

June 21, 1932.

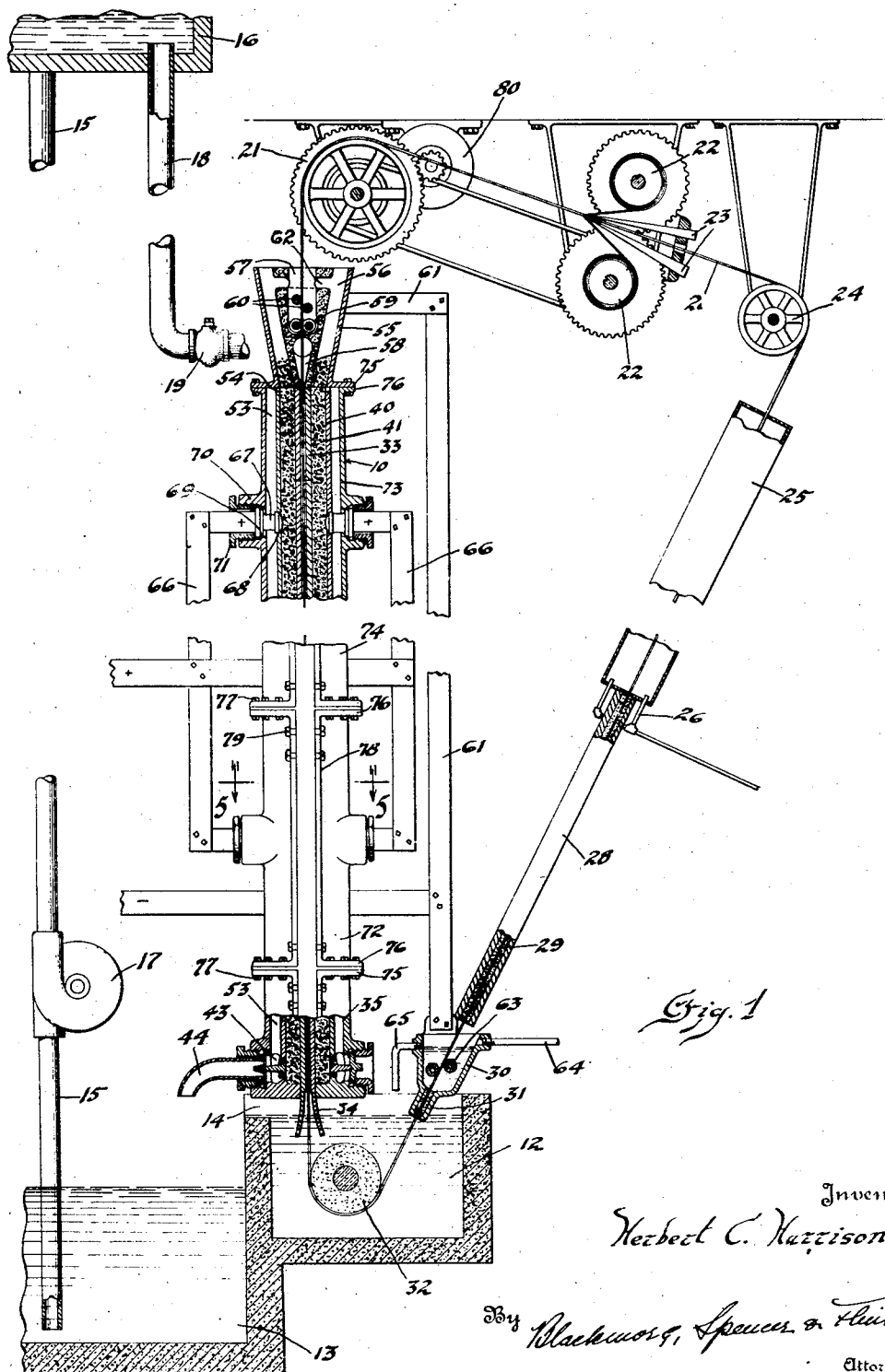
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1,864,490

