbouring electrode currents) can be assumed to correspond to the horizontal location of the electrode. This knowledge can be used to compensate not only for the reduced reading of the field by that electrode's own sensor, but more importantly the changed contributions to fields measured by neighbouring sensors.

[0100] Then, the measured currents are compared with the lower threshold current I_{min} and upper threshold current I_{max}.

In one embodiment, we might pre-establish I_{min} and I_{max} for the entire system. In another, we might dynamically adjust these values. For example, if there is a short in a cell, then a large fraction of the cell current will flow through the short, and the current through other electrodes will be less than nominal. If we had pre-established thresholds that were fairly sensitive, a short in one electrode might result in one or more other electrodes in the cell being erroneously categorized as poor contacts. But if we recalculate the minimum threshold dynamically, this should not occur. These thresholds I_{min} and I_{max} may also be adjusted manually or automatically based on a change in the rectifier current.

[0101] One embodiment sees the ECM bar being located beneath the anode header bars on the anode connection to the main ICCB side of the cell. This may be preferred where geometry provides a greater influence of anode currents on magnetic fields than the influence of cathodes. In that embodiment the shorts and bad contacts are detected by anode currents rather than cathode currents.

[0102] In this sense, the above mentioned embodiments and the following features of the invention comprise the implementation of various improvements in relation to the functionality, adaptability, control and/or human interface, of metallurgical systems wherein those systems are preferably electrometallurgical systems such as electrorefining or electrowinning systems. Additionally, such improvements may be applied to different types of systems in which the management of current passing through the electrodes is a key factor in the system operation and performance.

[0103] Accordingly, in a preferred embodiment of the application, the above mentioned improvements are implemented in electrometallurgical systems having electric current measurement devices such as hall effect sensors, for measuring the current through an electrode or a plurality of them as for example in an electrolytic cell or a tankhouse. In this regard, these improvements are directed to optimize both performance and operation of said at least one electrode such as to optimize the measurement of the current flowing through it.

[0104] The following sections define the improvements in relation to the systems, devices and/or means that are introduced in order to implement such improvements. For description purposes only, the following sections classify the main improvements according to the main area of impact, being important to bear in mind that in most cases improvements are related to more than one specific field. Therefore, the following description should not be considered a limitation on the type of improvement introduced by the various systems, devices and/or means described herein. In addition, it is relevant to indicate that the following improvements may be applied to metallurgical systems separately or as any possible combination thereof.

Functional Improvements

[0105] As already mentioned, functional improvements are intended to optimize the operation of metallurgical systems by maximizing its reliability, and therefore, the final production said systems are intended.

Electrode Correct Location and Misalignment

[0106] As previously indicated, in some tankhouses or cells, the system (crane, cell furniture, insulating blocks) for locating anodes and cathodes into the cell may not result in these electrodes being placed in exactly the same location every time. That is, the electrodes are not physically located by cell furniture or similar devices. Therefore, if the variation in the electrode placement is significant, it may be appropriate to have at least one or multiple magnetic field sensors in order to measure said variations. Then, by analysing the magnetic fields experienced by the sensors, it is possible to estimate the most likely offset of the electrode header bar from its nominal position. Accordingly, any offset indicia detected by a specific sensor will mean that the current in the corresponding header bar has a slightly different effect on the field experienced by neighbouring header bars, which means that the electric current measurement might be affected. Consequently, if the above referred offset is known (or at least is estimated), said knowledge can be used to modify algorithms described by others in the prior art to better compensate for the fields due to currents in neighbouring electrodes.

[0107] The degree of misalignment can also be reported as a metric for the use of cell house operators.

Double Contact Systems Measurement

[0108] In the simplest cells, anodes are connected to a bus bar on one side of the cell (without loss of generality said side will be called the right hand side of the cell), and cathodes are connected to a bus bar on the other (left hand) side of the cell. The left hand end of the anode header bar is insulated, and no current flows in that part. This means that when measuring cathode header bar currents, the only currents that flow that impact magnetic fields as seen by the sensors, are due to cathode currents.

