

March 30, 1937.

F. L. ANTISELL

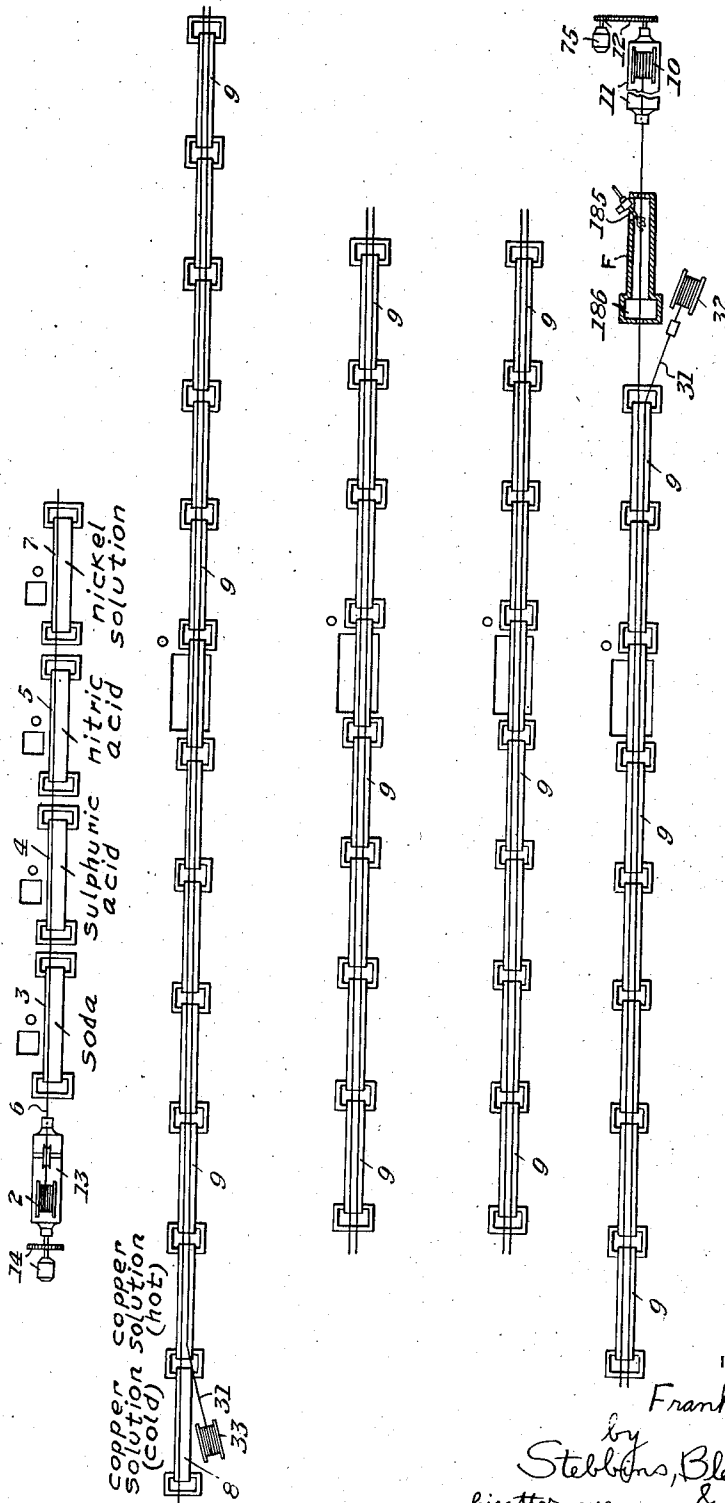
2,075,332

APPARATUS FOR THE ELECTRODEPOSITION OF METAL

Filed June 4, 1936

9 Sheets—Sheet 1

Fig. 1.



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9 Sheets-Sheet 2

Fig. 2.