ELECTROLYTIC APPARATUS

Filed Aug. 23, 1926

2 Sheets-Sheet 1



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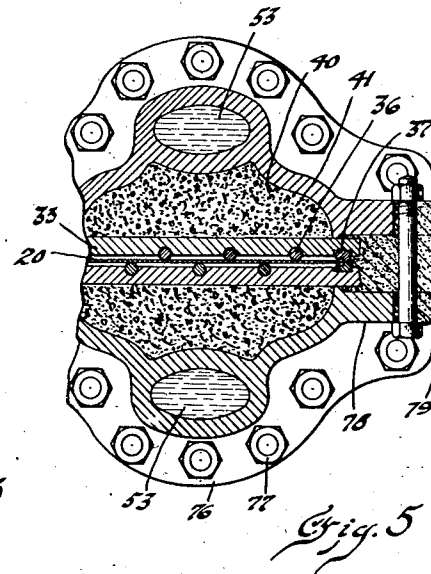
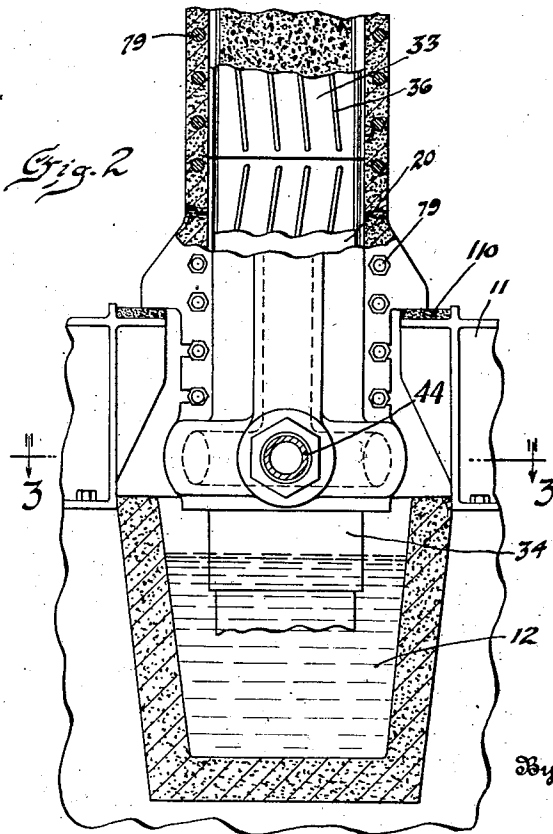
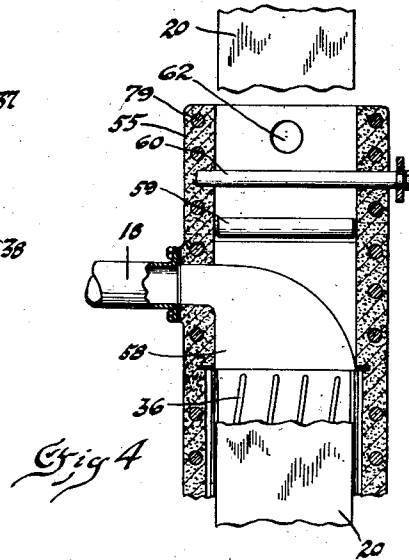
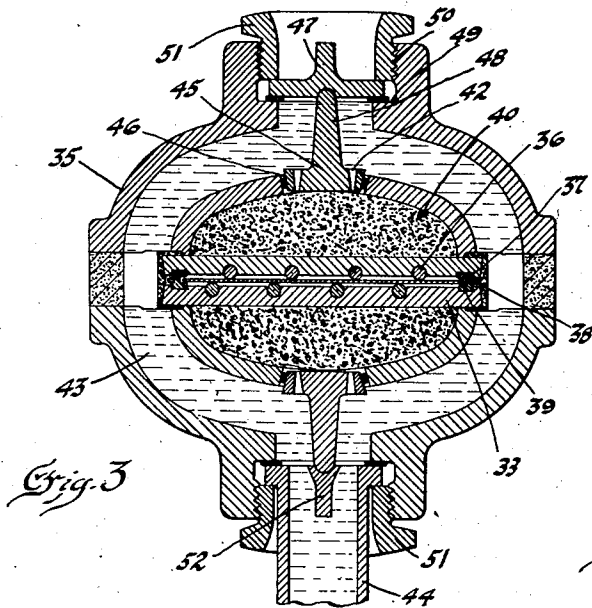
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ELECTROLYTIC APPARATUS

Application filed August 23, 1926. Serial No. 130,994.

This invention relates to the art of electrolytically depositing metal, such as copper, of good physical quality, at a high rate of speed.

In my prior patent 1,768,358 dated June 24, 1930, I have disclosed a process and an apparatus in which an electrolyte is circulated in contact with a cathode, in a cathode compartment of an electrolytic cell, under pressure higher than atmospheric, or higher than that outside of said compartment, while constantly renewing the richness or concentration of the electrolyte by a body or bodies of the metal to be deposited maintained in contact with or submerged in the circulating electrolyte. Stated specifically, it was contemplated in the process and apparatus of said prior application to make use of soluble anode material occupying one or more compartments of an electrolytic cell; another compartment containing the cathode being completely separated from the anode material by a non-conducting partition permeable to the electrolyte, and also, when saturated with electrolyte, permeable to the electric current. The cathode compartment was to be completely closed except for an inlet and an outlet for the passage of the electrolyte and a continuously moving cathode. Electrolyte was to be flowed through the cathode compartment in a rapidly moving stream under pressure considerably higher than that existing in the anode compartment or compartments. In the practice of said prior process a small proportion of the electrolyte forced into the cathode compartment passed through the permeable partition into the anode chamber or chambers, and thence into a collection reservoir where it joined with the electrolyte from the cathode compartment to be again circulated through the cell. In the cell shown in said application, the electrolyte flowed through the cathode and anode compartments substantially horizontally, the cathode compartment being in the nature of a tunnel of but slightly larger cross section than, and of form similar to, the cathode, which was caused to travel there-through.

The earlier process and apparatus referred

to have yielded excellent results at extremely high current densities. By their use copper has been deposited on a travelling ribbon cathode at a current density of 1000 amperes and more per square foot. But in order to get these high current densities a voltage of 12 to 14 volts per cell was required, and this made the cost too high for commercial purposes. The practical limit primarily set by the cost of power, was a current density of about 500 amperes per square foot, requiring a voltage of $7\frac{1}{2}$ volts per cell, more or less.

There were certain practical limitations on obtaining high current densities by the said prior practice inherent in the construction of the cell:

(1) The internal resistance was considerable. In that cell the actual spacing of the anode material from the cathode was approximately one inch. This spacing was determined by the thickness of the layer of high pressure electrolyte between the cathode and the porous partition, plus the thickness of the porous partition, plus the average distance of the soluble anode material from the low pressure side of the partition. This one inch spacing corresponded to the resistance of a considerably greater spacing, because the resistance of the porous plate itself was from three to five times that of the electrolyte.