[0109] However, in some cells, often known as Double Contact cells, each electrode header bar may be connected on both sides. While the anodes are still "fed" from the right hand side, the left hand sides of all the anodes are connected by an anode "balance bar" sometimes also known as an "equalizer bar". Similarly, the right hand sides of all the cathode header bars may also be connected to a cathode balance bar. If there happens to be a bad connection between a given anode and the main anode bus bar, current can still flow to said anode, by first flowing through other anode header bars, then the anode balance bar, and then into the header bar of the given anode. The same applies to cathodes. A double contact system is described in U.S. Pat. No. 7,993,501 (Freeport McMoRan Corporation), and U.S. Pat. No. 7,854,825, the disclosures of which are incorporated by reference in their entireties.

[0110] In cases where double contact systems are used, the magnetic fields generated in the vicinity of the cathode header bars may correspond not only to the currents in those header bars, but also to currents in the anode header bars.

[0111] Then, if a double contact system is used, it is possible to locate additional sensors directly aligned with (either under or over) the anode header bars. Using a slightly more sophisticated neighbouring electrode compensation algorithm, this will allow measurement of the currents in both the cathode header bars and the anode header bars. It will be useful to note, for calibration purposes, that the sum of the currents in the anode header bars (on the balance bar side) will be zero—that is, currents will enter the balance bar from some anode header bars, and will leave the balance bar into other anode header bars.

[0112] Using sensors aligned with the anodes assists with two aspects: (a) it is possible to get a more accurate estimate of the current in the cathode header bars, which is the most operationally useful quantity; and (b) estimates of the anode header bar balance bar currents can help to identify where there are bad connections between the anodes and main intercell contact bar. Thus the EMC design allows for the measurement of the current going through the adjacent electrodes on the balance bar for the purpose of correcting for the additional anode balancing current magnetic field and to provide a method of assessing current distribution issues within the cell.

Voltage Measurement

[0113] Another improvement implemented by the present application is related to multiple voltage measurement at various points along the electrical circuit of an electrolytic cell/plant, wherein voltage measurement means are installed.

[0114] Voltage measurement probes that are connected into an electrolytic circuit at various points including trunk bus bar, trunk bus risers, and different points along the length of an intercell contact bar on different contact bars, allow for the monitoring of individual cells and therefore, different voltage drops through the circuit. This helps improve the management of the overall circuit since voltage drops and corresponding power losses can be determined. Thus, cell voltage drop can be used in combination with other measurements, such as temperature and metal concentration, as a means of assessing deposition quality as is discussed further below. Accurate monitoring of cell voltage is also important for monitoring the overall performance of anodes, for example, titanium mixed metal oxide (MMO) anode performance. Titanium MMO anodes are used for their low voltage requirement as compared to traditional lead based anodes. A change in cell voltage can indicate an issue with the coating of the anodes within the cell. During maintenance operations it is possible for the cell to generate a voltage through the reverse plating of metal, if undetected this can result in permanent damage to the performance of titanium MMO anodes.

Automatic Adjustment of Short/Poor Contact Thresholds

[0115] In its simplest form, the system may classify a cathode as being in a "short circuit" condition once the current exceeds a particular static predetermined threshold value. However, it is better for such thresholds (for short circuits and bad contacts) to be dynamically calculated, using various parameters.

[0116] During a harvesting cycle, it may be that ⅓ of the electrodes are removed from the cell. This can mean that the other electrodes should expect to see 50% higher currents (assuming the rectifier total current remains constant). This means that the short threshold should be increased, so that this normal situation does not create spurious indications of shorts.

[0117] Similarly, if the rectifier current is decreased, each cathode should see a smaller current. Even if the distribution is perfect (i.e. no shorts or bad contacts) this may, depending on the threshold, result in classification of poor contacts.

[0118] Thirdly, if there is a short circuit in the cell, a larger-than-usual fraction of the total cell current will flow through that short, leaving less current to flow through the others. This might mean that some of the other electrodes are classified as bad contacts, even though they are actually operating nominally and there is no operational fault in those electrodes.

[0119] Then, according to the present application the thresholds for shorts and poor contacts can be calculated, by calculating means, as a function of (a) the total cell current, (b) of whether electrodes are missing due to harvesting, and (c) the existence of shorts or poor contacts elsewhere in the cell. Therefore, the present application establishes dynamic thresholds depending on the above parameters, which improves the reliability of the system management due to the continuous calculation of the thresholds.

