

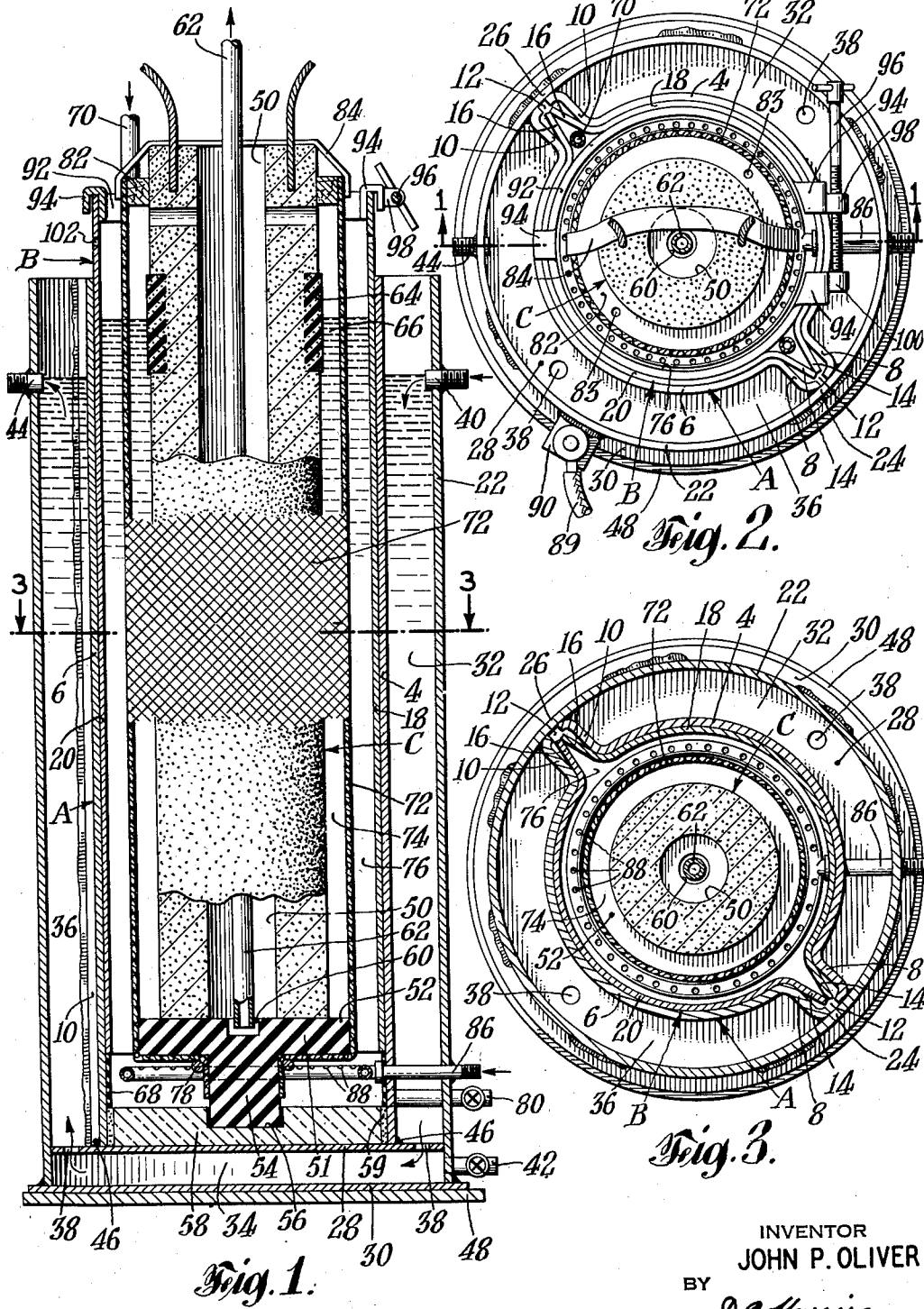
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ELECTROLYTIC CELL

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ELECTROLYTIC CELL

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This invention relates to an electrolytic cell adapted for continuous operation, to handle a continuous flow of electrolyte, to give an effluent of constant composition, and particularly adapted to the electrolysis at high current efficiencies of electrolytes which are to be oxidized or reduced at one electrode without lowering the current efficiency at the other electrode. Other matters relating to general improvements in the construction of electrolytic cells will be understood from the following description and accompanying drawing, and will more particularly be pointed out in the claims.