(2) The speed of the electrolyte in the high pressure cathode compartment was restricted. The current density permissible depends primarily upon the speed of the electrolyte relative to the surface of the cathode, and if sufficient pressure existed in the cathode compartment, and if this compartment were made long for the purpose of getting a fairly thick deposit with fair speed of movement of the cathode, thereby presenting considerable resistance to flow, an abnormal portion of the electrolyte passed through the porous partition, and so reduced the speed of the high pressure electrolyte at the exit end of the compartment.

In the improvement which is the subject of this application, I also provide a compartmented cell and cause a body of electrolyte to circulate through it. The resistance with-

in this cell is reduced by utilizing an anode, disposed close to the cathode, of a substance that is neutral to or insoluble in and impervious to the electrolyte, but a good electrical conductor; and this anode may constitute a partition dividing the cell into compartments, one of which is of tunnel form through which a ribbon cathode may move, and through which electrolyte may be forced at high pressure and speed. The other compartment or compartments may contain metal of the kind to be deposited, submerged in electrolyte flowing under lower pressure. The streams of electrolyte flowing from the cathode and anode chambers unite in the general body of circulating electrolyte.

As the partition defining the cathode compartment is impervious, the speed and pressure near the exit end thereof is not reduced by diversion of electrolyte through the partition into the other compartment, so that more rapid renewal of the electrolyte in contact with the cathode surface may take place, making possible the use of much higher current densities.

The employment of a neutral or insoluble anode raises the initial voltage required for the cell, as compared with a cell using soluble anodes, because the insoluble anode polarizes. For example, a cell with a soluble anode that would operate normally with a voltage of .3 volts, would require nearly 2 volts if the soluble anode were replaced by an insoluble one, as of lead, this amount of pressure being required to cause any current flow through the layer of gas collected on the anode. At first consideration, therefore, use of an insoluble anode would seem to present no advantage; but this not so, for the reason that the difference in voltage required with the closely lying insoluble anode does not vary with the current density employed, as it did in the prior practice described; the initial difference is preserved, but as the current density increases, very little additional voltage is required to operate the cell. This follows because the insoluble anode may be placed very close to the cathode—as close as $\frac{1}{16}$ th of an inch, which was substantially the spacing of the pervious, non-conducting partition of the prior practice described. The resistance, therefore, of the improved cell, is made up only of a layer of electrolyte substantially $\frac{1}{16}$ th of an inch in thickness, together with that necessary to be overcome to effect electrolysis with a given insoluble anode.

The use of impervious lead anodes spaced uniformly about $\frac{1}{16}$ th of an inch from the cathode allows operation of the cell with a current density of 500 amperes to the square foot and a pressure of approximately 3 volts. It could be operated with a current density of 1000 amperes to the square foot with a pressure of about $4\frac{1}{2}$ or 5 volts. Thus the

increase in current density bears no such relation to increase of voltage as it does in a cell having a resistance interposed between the electrodes consisting of a non-conducting porous plate, plus the electrolyte, where the average distance between the anode and cathode is one inch or so. This improved arrangement has the further advantage that, as the conductivity of the electrolyte is a practically negligible factor since the layer is only $\frac{1}{16}$ th of an inch thick, a highly conductive electrolyte need not be chosen, but a solution, as of copper, low in free acid and of high copper concentration, may be used, which, although a poor conductor, is a good solution for obtaining sound deposits at high current density.

Although an insoluble anode, as of lead, appears to cause violent polarization at the anode surface, and the electrolyte is discharged from the cathode chamber full of gas, yet the physical structure of copper deposited and the surface of the deposited layer, instead of showing signs of deterioration, appear to be improved in comparison with results obtained by the prior described practice.

The new apparatus used in the practice of this improved process comprises a cell in tower form, divided vertically into tunnel-like compartments by one or more partitions of insoluble anode material, for example, lead, Duriron or carbon, one of said compartments surrounding the cathode, and the other or others containing pieces of metal of the kind to be deposited on the cathode, for example copper shot. The electrolyte is forced into the upper end of the cathode tunnel or compartment under high pressure, said tunnel being closed except at the top and bottom ends where the electrolyte enters and leaves it. In the contemplated practice the cathode may consist of a metallic ribbon, as of copper caused to move continuously through the cathode chamber, preferably from bottom to top, in a direction opposite to that of the electrolyte flow.

The copper shot, or other pieces of metal of the kind to be deposited, immersed in the circulating electrolyte for the purpose of keeping up the strength of the bath, may be placed in the compartment or compartments separated from the cathode by the partition or partitions of anode material. Electrical connection with the anode is preferably made through these pieces, because thus the current may be more evenly distributed to the insoluble anode partitions, and also promote the dissolution of the metal pieces to keep up the metal concentration of the electrolyte. Portions of the electrolyte are caused to flow through the compartments outside of the cathode compartment, under lower pressure.

It is preferred to immerse the terminals

that make contact with the cathode under a cooling liquid adjacent both ends of the tower or cell.

In the accompanying drawings one embodiment of an apparatus constructed and adapted to operate in accordance with this invention has been illustrated. The detailed description to follow, containing references to the drawings, will further elucidate the nature and advantages of the invention.

In the drawings, in which like reference characters indicate like parts throughout the several views,

Fig. 1 is a side elevation partly in section, of an apparatus adapted to practice this invention;

Fig. 2 is a view at right angles to that shown in Fig. 1, of a fragment of the apparatus at its lower end;

Fig. 3 is a cross section taken on the plane indicated by a line 3—3 in Fig. 2;

Fig. 4 is a central vertical section through the upper portion of the cell illustrated in Fig. 1, taken substantially in the plane of the ribbon cathode; and

Fig. 5 is a transverse section on the line 5—5 of Fig. 1.