Pattern Detection to Identify Shorts/Poor Contacts

[0120] The classification of a cathode as being in a short condition has been described as an instantaneous comparison of the cathode current with the threshold—even if that threshold may not be a static number.

[0121] However, if a cathode has a slightly higher contact resistance on the bus bar or is at larger distance from its neighbouring anode, it may have a slightly lower current, and yet still develop a short. By observing a sequence of current measurements that increase sufficiently over time, it may be possible to conclude that the cathode is entering a short condition, even before it reaches the actual shorts threshold.

[0122] Also, as shorts form, they can dissolve and then reform leading to an oscillating current early in the short's life. An embodiment of the ECM bar may be configured to detect such oscillations to classify a cathode as entering a short condition.

[0123] Accordingly, the present application provides pattern detection means in order to provide a reliable short/poor contacts estimation algorithm, which helps to improve the system management.

Protection Means Against Physical Damage and Disruption with Electrode Movements

[0124] A significant improvement incorporated by the present invention includes the incorporation of a protection means or multiple protection means installed along the length of an ECM bar to protect it from mechanical damage and to avoid disruption to normal electrode movements, wherein the ECM bar contains the electric current measurement means. In this context, FIGS. **3** and **4** detail one kind of protection means designed as a deflector (**11**), wherein its design helps to avoid damaging the ECM bar (**2**) during the normal electrolytic cell crane operations and acts to push electrodes towards their correct location as they are lowered, e.g. during the introduction of electrodes (**3**, **4**), which can result in damaging the ECM bar (**2**) by hitting it with an electrode. Accordingly, it is important to highlight that the deflector design described in FIGS. **3** and **4** does not restrict the design of the protection means, being possible to use any kind of design that protects the bar from hits and other kinds of physical damage.

[0125] In addition, the protection means can be secured to the support means, the bar, or directly to any standard cell feature. This includes, but is not limited to the cell furniture, cell wall or capping boards.

[0126] As previously discussed, the prior art does not describe a design to overcome interfering with electrode movement and avoiding bar damage. The conditions in the cell are extremely harsh and robustness of design is critical. An identified means of ensuring no disruption to normal electrode movements and ECM bar damage is for the support means to include a deflector. The deflector must be capable of managing the weights of the electrodes as they are lowered at the rates that the crane system lowers them with the corresponding load. The load must not be transferred to the sensor bar but must be absorbed through transference to the cell wall and minimised through the angle of the surface of the deflector. The deflector must also protect the brackets that support the ECM bar.

End Seal Arrangement

[0127] Electronic components could be potted inside a material that allows for the bar not having an external housing. This potting material may consist of an acid resistant epoxy or other potting material.

[0128] Another improvement of the invention consists in including sealing means in one or both ends of an ECM bar (**2**) as shown in FIG. **5**, wherein said sealing means provide protection to the devices located within the bar. In this sense, according the FIG. **8** the sealing mean is comprised by a backing plate (**12**), a gasket (**13**), an end cap (**14**) and fastening means (**15**) like screws or any other attachment device.

[0129] Then, the seal arrangement of the invention provides sealing of one or both ends of the sensor bar by bringing together the backing plate (**12**), gasket (**13**) and end cap (**14**), so the gasket is sandwiched between the backing plate and end cap. Later, the fastening means (**15**) are loosely threaded through the end cap, gasket and into the backing plate, assembling the seal. Said seal assembly is inserted into the bar (**2**) or housing into its correct location. And finally, the fastening means are tightened reducing the distance between the end cap and backing plate, which results in reducing the thickness of the gasket. Due to Poisson's ratio, this results in increasing the width and height of the gasket. This increase in dimension creates the required seal between the seal assembly and the inner wall of the bar.

[0130] The main advantage of providing an end seal arrangement in one or both ends of an ECM bar is that it enables the bar to be sealed to protect the internal components, for example from preventing the electrolyte to contact electronics located inside the bar, or any other thing that can damage said components. In this sense, the end seal arrangement allows for the electronics to be slid into the bar, seal the bar and the main cable to/from the bar to exit out through a cable gland.

[0131] In addition, the seal arrangement it is also capable of being removed for servicing if required.