In the drawing:

Fig. 1 is a longitudinal section through the cell taken on the line 1—1 of Fig. 2;

Fig. 2 is a plan view of the cell; and

Fig. 3 is a section on line 3—3 of Fig. 1.

The cell and its operation will be described in connection with the continuous treatment of ferrous sulphate solutions where the desiderata are the deposition of a portion of the iron from the solution and the oxidation of another portion of the iron and the delivery of a constant flow of effluent of a substantially uniform composition. The cell is particularly adapted for the electro-winning of products, for instance metals as distinguished from the mere transfer of metals through the electrolyte as in a purely plating action.

In its general aspect, the cell comprises a container designated generally as A which serves, in the cell shown, as an auxiliary or secondary plating surface, a plural part primary plating surface designated generally as B, and a porous anode designated generally as C. The ferrous sulphate solution continuously enters the cell in such a manner that it is the electrolyte, and the effluent is withdrawn from the cell after passing through the anode. The anode may suitably be of porous carbon or graphite. Suitable porous carbon is described in patent No. 1,988,478, issued January 22, 1935, to B. E. Broadwell and L. C. Werking, and in the article entitled "Fabricated Porous Carbon," by L. C. Werking, appearing in vol. 74, page 365 (1938) of the Transactions of The Electrochemical Society. Anodes of porous carbon of grades 30, 40, and 50 as described in the article are preferred, being characterized by pores which are large enough to pass the desired quantity of liquor and to remain unplugged during the normal operation of treating the ferrous sulphate solution but yet sufficiently small that there is enough surface area at the walls of the pores which make contact with the moving elec-

trolyte to ensure that, if the cell is properly operated, the solute, in this case ferrous sulphate, will act as anodic depolarizer, discharge potential will be reduced, anodic gas (oxygen) formation will be prevented, and destructive attack on carbon or graphite anode minimized or entirely eliminated. A finer carbon, designated as grade 60, made available since the patent and publication, capable of retaining particles larger than 0.00047 inch, may also be used. Coarser grades, e. g., 20, are not excluded but, in general, grades 30-50 are preferred.

The container A is preferably of metal so as to be conducting and so that the cell may efficiently be heated or cooled; it is shown as comprising two parts 4 and 6 which hold the electrolyte. Each container part has longitudinal flange portions 8 and 10 which are spaced to provide longitudinal recesses 12 to receive longitudinal flanges 14 and 16 of the parts 18 and 20 of the primary plating surface B. The flanges 14 and 16 join the parts 18 and 20 in a smooth curve to minimize treeing of the deposited iron. For convenience, the parts 4 and 6 are separate and the outer edges of the flanges 8 and 10 are welded or otherwise joined together or to a shell 22 with a fluid-tight juncture. In a cell of a size suitable to form one unit of a bank of cells, the shell 22 has an inside diameter of 14 inches and the recesses are 1 3/4 inches deep and 3/8 inch wide; and the flanges 14 and 16 are 1 3/4 inches wide so that either part 18 or 20 will remain in place without the other. More open recesses are shown on the drawing for clarity, thus requiring that the portions 24 and 26 of the shell 22 which connect the flange portions 8 and 10 be a part of the side walls of the container which are principally the parts 4 and 6 and the flange portions 8 and 10.

The bottom 28 of the container is welded or otherwise joined to the parts previously mentioned with fluid-tight junctures to complete the vessel holding the electrolyte and to maintain the parts in assembled position. A base plate 30 which is welded or otherwise joined to the bottom of the shell 22 with a fluid-tight juncture serves as the base for the assembly and, with the associated parts of the device, forms the spaces 32, 34, and 36 for temperature regulating media, for instance hot or cold fluids, usually water, which are free to pass between the spaces by means of the openings 38 and may be introduced or withdrawn through the pipes 40, 42, and 44. The welding or other material for joining the parts is indicated at 46. The edge of the plate 30 should

extend a suitable distance beyond the periphery of the cell assembly to allow for such corrosion as may be occasioned by stray currents but any suitable anticorrosion installation may be used in connection with the cell. Preferably the cell rests upon a separate plate 43 which takes such corrosion as may be occasioned by stray currents.