The Figures 2, 3, 4 and 5 are shown on a larger scale than Fig. 1 in order to clarify details of construction.

Certain parts of the apparatus illustrated in Fig. 1, it will be understood, are somewhat diagrammatic, but illustrate the mode of operation intended.

Numeral 10 (Fig. 1) indicates generally an electrolytic cell disposed in substantially vertical position, and it may be here termed an "electrolytic tower," because of its tower-like form. This tower may be supported on frame-work 11, from which the tower is insulated by suitable insulating material 110 (Fig. 2). In the illustrated embodiment the tower is supported by the frame-work above an electrolyte tank, which has two compartments, 12 and 13. The compartment 12 receives electrolyte discharged from the cathode compartment of the cell, as will be later described. The electrolyte received into compartment 12 may flow over a weir 14, into the main compartment 13, which also receives the electrolyte flowing from other compartments in the cell directly into it, as will be more fully set forth hereinafter.

A pipe 15 extends from the compartment 13 to a tank 16, disposed at any desired height above the level of the upper end of the tower. Electrolyte may be pumped from the compartment 13 through the pipe 15 into the tank 16 by means of any suitable pump, indicated conventionally in Fig. 1 by numeral 17. From the elevated tank 16, a pipe 18 conveys electrolyte into the upper end of the tower. Said pipe 18 may have a valve 19 to control the flow, as desired.

The cathode used in this apparatus is in-

tended to be of ribbon form, and may be, as shown in the drawings, an endless ribbon, moved continuously at any suitable rate of speed, through a cathode compartment in the tower. The cathode ribbon which may be composed of copper, is indicated by the numeral 20. It may be caused to travel through the cathode compartment in either direction, but it is preferred to have it travel upward, in a direction counter to that of the flow of the electrolyte. For the purpose of supporting and moving the cathode, there is shown, somewhat diagrammatically, a drum 21, supported above the tower with its periphery tangent to the axis of the cathode chamber. From the drum 21 the cathode ribbon may extend between two winding spools, 22, which are intended to function as strippers in case the deposited metal is to be separated in sheets or ribbons from the cathode. Associated with the spools 22 there may be a pair of doctors or lifting wedges 23, the thin ends of which are arranged to engage the cathode ribbon and assist in separating therefrom the layers, which are being wound up on the spools 22. The ribbon 20 denuded of its deposits then passes over an idler guide pulley, 24. 25 indicates a cathode surface treating apparatus, specifically, a gas-containing tank, inclined as shown, having slits in its opposite ends in substantial registration with each other, through which the cathode 20 is guided in order that it may acquire a surface from which the deposit may be stripped. The lower end of the tank 25 is penetrated by one or more pipes 26, which communicate with a supply of gas, (not shown), such as ammonium sulphide, which reacts within the tank with the surface of the ribbon, thus forming on it a sulphide or other suitable coating, designed to promote free stripping of the deposited layers.

A guide, 28, embraces the ribbon 20 after it leaves tank 25. This guide 28 may consist of a pair of flat boards or other plate-like members, and may have layers of felt or the like, 29, in contact with the ribbon, for the purpose of cleaning and smoothing the layer formed upon the ribbon in the tank 25.

After leaving guide 28, the ribbon passes into a container 30, said container having a nozzle-like extension 31 at its lower side, through which the ribbon passes. This nozzle-like extension is lined, also, with felt or other soft material, serving to reduce the flow of liquid through the extension and to clean the surface of the ribbon as it passes out into the compartment 12 and around a guide roll 32, the periphery of which is tangent to the axis of the cathode chamber, so that the ribbon may be stretched in the cathode chamber and maintained midway of it, as it proceeds to and around the upper driving drum 21.

In order to drive the spools 22 which wind

up the stripped layers from the cathode 20, said spools are geared together so as to rotate in opposite directions, and they may be driven in the proper direction by any suitable connection with the cathode-driving drum 21, at the proper peripheral speed. It will be understood that the means for imparting movement to the cathode ribbon is shown diagrammatically only, and that the proper speed ratios and adjustment will be made as required by conditions.

The tower 10 may be of any desired height found practicable. For convenience of manufacture it is made of a plurality of sections assembled together with suitable packing material between the joints. In Fig. 1 the tower is shown broken away between its ends indicating that any desired number of sections may be assembled as needed. The tower is divided longitudinally into compartments by partitions 33, which serve as anodes; said anode partitions are impervious to, and insoluble in, the electrolyte used, and are good conductors of electricity. They may be made of a plurality of assembled plates of lead, carbon, Duriron or other suitable material in good conductive relation. The said partitions extend from the bottom of the tower substantially to the top; they are spaced from each other and form between them a tunnel-like compartment open only at its ends, said compartment conforming in cross section substantially to the cross section of the cathode, and having its inner walls uniformly spaced from the cathode a slight distance, say not over $\frac{1}{16}$ th of an inch. At the lower end of the tower the anode partitions are preferably provided with extensions 34, which project down into the electrolyte compartment 12, said anode extensions diverging toward their lower ends. At the lower end of the tower there is a special section 35, which is closed at its bottom except to provide for the entrance of the cathode and for the extension of the anode partitions.