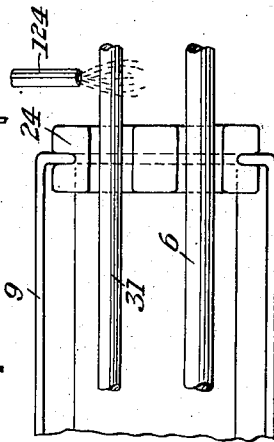
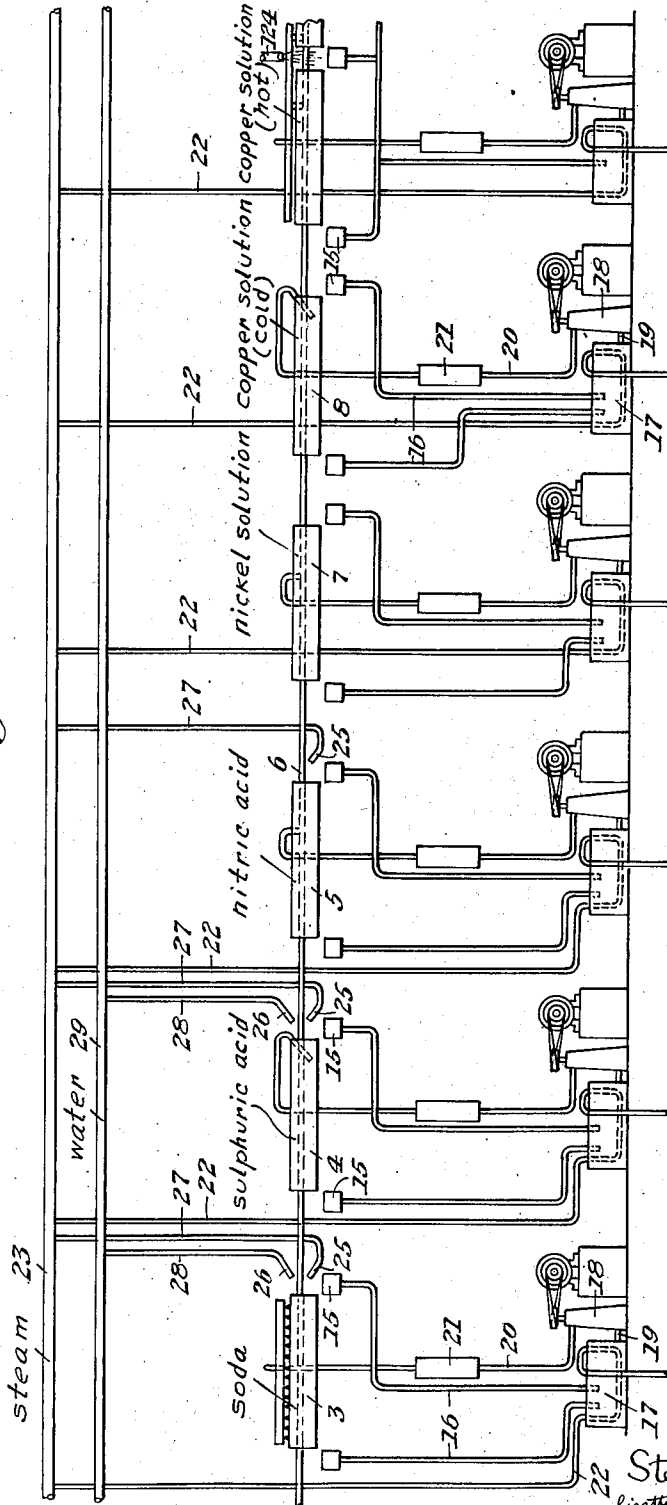


Fig. 13.

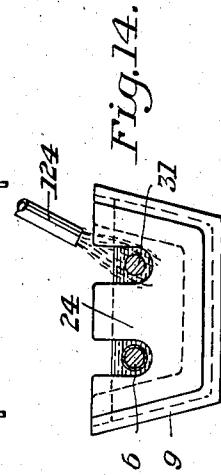


Fig. 14.