[0132] This sealing method can be used with a bar of any profile including square, round, rectangular, and angled as examples.

[0133] The design of the ECM bar requires the inside of the bar to have a profile that does not preclude the insertion of the electronics and support carrier into the bar. The secondary limitation in the profile of the bar is that it needs to be as narrow as possible to avoid interference with the crane/electrode movements in and out of the cell whilst remaining in close proximity to the electrode header bars. These two constraints preclude the use of flanges or threaded fittings for the purpose of providing a seal against the harsh operating environment and the electronics contained within the ECM bar. The use of a plate welded over the end of the bar was also impractical due to the heat generated during the welding process and the potential for damage to the electronics housed within the bar during this process.

Multiple ECM Bars Per Central Unit or Controller

[0134] Another improvement includes using controller devices to mediate the communications between each bar and the central server. For example, the central server may communicate wirelessly to the controller, but communications between the controller and the ECM bar(s) may be wired. This means that, in another embodiment, a single controller device may be shared by several ECM bars. In this context, the controller device may have separate communication buses to communicate with different ECM bars, or all bars may share a single bus.

[0135] The central server may communicate directly with the ECM bars without any intermediating controller if such a connection topology and protocol is suitable for the plant.

Electric Current Distribution Measurement

[0136] In one embodiment there may be two ECM bars in each electrolytic cell, wherein said bar may be specifically located on opposite sides of the cell. The purpose of this embodiment is to allow for the measurement of the cathode currents (and anode balance currents if in a double contact system) on the cathode contact side and on the opposite side of the cell the anode currents (and cathode balance currents if using a double contact system). Thus, this improvement allows measuring all the in and outflows of electrical currents through the respective electrolytic cells and obtain the full current distribution in the cell. The evenness of the current distribution is a quality measure for the cell performance since even current should lead to equal deposition on each of the cathodes which maximises deposit weight consistency, deposit surface morphology, minimises short circuit tendency and maximises current efficiency.

Concentration and Other Sensors

[0137] According to another improvement, the ECM bar of the invention considers the possibility of including concentration and other sensors as part of the ECM system. In this sense, the ECM bar can incorporate instrument readings for temperature, metal concentration, electrolyte flow or level, additive concentration, conductivity etc within specific cells.

Combining Measured Values to Determine Quality of Electrolytic Performance or Electrolyte Quality

[0138] The cell voltage increases with the total cathode current in the cell. The cell voltage is also affected by cell temperature, electrolyte composition and additive dosage rates, electrode spacing and anode age/condition/type. If these parameters are at target levels the relationship between cell voltage and current is predictable and this relationship can be best determined for any specific tank house through small scale testwork. Any deviation from this predicted relationship indicates that cell conditions are not optimal and actions should be taken to address. The ECM system measures total cell current and cell voltage and can be used as a measure of quality. If any of the other parameters are measured by the ECM system (e.g. temperature, concentration) then the ECM system can utilize that data to provide further definition of the probable issues responsible for poorer than optimal performance.

Estimation of Current Efficiency and Current Consistency for Each Electrode

[0139] Since the ECM system measures the current flow and detects the harvesting time of individual electrodes, in combination with a weighing system that weighs individual cathodes after (and perhaps before) harvesting, the ECM system can calculate the current efficiency for individual cathodes. It can track the individual electrode positions in a cell to determine whether current efficiency has a consistent trend for that position—which may indicate neighbouring anode problems, or in combination with an RFID system (or other cathode identification system) it can determine whether trends are due to issues with a specific cathode plate. In a less complicated fashion, the system can track the current flows in individual electrode positions and determine whether from one cycle to the next a trend is evident or whether for a specific cathode (with an RFID or other cathode identification system in place) there is a trend in current which may indicate an issue with the specific electrode.

Adaptability Improvements

[0140] As already mentioned, the adaptive improvements are intended to optimize the adaptability of metallurgical system where the current management is a key factor. In this context, the following improvements seek to maximize the flexibility of existing and/or new metallurgical systems.