Embedded in the inner faces of the anode plates which make up the said partitions 33, are bars or rods 36, of some insulating material insoluble in the electrolyte, such as glass, porcelain, or the like. The faces of these rods project slightly from the inner surfaces of the anode partitions, whereby they serve to center the travelling cathode ribbon and prevent it from coming into contact anywhere with the anode.

It is desirable to arrange said rods 36 in positions inclined to the direction of movement of the cathode and of the electrolyte, for the better protection of the cathode surface. Rods imbedded in opposite plates are preferably inclined in opposite directions in order to avoid any tendency of the flowing electrolyte to crowd toward one edge of the compartment.

At opposite edges of the cathode compart-

ment, insulating material is imbedded in the anode plates upon opposite sides of the edge portions of the cathode. This serves to prevent a heavy deposit upon the edges of the cathode strip, which would interfere with proper separation of the deposited sheet from the cathode. In practice, the said means for preventing the flow of current such as would increase the thickness of the deposit at the edges, serves also to space the anode plates from each other and to guide the edges of the ribbon; said insulating, spacing and guiding means is indicated by the numeral 37, and consists of two pairs of bars for each plate, said bars having smooth and flat surfaces 38 in contact with each other, and other surfaces 39 spaced apart sufficiently to permit the edges of the cathode strip to be guided between them. Said opposing bars 37 thus serve to guide the edges of the cathode strip, to prevent excess deposit on said edges, and to space the plates the required distance from each other.

On each side of the cathode compartment, completely separated therefrom by the impervious, insoluble anode partitions, are chambers 40, which, in practice, are filled with pieces of metal of the kind that is to be deposited from the electrolyte upon the cathode strip; in the practice of copper deposition these pieces of metal may be copper shot, and are indicated in the drawings by the numeral 41. The chambers 40 are closed at the bottom by the bottom plate of special section 35, but communicate with small ports 42 which allow electrolyte to drain from said chambers into an annular passage 43, from which it flows through a spout or short pipe 44 into the main compartment 13, of the lower electrolyte tank.

As a matter of practical construction, outward flaring conoidal ports 42 are formed in a plug 45, seated in a tapered hole 46 made in the outer walls of chamber 40, as shown in Fig. 3. Said plugs are properly packed and held in position by locking devices which bear upon tangs 48 projecting from the plug. One of said plugs is secured by a lock-plate 47 seated on a gasket on shoulder 49, formed in a threaded orifice 50, extending through the outer wall of lower section 35. Said lock-plate is held in place by a threaded plug 51.

The foregoing description of means for permitting drainage of electrolyte from chambers 40 applies specifically only to that side of the cell away from the compartment 13 of the electrolyte tank. The opposite side is provided with a similar plug, which is similarly locked in place, except that in place of the lock-plate 47, bearing upon the tang of the plug, the inner end of spout pipe 44, which is flanged and engaged by a plug 51, is provided with a cross member 52, which

bears upon the tang and holds the plug in place.

In addition to the cathode compartment and the two compartments for holding copper shot, or the like, referred to, the cell or tower has a vertical passage 53 outside of and adjacent each compartment 40. These passages communicate at their lower ends with the passage 43, (Fig. 1) which receives electrolyte from the lower ends of compartments 40. At their extreme upper ends, compartments 40 communicate with the passages 53 by means of small orifices 54. The orifices 54 tend to maintain the electrolyte at a substantially definite level in the compartments 40, excess flowing through the orifices and into the drainage passages 53, whence it proceeds downward into passage 43 and to the compartment 13 of the lower electrolyte tank.

A special section 55 projects upward above the upper end of the described chambers of the cell. Section 55 has passages 56, diverging upward, communicating at their upper ends with atmosphere, and at their lower ends with the compartments 40, which contain copper shot or the like, and are thus maintained at atmospheric pressure. Through these passages the metal fragments may be charged into said chambers. Said section 55 also has a passage 57, between passages 56, communicating with the upper end of the cathode compartment. This passage is of the same cross sectional area as the cathode chamber where it communicates with said chamber. From there it expands upward as indicated at 58, the large upper end of this tapering portion being in side communication with pipe 18 which conducts electrolyte into it. It constitutes a high speed nozzle. Immediately above the entrance of pipe 18 the said passage is narrowed to a width sufficient only to permit free travel of the cathode ribbon. Above the narrowed portion is a considerably enlarged chamber, in which there is mounted a pair of baffle rolls 59 preferably covered with rubber or equivalent material, in engagement with opposite sides of the cathode.

In the enlarged space of passage 57 above rolls 59, is a pair of contacts 60, constituting terminals of a conductor 61, for the purpose of conducting current to the cathode. The contacts are preferably bars with smooth curved surfaces arranged one slightly above the other on opposite sides of the cathode, so that firm pressure may be exerted on the cathode without pinching it.

By the described construction electrolyte may be forced into the entrance passage 58 and through the cathode chamber at high speed and pressure. The pressure may be very much higher than atmospheric, depending upon the head used. Electrolyte escaping upwards from the tapered entrance 58 will be baffled by the rolls 59; it will rise

above the contacts 60, so that said contacts will be submerged in a cooling liquid thereby preventing injuriously heating the thin cathode, and preventing sparking at the contact surfaces. Passage 57 communicates with passages 56 through ports 62, thus allowing electrolyte to flow into chambers 40 slowly, under atmospheric pressure only, and preventing over-flow over the top of the tower.