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9 Sheets—Sheet 3

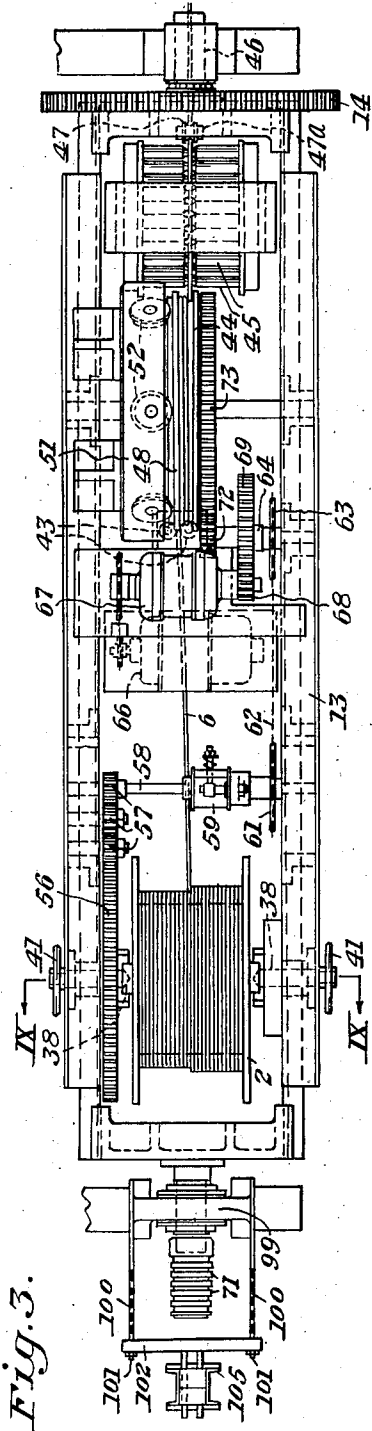


Fig. 5.

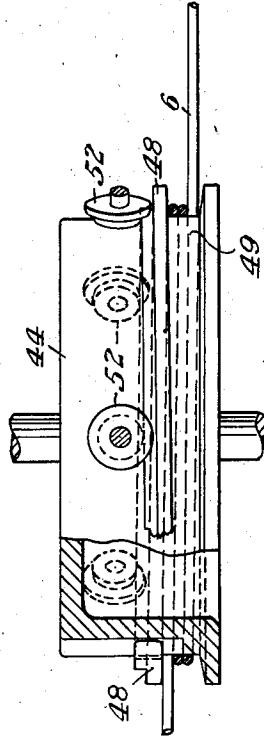
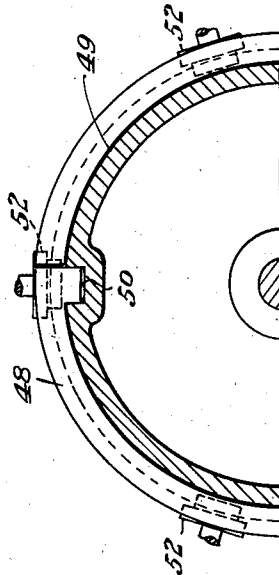


Fig. 6.



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Fig. 8.