ECM Bar for Measuring Two Adjacent Cells

[0141] One of the improvements for the adaptability of the system includes mounting one ECM bar on top of an electrolytic cell (or any of the cell features including but not limited to cell furniture, cell walls, or intercell contact bar), supported by brackets that act as hinges, wherein said ECM bar has the potential to measure two adjacent cells by rotating it into the correct position. This allows installation of one ECM bar per two adjacent cells in order to reduce cost of measuring the electric current. FIG. **6** shows an example of an ECM bar (**2**) installed over two adjacent electrolytic cells (**16**, **17**) wherein said bar is attached by support means (**18**) comprising rotating means (**19**) for rotating it around one axis, wherein said support means (**18**) can be either attached to any of the existing cell features. These include, but are not limited to, the cell furniture, the cell walls or the intercell contact bar. In addition, the ECM bar (**2**) can be fixed to said support means (**18**) using cable ties or other means of attachment. The rotating means (**19**) allow the bar to be moved out of place when electrodes need to be removed from the cell or modifications to the electrode placement need to occur (thus the hinged arrangement also acts as a protection means for the ECM bar). This configuration results in the possibility of sitting said ECM bar over the electrode header bars of one cell at a time.

[0142] In addition, the ECM bar of the above configuration may contain a device that allows it to determine which orientation the bar is sitting in, which facilitates the operation of the referred adaptability improvement.

ECM Bar Outer Compartment Material.

[0143] The outer compartment of the ECM bar may be constructed from any material including stainless steel, other metals, plastic or composite. This includes materials that contain a sacrificial outer coating or sheath that is replaced at time or using condition based frequencies.

In-Built ECM Bar

[0144] The ECM bar can be incorporated into the design of a tankhouse's cell walls or cell furniture. A pocket of sufficient volume would need to be made available in either the cell walls or cell furniture for the device to sit. This kind of arrangement is suitable for new cell designs, specially directed to incorporate electric current measurement devices.

Support Mean Designs

[0145] The ECM bar can be supported by support means (**18**), as brackets or any other means that allow supporting the bar, wherein said support means (**18**) can be attached to the cell furniture as shown in FIGS. **7** and **8**, fitted underneath the capping board of the cell as shown in FIG. **9** and/or attached to the exposed surfaces of the capping board as shown in FIG. **10**. Accordingly, the support means (**18**) can be either bonded to the cell furniture, attached using fasteners, or have a clip like device that attaches it to the cell furniture, or a combination of these as shown in FIGS. **7** and **8**; can be either bonded to the top of the cell wall, or have a clip like device that attaches it to the back of the wall, or both as shown in FIG. **9**; and can be either bonded to the capping exposed surface, or attached using fasteners, or both as shown in FIG. **10**.

[0146] The ECM bar can sit inside each support means channel, with grub screws used to fix the bar into position and/or the ECM bar can be fixed to the brackets using cable ties or other means of attachment.

[0147] The above features might depend in the kind of cell that is going to be adapted in order to use ECM bars. In this context, FIGS. **7**, **8**, **9** and **10** describe different support means (**18**) according to the above description.

Portable ECM Bar

[0148] Another improvement consists of providing a portable version of the ECM system wherein the bar is not permanently fixed to the cell and can be moved around the tankhouse, being able to be placed down on top of the electrodes, or perhaps attached to a handle so that an operator can move the instrument to the appropriate place. The portable bar may be the full length of the cell with sufficient sensors for the number of electrodes in the cell or a short version to measure the field around for example 5 or 10 adjacent electrodes, with the understanding that the estimates of the currents in the electrodes at each end may be less accurate due to the contributions of fields from neighbouring electrodes that do not have sensors. In this context, the portable ECM bar allows improving the system adaptability by being possible to use said bar as an instrument in different electrolytic cells.

Modular ECM Bar

[0149] In the same context described above, the ECM bar could be made up of a multiple number of smaller bars that can be either physically connected or positioned end to end to each other.

ECM Bar Powered from the Electrode Header Bars

[0150] Other adaptability improvement consists in powering the ECM bar from the electrode header bars rather than the ICCB's or mains power when utilizing an on top hinge type bar positioning arrangement. This helps to reduce using different power sources which improves the management of the system.