The anode C is of the porous carbon type previously described and is preferably circular with a central well 50. The bottom of the anode is a block 51 of insulating material cemented or otherwise fastened to the upper conducting tubular portion and preferably has the construction shown, presenting a circular flange 52 and means for centering the anode in the cell, for instance a centering projection 54 which fits into a cooperating well 56 in a centering base 58. The base 58 is of any material, preferably insulating, which does not affect the electrolyte, for instance cement or molded plastic and may be held in place in any suitable manner, as by an adhesive 59 or by a tight fit against the container walls, or both. The bottom of the anode well 50 is preferably provided with a smaller auxiliary well or depression 60 to receive and center the bottom of a tube 62 through which the effluent is withdrawn from the cell by any suitable means (not shown), for instance a pump or siphon. It has been found that this construction gives a uniform flow of electrolyte through the anode.

A porous graphite anode of No. 40 grade (the grade designation here used being that described in the Working article) with relatively thick walls is very suitable for use in the present cell for the treatment of ferrous sulphate solutions. The preferred wall thickness depends on operating conditions, particularly current density and rate of flow of solution through the porous anode, increasing thickness not only lowering the electrical resistance of the anode but, in addition, tending to minimize structural irregularities which might influence uniformity of flow throughout the electrode itself. By way of example, a No. 40 grade cylindrical anode with an outer diameter of 6½ inches at the conducting portion, a conducting length of 28 inches and a wall thickness of 2 inches will handle a current of 200 amperes and a flow of 170 cc. per minute of an electrolyte containing about 80 grams per liter of ferrous iron, to yield an effluent in which the iron is about two-thirds ferric iron and one-third ferrous iron. The size of pore should be correlated with the flow of electrolyte through the porous electrode, for any given current, to prevent destructive attack on the anode. The pores should be small enough and the flow of electrolyte should be fast enough to sweep ferric iron through the anode as fast as it is formed and to present to the surface of the anode sufficient fresh electrolyte containing ferrous iron to permit anodic depolarization and thus to prevent the generation of oxygen at the anode. When a fluid moves past and in contact with a solid, the solid exerts a drag or so-called "skin-effect" whereby the layer of the liquid which is next to the solid moves more or less slowly. If this layer of electrolyte which is in contact with the anode surface moves too slowly all of its iron will be oxidized to ferric iron and oxygen which will attack the anode will be generated at the anode surface. The number of pores should be sufficiently great to pass the required volume of liquor but each pore should be sufficiently small that the electrolyte passes through it at such a rate as to sweep ferric iron away from the anode

surface and present ferrous iron for oxidation in such an amount that no gas is generated.

Thus, the grade of porous carbon or graphite must be such that adequate depolarization and flow rate are accomplished simultaneously. Excessive fineness makes it difficult to maintain satisfactory flow of electrolyte through the porous electrode and increases the danger of plugging by suspended matter, hydrolysis products, and the like. With too coarse a porous electrode, on the other hand, the surface velocity may be reduced to a point where depolarization does not take place efficiently, the anode voltage, as determined by single electrode potential measurements, rising from the desired Fe^{II} : Fe^{III} equilibrium voltage toward the discharge potential of oxygen. A further result of excessive pore diameter and insufficient surface velocity is back diffusion of ferric salt, re-solution of electro-deposited iron, and lowering of current efficiency.

The anode is preferably provided with a surface insulation 64 of any suitable type at and adjacent to the surface of the electrolyte 66. This is important when porous carbon anodes are used in processes such as an anodic oxidation of ferrous sulphate. In electrolysis, there is a pronounced tendency for a higher current to pass through the electrodes near the leads, and near the surface of the electrolyte, rather than well below the surface of the electrolyte and away from the leads. In the treatment of ferrous sulphate using the porous carbon anodes, if the current anywhere on the anode is more than sufficient to oxidize to ferric iron all of the ferrous iron which enters the anode at any particular area, there is a tendency toward oxygen formation and destructive attack of the electrode, the latter characterized by softening and disintegration of the carbon or graphite, and great reduction in its useful life. Also, oxygen or other gas within the anode blocks the passage of electrolyte through the porous electrode; the affected portions no longer function as depolarizing porous electrodes; the remaining portions are overloaded; and current efficiency and anode life are reduced. The insulation 64 thus prevents the excessive flow of current which would occur (save for the insulation) at the surface of the electrolyte and prevents a high current density at that portion of the anode which is immediately adjacent the surface of the electrolyte. A further objective of the insulation 64 is to facilitate matching of anode and cathode areas, thus preventing excessive local current densities at the latter and so eliminating the edge effects, nodulization and treeing of electro-deposited metal associated with uneven current distribution. For this reason the cathode preferably extends slightly beyond the active anode surface, so that a comparatively thin metal deposit, rather than the heavy, nodulized or tree-forming plate is produced near the cathode edges. For the cell as described, an active cathode area extending about two inches beyond (above and below) the active anode area, with an electrolyte level about two inches above the top of the active anode surface, has been found satisfactory. This correlation, while it prevents the development of anodic gas and consequent corrosion and gas plugging or blocking of the anode, yields a cathodic deposit which shows a tapering toward the edges, without treeing or nodulization.