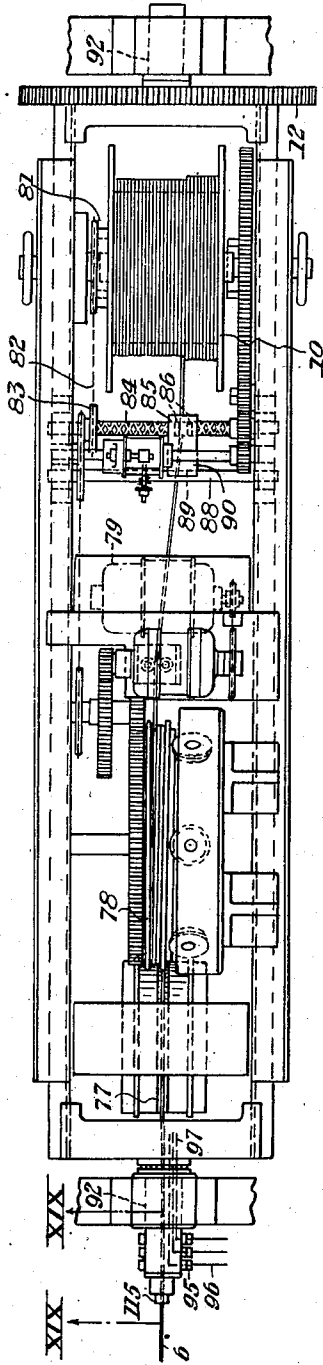
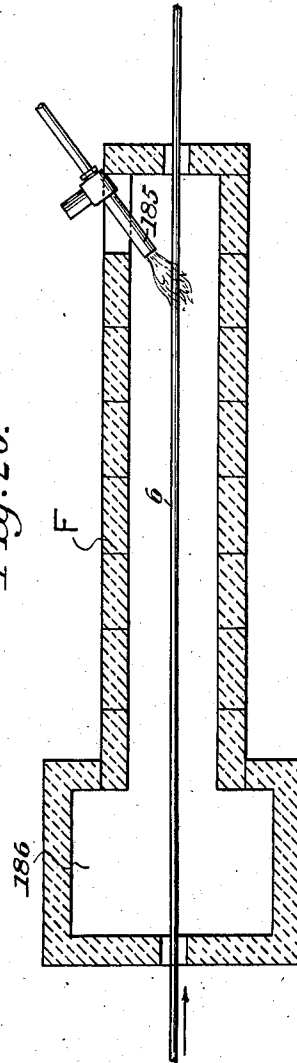


Fig. 20.



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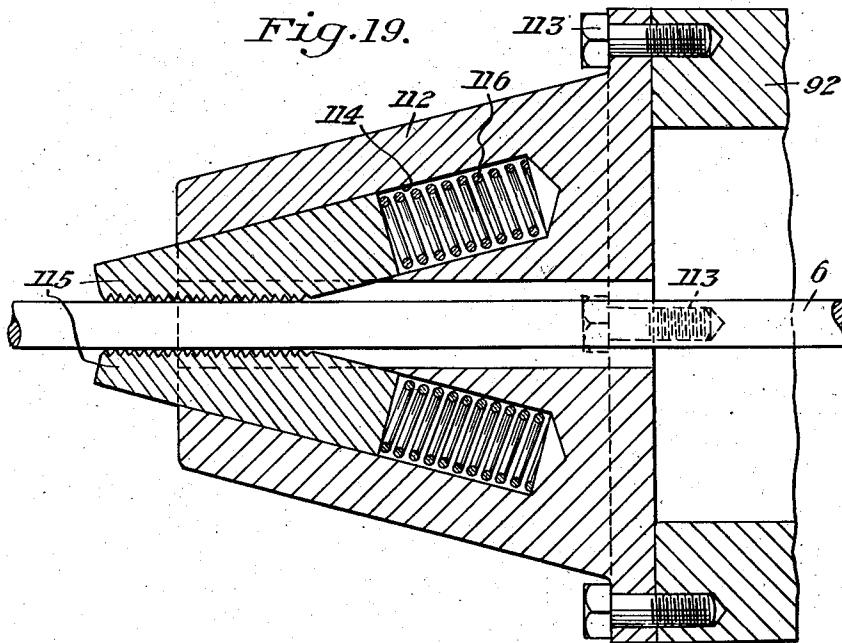
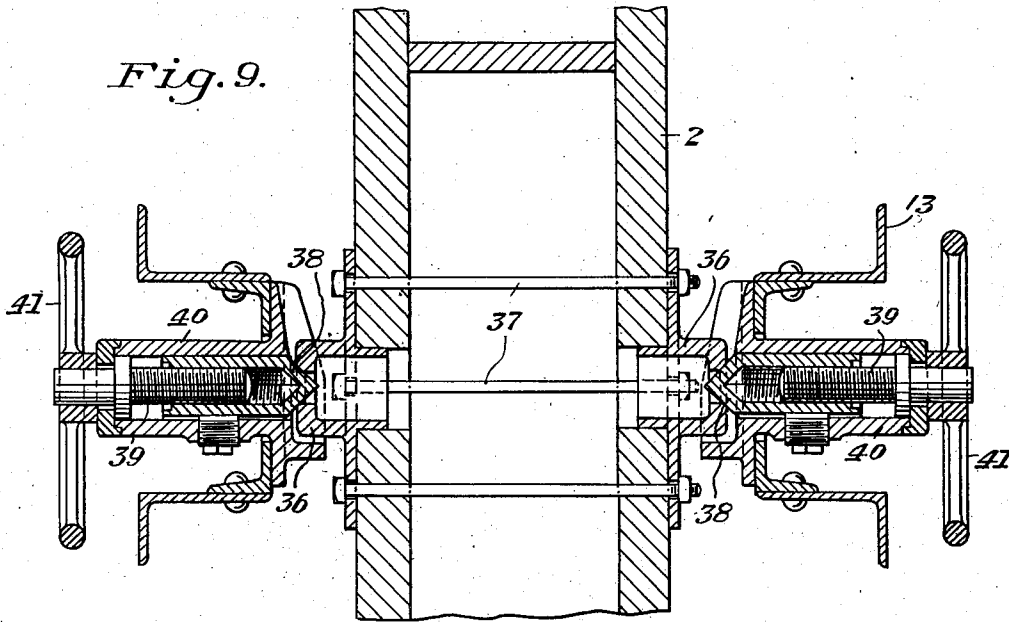
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Fig. 11.