Integration with Other Systems

[0151] Some tankhouses have other systems which yield certain data about tankhouse operations. For example, there may be an optical inspection system which assesses the quality of the metal plated onto each cathode, or a system that weighs the metal harvested from each cathode. When these data are combined with data from the system of the invention, information of even greater value can be obtained. For example, it may be discovered that particular optically-detected defects occur more frequently from some cells than others, or some cells yield less production than others. Some tankhouses may have cathodes with RFID, barcode, or other identifiers, that can be sensed by a crane, stripping machine, or other device. When this data is integrated with information from the current sensing system it may be possible to detect (for example) that a certain cathode experiences more variable current, bad contacts or shorts more often than others.

[0152] In this context, the current sensing system of the invention could be also integrated with other systems to form an integrated tankhouse management system that provides unified overall management and control of all (or many) aspects of the tankhouse. Other systems may include cathode tracking systems, stripping machine, optical inspection, product weighing, flow monitoring, electrolyte analysis, pumping, scheduling, rectifier control, and electrolyte additive management.

Control Improvements

[0153] As already has been mentioned, the control improvements are intended to optimize operation and maintenance of metallurgical systems wherein the electrode current management is a key factor. In this context, the following improvements seek to enhance control and system reliability.

Shorts Prioritization

[0154] In traditional tankhouse operations, operators may scan the cells systematically, detecting and clearing shorts and bad contacts. With a real time current monitoring apparatus, it is possible to spend more time clearing, and less time detecting shorts and bad contacts.

[0155] In this context, the system has prioritization means that can recommend an optimal order for clearing shorts, using parameters such as: the age and severity of the short, the distances that an operator has to walk between the shorts, the number of operators on shift and other parameters related to any of the above indicated improvements.

Calibration

[0156] 1. The need for calibration: The magnetic fields experienced by the sensors is dependent not only on the currents in the relevant electrode header bars, but also the earth's magnetic field, and possibly fields due to currents in other conductors (e.g. bus bars) that may, or may not, be directly related to cell operation. If there are fields from bus bars that supply the cell current, these may vary as total cell current varies. It may be possible to derive a theoretical correction for such fields, or it me be necessary to use an empirical technique (i.e. calibration) to correct for them.

[0157] Calibration typically involves measuring the current in every cathode header bar along the length of a cell. If the cell uses double contact arrangements, it may require measuring every anode header bar current as well, which can be tedious.

[0158] 2. Using harvesting for initial calibration and updates: Checking the calibration of the system requires comparison of the system's estimate of the current with an independent measurement of the current. If there is any difference, then adjustments can be made to system parameters. Most of the time, it is tedious to acquire independent measurements of the currents (for example, with a hand held clamp meter). However, during the harvesting cycle, it is certain that the current through some of the cathodes is zero, since the cathodes are physically removed. This information can be exploited during initial commissioning of the system, and throughout its service, to set and fine-tune some of the calibration parameters. Importing of rectifier current values either manually or by importing from site systems provides an additional known value that can be used during initial commissioning of the system, and throughout its service, to set and fine-tune some of the calibration parameters

Human Interface Improvements

[0159] As mentioned above, the improvements to the human interface of metallurgical systems are designed to optimize the display of electrodes, cells and/or tankhouse information, which consequently optimize the management and control performed by the operator. In this context, it seeks to maximize the ease of operation, enhancing control and system reliability.

Short Circuits and Poor Contact Electrodes Identification

[0160] Among the improvements provided by the present application are visualizing means to visualize the status of electrodes, cells, and/or tankhouses. Said means also comprise control means that allows operators to take actions according to the visualized status.

[0161] In an embodiment of this improvement is a method of using a steerable laser pointer mounted to the underside of the tankhouse crane(s) or supported independently that highlights electrodes that are operating outside of their preferred range (short circuit or poor contact). Then, said kind of visualization means allows operator to easily identify a specific electrode within the tankhouse. In addition, this method could incorporate laser distancing or laser localization.

[0162] In another embodiment of the invention, a visualization means such as an LED(s) mounted/located within the cell furniture or in close proximity to the electrodes, allows for identifying specific electrode status. Said status may be normal operating, high current (short), low current (bad contact) and other parameters as necessary.

Electrodes/Cells Status Visualization

[0163] Another embodiment of the above description also includes a status means that, as described above, allows knowing the status of a specific electrode/cell. In this context, the present invention provides status means for showing relevant information to the users of the human interface devices. This kind of status means helps the operators to take the correct actions regarding the operation status of the system.