The insulation is preferably in the form of a band of a material which is non-absorptive of the electrolyte, applied to the surface of the elec-

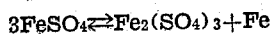
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trode and wide enough to extend a sufficient distance above the electrolyte level to prevent creepage of the electrolyte up the anode and a leakage current over the surface of the insulation. An excellent insulation is provided by a fluid insulation material applied to and soaked into the porous anode a sufficient distance (about 1/4 inch or more) to afford a grip; and then hardened to give a non-conducting surface band. This may be accomplished by applying to the anode a melted insulating wax or other material or by applying a solution of an insulating material in a volatile solvent or a varnish which will harden in situ to form the insulation after being applied to the anode, or by other convenient means. With an anode of the dimensions previously given carrying 200 amperes as stated and with the anode and the cathode 1 1/2 inches apart, insulation extending 2 inches below the surface of the electrolyte is satisfactory. The depth of the insulation may be less with wider electrode spacing or less current, or both.

In addition, the upper portion of the electrode, e. g. to the lower edge of the insulating band, preferably is waterproofed to prevent the acidic electrolyte from drawing up through the anode and corroding the electrical connections. Such waterproofing may be accomplished prior to the application of the insulating band, by dipping in molten paraffin or by soaking in a solution of wax, or equivalent, in a volatile solvent. Conductivity from the electrical connections to the main body of the anode is through the contacting conducting particles from which the anode is made, hence is not affected by the waterproofing treatment.

In connection with the matter of current density, the relative positions of the bottoms of the electrodes is of importance as is the insulation of the cross section of the anode at its bottom. The conducting portion of the anode ends above the bottom of the removable cathode primary plating surfaces and the flow of current from the cross section of the bottom of the conducting portion of the anode is prevented by the insulating block 51. The difference in level between the bottom of the conducting portion of the anode and the bottom of the removable cathode is about 2 inches with the electrodes spaced as herein described and using the current stated. This prevents treeing of the deposit at the bottom of the removable primary cathode sections 18 and 20 and reduces deposition of metal on any exposed portion of the auxiliary or secondary cathode. Completely to prevent such deposition, the exposed lower portion of the auxiliary cathode may be protected with a suitable non-conducting coating 68 which is preferably sufficiently thick and rigid to provide a seat and stop for the bottom of the removable cathode. Any suitable material, for instance cement or plastic, may be used.

It is well established that, in the electrolysis in question, any back diffusion of anodically oxidized ferric salt to the cathode will reverse the electro-deposition reaction



and, by redissolving electrolytic iron, as indicated by reading the foregoing equation from right to left, reduce the electro-chemical efficiency of the process. To a large extent the porous anode serves to prevent such reversal, the oxidized electrolyte being drawn through the porous carbon at relatively high speed, thus minimizing back

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diffusion toward the cathode. Further, to prevent access of ferric ions to the cathode and to insure a maximum concentration of ferrous ions at that point, the electrolyte is preferably introduced through one or more pipes 70 which deliver the liquid between the cathode and a foraminous screen 72 located between the electrodes. The screen 72 acts as a barrier and additional safeguard against back diffusion of ferric ions. In contradistinction to ordinary forms of diaphragms, which, because of their relatively low permeability, introduce considerable electrical resistance into the cell, the screen in question is very permeable, offering no substantial resistance either to flow of electrolyte or of current. It makes a rough separation of the cell into anode compartment 74 and cathode compartment 76 and, by forming a barrier at which there is an appreciable velocity of electrolyte flow from cathode to anode compartment, it reduces the opportunity for ferric ions to diffuse toward the cathode. The screen also keeps from the anode compartment such solid particles as may be in the cathode compartment and may plug the pores of the anodes. The screen may be of any of the usual materials which are suitable for use with the electrolyte in the cell, for instance asbestos or glass fabric, where the electrolyte is acidic ferrous sulphate solution.