Electrical contact is made with the cathode not only through the contacts 60 at the upper end of the tower, but also through contacts 63, which are immersed under a liquid, preferably water, in the previously described container 30, near the lower end of the tower, through which the cathode ribbon travels. Said contacts 63 are preferably rollers disposed in the same relation to the cathode as are the bars 60. Rollers 63 are in electrical communication with the walls of chamber 30, which are made of conductive material, and secured in conductive relation to conductor 61. It will be observed in Fig. 1 of the drawings, that the said container 30 is not in conductive relation to the anode. Water may be led in a small stream through a pipe 64 into container 30, and may be maintained at the required level in said container by an over-flow orifice communicating with pipe 65, which discharges into the compartment 12 of the electrolyte tank. The water, besides preventing sparking at the contact surfaces and undue heating of the cathode, serves to wash and condition the coating on the cathode. The addition of this slight amount of water to the electrolyte does not weaken the solution because it replaces evaporation or other losses of water incident to the normal operation of the cell and is rather beneficial.

The flaring lower terminals 34 of the anode partitions provide space for the entrance of the advancing cathode strip into the cathode chamber. As these ends dip into the electrolyte in said chamber 12, and as the electrolyte flowing from the lower end of the cathode chamber comes between the cathode and said extensions 34, deposition is initiated in the space between the extensions so that when the cathode strip has entered the actual cathode chamber of the cell, there is already started on the strip a minute deposit, which is deemed advantageous in the operation.

Conductors 66 carry current to the anode partitions. Each conductor 66 terminates in two contact plugs 67, suitably spaced apart along the length of the cell. Each contact 67 consists of a plug passed through a drain conduit 53 and having its inner end penetrating and closing an opening 68, in the outer wall of the respective chambers 40 through which current is to be conducted by it. Each plug 67 is flanged as at 69, the flange engaging a shoulder in a counterbored opening formed in projection 70, cast on the particular

tower section through which anode contact is made. A hollow screw-threaded plug 71, bearing upon the outer face of flange 69, holds the plug in place, with its inner end protruding slightly into the chamber 40, in electrical contact with the copper shot or other metal pieces therein. Current is conducted from the plugs 67 to and through the metal pieces and to the anode partitions 33.

By this arrangement current is conducted uniformly and distributed with facility throughout each anode partition. The overflowing electrolyte in drain passages 53 tends to cool the plugs.

The electrolytic tower illustrated may be built of sections of cast ferrous metal alloy containing about 14% of silicon commonly known as Duriron, which has the property of resisting attacks of the electrolyte and its acid ingredients. Two of the sections, as shown, are constructed to receive electrical contacts for the anodes. These two are preferably the lower section 72, which rests on top of said special lower end section 35, and the upper section 73, upon which is mounted special extension section 55, before described. In between the contact bearing sections 72 and 73, there may be one or more intermediate sections, 74. The upper and lower special sections are preferably cast with circumferential flanges 75. The sections intermediate said special sections have similar flanges 76 on each end. These circumferential flanges may be fastened together by bolts, as indicated at 77. Between the flanges rubber gaskets and other packing suitable for the purpose may be inserted, as required.

Each of the described sections 35, 72, 74, 73 and 55, is composed of two halves divided longitudinally or vertically, and each half has longitudinal flanges 78, through which may be passed bolts 79, to secure the halves together, as is plainly indicated in the drawings. The halves of said sections clamp between them, as indicated in Figs. 3 and 5, the spaced anode partitions 33, thereby forming, when all sections are assembled, a cell having the cross sectional appearance indicated in said last mentioned figures. Spaces between the flanges 78 and the edges of plates 33, and around the bolts may be filled with any suitable cement. For this purpose I prefer to use a sulphur cement, which may be rendered fluid and poured into the cavities to be filled, where it will solidify and form a most excellent filling material. This cement may also function as the packing material in the space between the circumferential flanges 76 not occupied by the gaskets. The same material serves excellently as a material from which to form the central member in which are the passages 56 and 57 of the special section 55.

In operation a cathode ribbon, say of copper, of suitable gauge, may be threaded

through the tunnel-like compartment constituting the cathode compartment. If the cathode is to be in the form of an endless band, the ends of this strip may be united, after having been directed around the driving and guide drums, through the coating tank and cleansing guide, between the stripping devices (if such be used), and between the electrical contacts provided for it. Chambers 40 are assumed to have been filled with copper shot or other metal of the kind to be deposited from the electrolyte. A suitable body of electrolyte may be poured into the compartments 12 and 13 of the lower electrolyte tank. If copper is to be deposited, the electrolyte may be a fairly concentrated solution of copper sulphate, with little free acid. With the cathode in place and chambers 40 filled with metal, the electrolyte may be started in circulation by pump 17. Conductors 61 and 66 being then connected electrically with a source of electrical energy, and drum 21 being caused to revolve, as by electric motor 80, the cell is in operation. The electrolyte flows continuously from the elevated head or tank 16 through pipe 18 into the tapered inlet 58, under relatively high pressure considerably above atmospheric. From said tapered inlet 58, a major portion of the electrolyte flows at high speed downward through the cathode chamber on each side of the ribbon cathode, spurting from the lower end between the anode extensions 34 into the compartment 12 of the lower electrolyte tank. Owing to the position of the extensions 34, which project into the bath in compartment 12, the kinetic energy of the stream is quickly destroyed. Overflow from the compartment 12 into compartment 13 takes place quietly over the weir 14. A minor part of the electrolyte forced into the entrance 58, flows upward through the narrow slot above this entrance on each side of the cathode. The baffle rollers, 59, prevent any great turbulence in the upward flowing electrolyte, and hold down its volume. The electrolyte wells upward from the baffle until it reaches the ports 62, through which it flows into each of the compartments 40. These ports 62 prevent the electrolyte from flowing over the top of the upper section 55. Should the electrolyte passing through the small orifices 42 in the plugs at the bottom of chambers 40 be insufficient to carry away all that flows into them through upper ports 62, the excess will overflow through the small upper ports 54, into the drain passages 53, and so into the substantially horizontal passage 43 in the lower section, whence it will flow through the spout or discharge pipe 44 having joined with that which flows from the orifices 42, into the compartment 13. By this arrangement, the streams flowing from the chamber separated by the anode partitions are so spaced that no electric current