[0164] In an embodiment of this improvement, a status means includes using augmented reality glasses that allow the operators to see the status of the electrodes and cells as they move through the tankhouse. This may utilize lasers or GPS or other localization technology to determine the location of the user and hence which cell they are looking at.

[0165] In addition, the present invention also includes the use of image recognition software on a tablet or laptop computer with a camera, or any other visualization device, wherein said device superimposes the identification number of each of the electrodes or the ECM system status of each of the electrodes on a real time image of a cell. In an embodiment of this improvement the system may use GPS or other localization capability as well.

Alarms and/or Reports

[0166] Another improvement of the present invention includes allowing operators to configure one of more alarm mechanisms or alarm means (including visual indicators, audible, emails, pagers, and short message service) for the system to indicate when shorts or other operational problems arise.

[0167] Information may be presented through any kind of visualization device, for example an on-screen display, a printed report, or in text in email or SMS, or even computer generated voice.

[0168] In relation to the above improvements, optical indicators or visualization means at each electrode in each cell in the tank house may be used to indicate the location of problems. This may use lights (e.g. LEDs) physically located near the electrodes as described above. An alternative may be a roof/wall mounted laser system, such as those used for light show entertainment, which can be configured to "draw" an indication on the floor of the tankhouse, as described in one of the preceding improvements. In the simplest embodiment this may just be a status light located at the end of each cell to provide an alternative means of identifying the cell with a problem to be addressed:

[0169] Such an alarm system could also be matched with an automatically generated report that provides a snapshot of the operational health of the tankhouse, including a prioritised list of corrections to be made.

Auto Detection of Harvesting

[0170] Finally, as indicated above operators will periodically need to harvest the plated metal from the cathodes. In electrowinning operations, this is typically performed by lifting out ⅓ (or ½) of the fully plated cathodes from the cell, delivering them to the stripping machine, and then putting some blank (unplated) cathodes back into the cell in their place. Then, the next ⅓ of fully plated cathodes are removed, and replaced with blanks. Finally, the last third is harvested. According to this improvement, the measurement system is able to detect, even in the presence of noise, when these events are occurring, and to record these events. In plants with manual cranes and no cathode-tracking system, there may be no other record of when each cathode is harvested. This information can be useful for tracking down problems, for avoiding situations where cells are not harvested on the correct time frame, as well as documenting and planning the activities in the tankhouse.

1. An electric current management (ECM) system for improving the operation within electrolytic plants, comprising:

at least one electrolytic cell having at least two electrodes within an electrolyte medium;

a plurality of sensor means for measuring the current passing through one or more electrodes, wherein said sensor means are located inside at least one electric current management bar;

one or more ECM bars installed in one or multiple operating electrolytic cells,

support means for supporting the ECM bar or bars for each cell,

a protection means for the ECM bar.

2. Electric current management system according to claim **1**, wherein the protection means comprises a deflector installed above the ECM bar.

3. (canceled)

4. (canceled)

5. (canceled)

6. Electric current management system according to claim **1**, wherein the support means and the protection means are retrofitted to an existing cell or wherein the support means and protection means are in form of a permanent fixture of the cell, the cell furniture or the cell insulators.

7. Electric current management system according to claim **1**, wherein the support means and protection means may be attached to the cathode ventilation hoods that rest on top of the cells or to flaps that may be attached to the side of such hoods, wherein the ECM bars would be lifted off the cell with the ventilation hood when cells are to be harvested.

8. (canceled)

9. Electric current management system according to claim **1**, wherein the ECM bar comprises a corrosion resistant and sealed housing that encapsulates the sensor means and optionally other electronics equipment.

10. (canceled)

11. (canceled)

12. Electric current management system according to claim **9**, wherein the housing is protected by a non-conductive sleeve.

13. Electric current management system according to claim **1**, further comprising one or more sensor means for measuring the variation due to electrode incorrect location and/or misalignment in order to determine the offset of the electrode header bars from their nominal positions.

14. Electric current management system according to claim **1**, wherein in case of using a double contact system additional sensor means are directly aligned with anode and cathode header bars for measuring the magnetic field near both sets of electrodes.