The screen may be fastened in place in any suitable manner. In the present construction disclosed herein, the lower portion of a tubular screen of glass fabric is brought outside of the flange 52 of the anode and then fastened onto the bottom of the anode as by a cord 78. At the bottom of the cell, the screen is spaced from both of the electrodes in any suitable manner but preferably the diameter of the flange 52 is such as properly to effect this spacing. The flange and adjacent bottom portions of the anode are also preferably so spaced from the block 58 that any solid particles in the cathode chamber can settle into this space to facilitate their removal when the cell is cleaned. A pipe 80 permits the cell to be emptied and the cell and screen cleaned and washed without removing the anode assembly and also permits any sediment to be drained while the cell is in operation. The screen and anode are preferably a unitary assembly in order that they may be assembled outside of the cell and inserted into the cell as a unit.

The screen is preferably under tension to keep it spaced from the anode. In the cell shown, the top of the screen is fastened to a circular spacing ring 82 of any suitable material, preferably, insulating, for instance wood or hardened plastic, and provided with a hole or holes 83 through which additions to the cell solution, e. g. the acid used in starting the cell, can be made directly into the anode compartment. The top assembly is supported from the top of the anode by a strap 84 or other supporting means, preferably removable and tensioning, for instance elastic rubber or other suitable material, which keeps the screen tensioned and in place and prevents sagging of the screen. The screen should not touch the cathode else an even deposit may not be obtained or the deposit may grow into the screen with consequent tearing of the screen when the cathode is removed; further, such deposition shortens the electrolytic path and causes lower resistance, favoring continued growth of deposit, frequently in the form of

treeing which, in extreme cases, may actually reach to the anode and so short-circuit the cell. The spacing ring 82 is preferably slidable along the anode so that it can move to keep the screen tight. A suitable screen is glass cloth about $\frac{1}{8}$ inch thick spaced about $\frac{1}{2}$ to $\frac{3}{4}$ inch from the anode giving a smaller anode chamber than cathode chamber, which chambers together form the electrolyte chamber with the electrolyte freely movable from the cathode chamber to the anode chamber. The larger cathode chamber allows a relatively thick layer of metal to be built up before the cathode has to be changed and renders the screen less liable to injury. A screen of sufficient rigidity to be self-supporting may be used, if desired.

To ensure smooth deposits of reasonable thickness, the electrolyte in the cathode chamber may be kept in motion to sweep from the cathode any gas bubbles which may form at or tend to adhere to the deposit. In the present cell, the continuous introduction of electrolyte into the cathode compartment will do this to a large extent. However, auxiliary stirring by any suitable means may be used. In the cell shown, such stirring may be effected by a gas introduced into the cathode chamber through the pipe 86 and the connecting perforated tube having numerous small openings 88 to permit the escape of the gas. The tube is preferably of insulating material, for instance plastic, and is located outside of the screen 72 and below the bottom of the primary plating surface B but above the bottom of the electrolyte chamber. This construction effects such slight evenly distributed auxiliary movement of the electrolyte, for instance, pickle liquor, as may be desirable in addition to that effected by the introduction of the pickle liquor into the relatively small cathode chamber but provides a volume of relatively quiescent liquor below the stirring tube 86 in which sediment may collect and be withdrawn from time to time through the pipe 80 while the cell is in operation. The gas which is used for stirring may be air or may be inert or non-oxidizing. A feature of the invention is that, where the stirring is effected by gas, only a small amount of gas need be used because of the electrolyte movement obtained by the continuous flow of electrolyte through the cell. Inert gas, for instance nitrogen, is costly and air has a tendency to oxidize the ferrous iron in the pickle liquor to the ferric state and thus decrease the deposit of iron per unit of electricity. In either instance benefits are derived from the ability to use a minimum amount of gas for auxiliary electrolyte movement while effecting a large portion of such movement by means of the flow of liquor through the cell. The liquor in the anode chamber is preferably not stirred and is relatively quiescent.