can flow from one to the other, to rob the cell of any of the current needed for electrolysis. Electrolyte flows at high speed through the cathode chamber under a pressure higher
 5 than atmospheric, and flows through the other chambers within the cell at slow speed under atmospheric pressure, so that there exists in the chambers, a difference of pressure considerably in favor of the cathode chamber.
 10 ber.

Thus it will be apparent that high current densities produced at relatively low electrical pressure, may be caused to flow opposed by low resistance, across the thin layer of
 15 electrolyte which is interposed between the cathode and the insoluble anodes.

Although I have described and illustrated, as required by the patent laws, one embodiment of an apparatus involving the principles
 20 of my invention, it is not intended that I shall be limited to the specific embodiment shown, since other forms may be constructed without departing from the principles of the invention.

25 What I claim and desire to secure by Letters Patent is:

1. A tower-like electrolytic cell in combination with means for circulating electrolyte through said cell from top to bottom thereof
 30 and means for continuously moving a cathode into and through said cell, in a direction opposite the direction of flow of the electrolyte.

2. An electrolytic cell having a cathode, and means for causing it to move through said
 35 cell, conducting means terminating in solid contact means, a container outside of the cell in which said contact means is disposed, and means for guiding said moving cathode in engagement with said contact means, said container being adapted to receive a liquid covering
 40 the area of contact.

3. An electrolytic cell having a cathode and means for causing it to move through said cell, conducting means terminating in solid
 45 contact means, a container outside the cell adapted to receive liquid in which said contact means is disposed, means for guiding said cathode in engagement with said contact means, said container having an opening in
 50 the bottom to permit the passage of the cathode, said opening being lined with wiping material adapted to substantially close the space around the cathode and to wipe the cathode.

4. An electrolytic cell in the form of a tower, a cathode and means for causing it to travel therethrough, means for circulating an electrolyte through said cell, electric conducting means terminating in contacts engaging
 60 the cathode at both ends of the tower, the contact at the upper end being effected under the electrolyte, a container at the lower end outside the cell, the lower contact means being disposed within said container, which is
 65 adapted to receive a liquid, and means for

guiding the cathode through said liquid in engagement with said contact means.

5. An electrolytic cell divided into compartments by a partition of impervious, insoluble anode material, one of said compartments containing the cathode and another
 70 containing metal of the kind to be deposited from the electrolyte, said metal being in contact with said anode partition throughout a large part of the surface of the latter, conducting means terminating in means for making
 75 electric contact with said metal, conducting means having contact with said cathode, and means for circulating electrolyte in separate streams through said compartments.
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6. A combination of an electrolytic cell with means for moving a ribbon cathode therethrough, a tank through which the cathode moves and means for admitting to the tank a gaseous fluid capable of reacting superficially with the cathode.
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7. An electrolytic apparatus comprising a cell, an impervious partition constituting an insoluble anode dividing said cell into compartments, a cathode in one compartment, and
 90 metal of the kind to be deposited from the electrolyte in another, means for circulating electrolyte in separate streams through said compartments, and means whereby said streams are mingled after leaving the compartments.
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8. An electrolytic apparatus as defined in claim 7, in which the electrolyte circulating means causes the electrolyte stream flowing through the cathode compartment to move
 100 at a higher rate of speed than that flowing through the other compartment.

9. An electrolytic apparatus as defined in claim 7 in which the electrolyte circulating means causes the electrolyte stream to move through the cathode compartment under pressure higher than atmospheric.
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10. An electrolytic cell having a cathode, a cathode-containing compartment of tunnel form, defined by partitions of impervious, insoluble anode material, completely closed except at opposite ends, said compartment having a cross section similar to that of the cathode, the surfaces of the cathode being uniformly spaced slightly from the anode partitions; another compartment containing metal of the kind to be deposited, means for circulating electrolyte through said compartments in separate streams, and means for uniting the streams after they have left the compartments.
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 115
 120

11. An electrolytic cell having a travelling ribbon cathode, and a cathode compartment of tunnel form, defined by partitions uniformly spaced slightly from the cathode and having insulating material interposed between their opposing edge portions and the edges of the cathode.
 125

12. An electrolytic cell having a cathode compartment of tunnel form defined by parti-
 130

tions of material constituting anodes, the extremities of said anodes projecting divergently from one end of the cell, means for circulating electrolyte through said cell, and means for causing a cathode to enter said compartment between the divergent anode extremities and move through said compartment.

13. An electrolytic cell having a travelling ribbon cathode and a cathode compartment of tunnel form the wall of said compartment having bars of hard insulating material imbedded in the inner face and projecting slightly therefrom, said cathode moving in juxtaposition to the tunnel wall and bars of insulating material serving to prevent contact between the cathode and the wall.

14. An electrolytic cell as defined in claim 13, wherein the insulating bars are arranged obliquely to the direction of travel of the cathode.