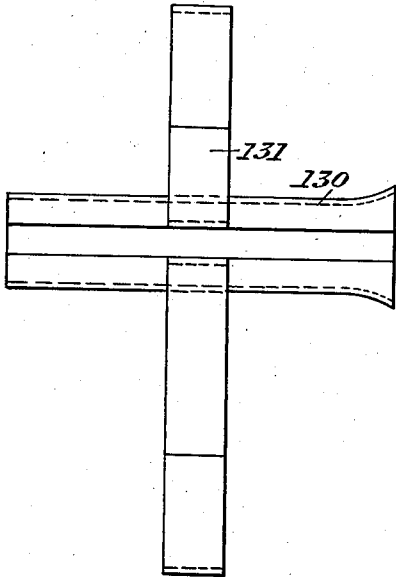


Fig. 10.

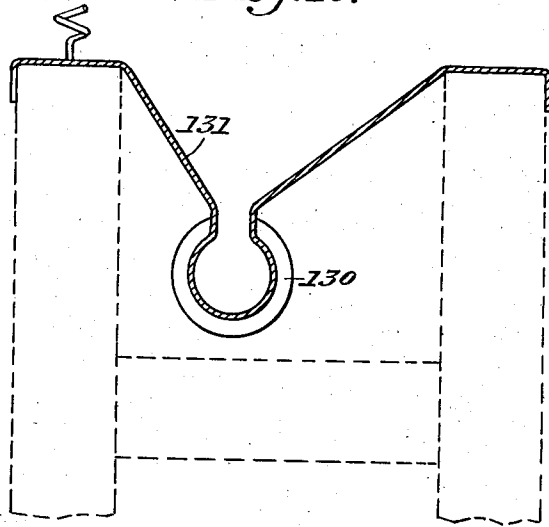
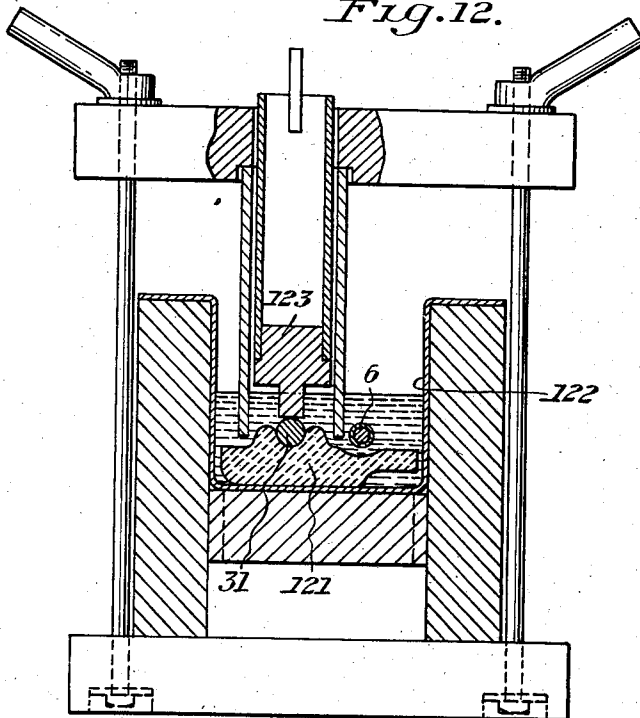