In assembling the cell, the outer unit comprising the container A, the parts integral therewith, the tube 86 and the base 58 are first assembled. The parts 18 and 20 of the primary plating surface B are then slid into the container A to the proper depth. The parts 18 and 20 may be of any metal capable of receiving the deposit, for instance copper or aluminum, but are preferably of slightly springy metal, preferably iron, mild steel, or stainless or other corrosion-resistant alloy steels or Monel metal so that the spring of the metal causes the parts to bind against the container A thus holding the parts 18 and 20 in place by friction and providing electrical contact with the container A to which current is

conducted through a conductor 89 connected in any suitable manner to the outer unit, as by a lug 90 on the shell 22. The parts 18 and 20 are preferably of about 22 gauge metal for mild steel, or thinner for the more rigid metals, so that they are sufficiently strong to support themselves and are not easily bent but yet are sufficiently flexible that they can be flexed with the hands to loosen the deposited metal. The flanges 14 and 16 of the parts 18 and 20 slide down the recesses 12 to guide the parts 18 and 20 in their travel, and the flanges 14 and 16 are preferably so formed that each flange meets its cooperating flange in the recess. This meeting of the flanges closes the recesses 12 to prevent plating of the metal in the recesses and, because of the springy character of the parts 18 and 20 and the flanges, forces the parts 18 and 20 firmly in contact with the container A. The flanges 14 and 16 preferably meet in a line beyond the normal "throwing" power of the metal so that the parts 18 and 20 are not united by the deposit and can separately be inserted or withdrawn from the cell after receiving a deposit. For particularly heavy deposits, danger of bridging may be avoided by painting the flange portions 14 and 16 with an insulating material, for instance asphalt or other paints.

Suitable means may be used to ensure that the plating surfaces 18 and 20 remain in place and have sufficient electrical contact with the outer unit of the cell. A preferred device for effecting this is an expandable ring 92 which may be supported in place in any suitable manner, as by the integral hooks 94, and which may be expanded or contracted by the threaded rod 96, working in the threaded ear 98 and bearing 100. While the parts 18 and 20 may be held in place in any suitable manner, the friction fitting described is preferred as it is simple, enables the primary plating surfaces to be clamped in place after adjustment to the proper depth, allows one part of the primary plating surface to be removed without the other and obviates the necessity of disconnecting and connecting leads when the plating surfaces are changed. Any suitable means, for instance holes 102 (or lugs) at the tops of the parts 18 and 20 enable the parts to be gripped for removal from the cell.

It is important to note that in the cell there is a secondary or auxiliary conductive surface (the container A in the cell shown) to receive the current when one of the primary plating surfaces 18 or 20 is removed and that this auxiliary plating surface is positioned as closely as possible to the position of the primary plating surface. While any primary plating surface, that is, either of the parts 18 or 20, may be withdrawn and replaced in the matter of a minute or so, if the auxiliary conducting surface were not in substantially the same position as the primary plating surface, the current would flow between the anode and the primary plating surface (18 or 20) which is still in the cell. This would cause a higher current density on the portion of the anode opposite the primary plating surface remaining in the cell which might cause the formation of anodic gas with the corrosion and gas blocking of the anode heretofore described, particularly if the cell is running at substantially full capacity. Temporary compensating adjustments in the flow of current and liquor could be made to take care of this temporary condition but the auxiliary conductive surface and its position automatically take care of the condition and obviate the necessity for the adjustments as well

as the possible damage to the anode and enables the cell to operate continuously under established conditions. There will be a slight deposition of metal on the secondary conductive or plating surface during the absence of the primary plating surface but with the present cell, the cathode renewal can be accomplished so easily and quickly that deposition on the auxiliary cathode during the change-over period should be too slight to cause difficulties; should it become thick enough to interfere with insertion of primary cathodes or the spacing of these, it can readily be removed by acid pickling, by anodic stripping, or by other convenient methods.

A cylindrical cell with cylindrical electrodes is advantageous, particularly for the type of reaction herein used for illustrative purposes where a metal is to be deposited. In the cylindrical cell disclosed, the more expensive electrode is at the center and hence can be smaller. The electrodes of greater area are the less expensive electrodes and they receive the deposit and the larger their area the less frequently they have to be changed to prevent shorting of the cell as the deposit increases in thickness. Also, with circular cylindrical electrodes, full advantage can be taken of every conducting portion of the face of the smaller electrode and yet obtain an even deposit on the face of the larger peripheral electrode.

A further advantage of the cylindrical electrode is that only its top and bottom edges have to be insulated to ensure satisfactory cathode deposits as previously described, whereas all four edges of a rectangular electrode must be so treated and a correspondingly greater portion of the electrode is thus inoperative.

Another advantage of the cylindrical centrally located porous electrode is that it permits the use of a smaller central well than does a flat vertical electrode of the same active outer area, this leading to more rapid circulation and more frequent replacement of solution in the well and more uniform flow through the porous carbon and thus more uniform depolarization at the active surface.