15. An electrolytic cell having a travelling ribbon cathode and a cathode compartment of tunnel form composed of spaced partitions having bars of hard insulating material arranged obliquely in the inner surface of each partition, the bars in one partition being oppositely inclined with respect to the opposite bars in the other partition.

16. An electrolytic cell having a cathode chamber comprising two partitions of impervious, insoluble anode material, said partitions being spaced at their edges by bars of hard insulating material having grooves in which the edges of a ribbon cathode are adapted to be guided, the spacing bars at one edge of the chamber being separated from the spacing bars at the other edge a distance but slightly greater than the width of the cathode, whereby both edges of the cathode are guided in the grooves of said bars.

17. A tower-like electrolytic cell having a travelling ribbon cathode, and a cathode compartment of tunnel-like form open only at its upper and lower ends, said cell having an extension above the cathode compartment, there being an inlet into said extension which is in communication with said compartment and with a source of supply of electrolyte said extension having a narrow slot above the inlet in the plane of the cathode compartment, through which the ribbon cathode moves; baffling devices above the narrow slot in contact with said cathode, and means for circulating the electrolyte under pressure.

18. Means as defined in claim 17, in combination with electrical conducting means and contacts disposed above the baffles, within the extension, said contacts being in engagement with the cathode and so disposed as to be submerged in the electrolyte rising above the baffles.

19. A tower-like electrolytic cell having a travelling ribbon cathode a cathode compartment of tunnel-like form, open only at its up-

per and lower ends, and a compartment adapted to receive metal of the kind to be deposited from the electrolyte; an extension projecting upward from said cell, said extension having a passageway communicating with the metal containing compartment and with the atmosphere at the upper end of the extension; said extension also having a central vertical passageway including a high speed nozzle, communicating with the cathode compartment, and a lateral orifice in the nozzle portion communicating with a pipe leading from a source of electrolyte under pressure; said central passageway being restricted above the entrance of electrolyte into the nozzle portion so that the cathode may freely pass; baffling means to restrict the upward movement of electrolyte; there being a port above the baffling means communicating between the central passage and the passage leading to the metal-containing compartment, whereby electrolyte can be supplied to the latter.

20. An electrolytic tower comprising a cathode compartment open only at its upper and lower end; other compartments adapted to contain metal of the kind to be deposited; means for forcing electrolyte under pressure into the cathode compartment, a chamber above the entrance of electrolyte having a restricted bottom opening through which the cathode passes, said restricted opening communicating with the entering electrolyte, means for checking without preventing the rise of electrolyte in the chamber, there being passages leading from the chamber above said checking means into the compartments for containing metal.

21. A tower-like electrolytic cell, having a travelling ribbon cathode; impervious, insoluble partitions of anode material separating the cell into compartments, one of which incloses the cathode and another contains metal of the kind to be deposited from the electrolyte; an extension above the said compartments provided with passages communicating with the respective compartments; means for circulating an electrolyte and forcing it under pressure into that passage in the extension which communicates with the cathode compartment; there being a communication near the upper end of the extension between the passages leading to the cathode and other compartments.

22. Means as defined in claim 21, with the addition of drainage conduits extending lengthwise of the tower, and having communication at their upper ends with the chambers containing metal whereby the level of the electrolyte in said chambers may be maintained.

23. A tower-like electrolytic cell, divided vertically into compartments by an impervious, insoluble partition constituting an anode, one of said compartments inclosing

a cathode and the other metal of the kind to be deposited from the electrolyte; means for circulating electrolyte through said compartments from top to bottom in separate streams which unite after leaving said compartments; a drainage conduit, said metal containing compartment having means substantially level with the upper end of said anode partition for permitting overflow of electrolyte into the drainage conduit in order to maintain the level of the electrolyte at the level of the upper end of the anode partition.

24. An electrolytic cell composed of sections divided longitudinally, two partitions constituting impervious insoluble anodes, dividing said cell into compartments, insulating means disposed between the edges of said partitions, said insulating means spacing said partitions so as to provide a cathode compartment between them, the edges of said partitions being disposed between the sections; and means for securing the sections together with the edges of the partitions clamped between them.

25. An electrolytic cell composed of sections divided transversely and longitudinally, parallel, slightly spaced apart partitions dividing said cell into compartments, the edges of said partition being disposed between the longitudinal edges of the sections, means for securing the ends of said sections one to another, and means for securing the side edges of said sections together with the edges of the partition clamped between them.

26. A tower-like electrolytic cell having a cathode tunnel open at the top and bottom, a conduit in closed communication with the opening at the top of said tunnel, means for forcing electrolyte thru said conduit into and thru said tunnel under pressure higher than atmospheric, and means for moving a flexible cathode into and thru said cathode tunnel.

27. An electrolytic cell having a cathode, means for causing the cathode to move through said cell, conducting means terminating in solid contact means, a container in which said contact means is disposed, and means for guiding said cathode in engagement with said contact means; means for causing liquid to flow into said container, said container having a liquid level maintaining means adapted to maintain the level of the liquid therein, means for circulating electrolyte including a reservoir for receiving electrolyte from the cell, said liquid level maintaining device consisting of an overflow conductor arranged to discharge into the electrolyte reservoir.

28. An electrolytic cell composed of sections divided longitudinally, the side edges of said sections having flanges; parallel slightly spaced apart partitions dividing said cell into compartments, the edges of said partitions being disposed between the sections, means for securing the sections together with

the edges of the partitions clamped between them and a hardened elastic cement filling the space between the flanges not occupied by the partitions.

In testimony whereof, I affix my signature. 70
HERBERT CHAMPION HARRISON.

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