15. (canceled)

16. (canceled)

17. (canceled)

18. Electric current management system according to claim **1**, further comprising an internal or external weighing system for measuring the cathode weights before and after harvesting.

19. Electric current management system according to claim **1**, further comprising a tracking system that records the charge passed through a particular electrode, wherein said electrode may be used in different positions in different cells throughout its life.

20. (canceled)

21. (canceled)

22. (canceled)

23. Electric current management system according to claim **1**, further comprising integrating means for integrating with other systems for providing an integrated tankhouse management system that provides unified overall management and control of all or many aspects of the tankhouse.

24. Electric current management system according to claim **1**, further comprising prioritization means that recommend an optimal order for clearing shorts and/or resolving different issues by considering the age and severity of the issue, the distance that an operator has to walk between the issues, the number of operators and other parameters.

25. Electric current management system according to claim **1**, further comprising electrode state and/or cell state indicators, which can be luminous indicators such as LEDs, RFID tags, or any other type of indicator useful for indicating the different states of the electrode and/or cell and for identifying the exact location of the issue, wherein said state and location can be visualized in display devices.

26. (canceled)

27. An electric current management system for improving the operation within electrolytic plants comprising:

at least one electrolytic cell comprising at least two electrodes within an electrolyte medium;

a plurality of sensor means for measuring the current passing through one or more electrodes, wherein said sensor means are located inside at least one electric current management bar;

one or more ECM bars installed in one or multiple operating electrolytic cells,

support means for supporting the ECM bar or bars in each cell;

a magnetic channelling device for the channelling of the magnetic flux.

28. (canceled)

29. (canceled)

30. (canceled)

31. An electric current management method for improving the operation within electrolytic plants, the method comprising the step of:

measuring the current passing through one or more electrodes in contact with an electrolytic medium by a plurality of sensor means located inside an electric current management bar part of an ECM system, said ECM system further comprising one or more ECM bars installed in one or multiple operating electrolytic cells; a support means for supporting the ECM bar or bars in each cell; a protection means for the ECM bar.

32. (canceled)

33. Electric current management method according to claim **31**, wherein sensor readings from one or more sensor means are used for compensating for the non-correct location of one or more electrodes.

34. Electric current management method according to claim **31**, further comprising comparing the measured currents with pre-established threshold currents.

35. (canceled)

36. Electric current management method according to claim **34**, wherein the threshold currents are dynamically adjusted based in the total cell current, whether electrodes are missing due to harvesting cycles and in the existence of shorts or poor contacts elsewhere in the cell.

37. Electric current management method according to claim **31**, further comprising pattern detection means for identifying shorts and poor contact patterns for estimating the occurrence of said operation issues.

38. Electric current management method according to claim **31**, further comprising measuring all the in and out flows of electric current for obtaining the full current distribution in the cell.

39. Electric current management method according to claim **31**, wherein the step of measuring comprises measuring the cathode current of two cathodes adjacent to a single anode, being possible to infer the amount of current that is passing through that specific anode and therefore detect poor anode contacts or anodes that are not operating at the current level that would normally be expected.

40. (canceled)

41. (canceled)

42. (canceled)

43. Electric current management method according to claim **31**, further comprising the step of weighing the individuals cathodes after or before harvesting for measuring the current efficiency and consistency, and establishing if there is a trend for specific electrodes positions.

44. Electric current management method according to claim **31**, further comprising the step of prioritizing an optimal order for clearing shorts and/or resolving different issues by considering the age and severity of the issue, the distance that an operator has to walk between the issues, the number of operators and other parameters.

45. Electric current management method according to claim **31**, further comprising the step of calibrating the electric current management system, wherein the calibrating step comprises using the harvesting cycles for initial calibration and updates.

46. (canceled)

47. Electric current management method according to claim **31**, further comprising sending alarms and/or reports for indicating the operation issues, wherein said information may be displayed using any kind of displaying or visualization device, and further comprising detecting and recording harvesting, cell cleaning and electrode straightening events, which are identified and utilised to assist operation of the tankhouse.

48. (canceled)

49. (canceled)

50. (canceled)

51. (canceled)

52. (canceled)

53. (canceled)

54. (canceled)

55. Electric current management method according to claim **31**, further comprising the steps of:

transmitting measured data to central units through communication means; and

processing the measurements in central units.

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