It will readily be understood that the cell described herein is of general use. The central electrode may be the cathode where a reducing effect is desired. Also, the electrolyte to be treated may be introduced into the cell in the well of the central electrode. The peripheral electrode may be of any material suitable to the electrolyte and the chemical reaction desired in the cell. Also, the peripheral electrode may be in more than the two parts shown or may be in only one part which, however, is preferably split longitudinally and is springy and provided with at least one set of flanges so that it can be guided into place by the recess 12. The invention is susceptible of modification within the scope of the appended claims.

The use of the cell in treating pickle liquor is disclosed in the copending patent application of Heise, Schumacher, and Wilson, Serial No. 737,000, filed March 25, 1947.

What is claimed is:

1. An electrolytic cell comprising an open-top container adapted to hold liquids and oppositely disposed electrodes, at least one of the electrodes comprising a primary current receiving element and a secondary current receiving element, said elements and other electrode extending longitudinally of the cell from the open top toward the bottom of the cell and having conducting

portions contacting the electrolyte but ending short of the bottom of the cell, the construction and location of the parts being that: said primary element is a sheet of thin conducting material substantially conforming to the shape of the other electrode, is slidably removable from the cell as a unit independently of other parts of the electrodes, lies between said secondary element and said other electrode, is positioned to prevent the passage of current directly from said other electrode to said secondary element, and extends farther into the cell than said other electrode the distance between the adjacent conductive ends of the primary element and said other electrode contacting the electrolyte being greater than the distance between the end of the conductive portion of said other electrode and the nearest conductive portion of the primary element; said secondary element is of conducting material, substantially conforms to the shape of said other electrode, lies directly behind and closely adjacent to the primary element and extends farther into the cell than said other electrode, the distance between the adjacent conductive ends of the secondary element and said other electrode contacting the electrolyte being greater than the distance between the end of the conductive portion of said other electrode and the nearest conductive portion of the secondary element; the secondary element being connected into the electric circuit and positioned to receive the current progressively as the primary element is progressively slid out of the cell and both elements receive less current at the ends innermost in the cell than at other places; and cooperating parallel guides on the primary element and secondary element for holding the primary element in the relative position stated and enabling the primary element to be slid past the secondary element and out of the cell through the open top, said guides lying at a greater distance from said other electrode than the primary element.

2. An electrolytic cell comprising an open-top container adapted to hold liquids and oppositely disposed electrodes, at least one of the electrodes comprising a plurality of primary current receiving elements and a secondary current receiving element, said elements and other electrode extending longitudinally of the cell from the open top toward the bottom of the cell and having conducting portions contacting the electrolyte but ending short of the bottom of the cell, the construction and location of the parts being that: the primary elements are so disposed that together they surround the other electrode, each primary element is a sheet of thin metal substantially conforming to the opposite portion of the other electrode, is slidably removable from the cell as a unit independently of other parts of the electrodes, lies between said secondary element and said other electrode, is positioned to prevent the passage of current directly from said other electrode to said secondary element, and extends farther into the cell than said other electrode, the distance between the adjacent conductive ends of the primary elements and said other electrode contacting the electrolyte being greater than the distance between the end of the conductive portion of said other electrode and the nearest conductive portion of a primary element; the secondary element is of conducting material, substantially conforms to the shape of said other electrode, lies directly behind and closely adjacent to each primary element, and extends farther into the cell than said other electrode, the

distance between the adjacent conductive ends of the secondary element and said other electrode contacting the electrolyte being greater than the distance between the end of the conductive portion of said other electrode and the nearest conductive portion of the adjacent secondary element; the secondary element being connected into the electric circuit and positioned to receive the current progressively as the adjacent primary element is progressively slid out of the cell and both elements receive less current at the ends innermost of the cell than at other places; and cooperating parallel guides on the primary element and secondary element for holding the primary element in the relative position stated and enabling the primary element to be slid past the secondary element and out of the cell through the open top, said guides lying at a greater distance from said other electrode than the primary element.

3. An electrolytic cell comprising a central electrode, an open-top container adapted to hold liquids surrounding the electrode and a primary current receiving element between the container and said electrode, said element and electrode extending longitudinally of the cell from the open top toward the bottom of the cell and having conducting portions contacting the electrolyte but ending short of the bottom of the cell, the construction and location of the parts being that: the container is of conducting material, substantially conforms to the shape of the central electrode, has a conducting surface exposed to the electrolyte when the primary current receiving element is not in place in the cell which surface extends near to the bottom of the cell than does the end of the central electrode, and has a recess extending longitudinally from the top of the cell to substantially the end of the conducting surface; the primary element is a sheet of thin conducting material, substantially conforms to the shape of the central electrode, lies closely adjacent to the container, has a conducting surface exposed to the electrolyte which extends nearer to the bottom of the cell than does the end of the central electrode, is of a size to cover and is positioned covering the adjacent portions of the container, and has a flange which slidably interfits with the recess in the container, the primary element being positioned within the cell and with relation to the container and the central electrode by the interfitting of the flange and the recess, and being slidable out of the cell by the flange sliding in the recess, the container being connected into the electric circuit to progressively take the current as the primary element is slid out of the cell.

4. An electrolytic cell comprising a central electrode, an open-top container adapted to hold liquids surrounding the electrode, and a plurality of primary current receiving elements between the container and said electrode, said elements and electrode extending longitudinally of the cell from the open top toward the bottom of the cell and having conducting portions contacting the electrolyte but ending short of the bottom of the cell, the construction and location of the parts being that: the container is of conducting material, substantially conforms to the shape of the central electrode, has a conducting surface exposed to the electrolyte when the primary elements are not in place in the cell which surface extends nearer to the bottom of the cell than does the end of the central electrode, and has recesses extending longitudinally from the top of the cell

to substantially the end of the conducting surface; the primary elements are so disposed that together they surround the central electrode, each primary element is a sheet of thin conducting material substantially conforming to the opposite portion of said electrode, lies closely adjacent to the container, has a conducting surface exposed to the electrolyte which extends nearer to the bottom of the cell than does the end of the central electrode, is of a size to cover and is positioned covering the adjacent portions of the container and has a flange disposed to lie and to slide within one of said recesses and to contact the flange of an adjacent primary element within the recess, the primary elements being positioned within the cell with relation to each other and to the container and to the central electrode by the interfitting of the flanges and the recesses and the contact of the flanges, each primary element being slidably removable from the cell as a unit independently of other parts of the electrode, the container being connected into the electric circuit in parallel with said elements, the portion of the container in back of the element being removed progressively taking the current as the element is slid out of the cell.

5. An electrolytic cell comprising an open-top container adapted to hold liquids, a central, hollow porous carbon electrode and a peripheral electrode substantially surrounding the central electrode, the peripheral electrode comprising a primary current receiving element and a secondary current receiving element, said elements and central electrode extending longitudinally of the cell from the open top toward the bottom of the cell and having conducting portions contacting the electrolyte but ending short of the bottom of the cell, the construction and location of the parts being that: said primary element is a sheet of thin conducting material substantially conforming to the shape of the opposite portion of the central electrode, is slidably removable from the cell as a unit independently of other parts of the electrodes, lies between said secondary element and the central electrode, is positioned to prevent the passage of current directly from the central electrode to the secondary element, and extends farther into the cell than the central electrode, the distance between the adjacent conductive ends of the primary element and the central electrode contacting the electrolyte being greater than the distance between the end of the conductive portion of the central electrode and the nearest conductive portion of the primary element; said secondary element is of conducting material, substantially conforms to the shape of the central electrode, lies directly behind and closely adjacent to the primary element and extends farther into the cell than the central electrode, the distance between the adjacent conductive ends of the secondary element and the central electrode contacting the electrolyte being greater than the distance between the end of the conductive portion of the central electrode and the nearest conductive portion of the secondary element; the secondary element being connected into the electric circuit and positioned to receive the current progressively as the primary element is progressively slid out of the cell and both elements receive less current at the ends innermost in the cell than at other places; and cooperating guides on the primary element and secondary element for holding the elements in the relative positions stated and enabling the primary ele-

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ment to be slid past the secondary element and out of the cell through the open top.

JOHN P. OLIVER.

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1,904,432
2,000,815
2,066,347
2,117,294
2,193,323
2,406,956
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Number
455,810
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Name	Date
Allen	Apr. 5, 1921
Eaton	Feb. 18, 1930
Fink	Apr. 18, 1933
Berl	May 7, 1935
Gronningsaeter	Jan. 5, 1937
Buchser	May 17, 1938
Nitzschke	Mar. 12, 1940
Matthews	Sept. 3, 1946
Jones	Aug. 2, 1949

FOREIGN PATENTS

Country	Date
Great Britain	Oct. 28, 1936
Italy	July 23, 1936