Fig. 12.



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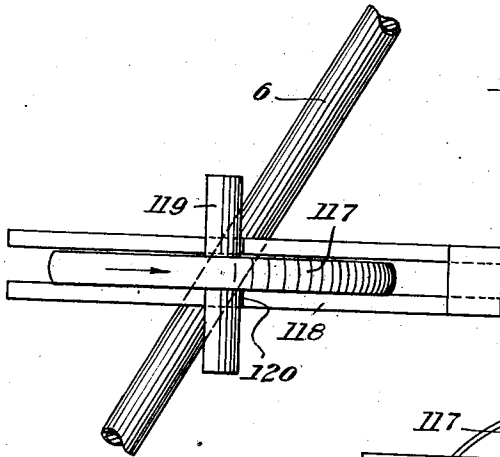


Fig. 15.

Fig. 16.

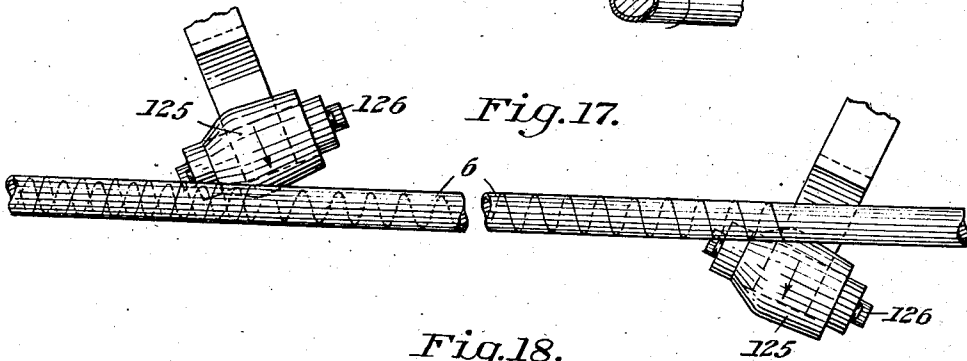
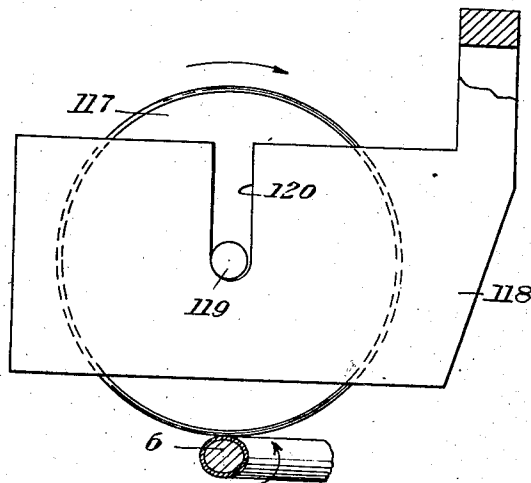
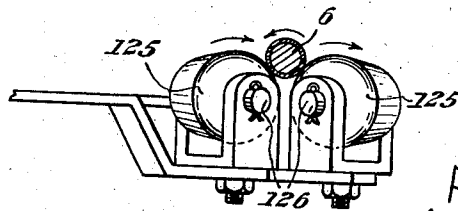


Fig. 17.

Fig. 18.



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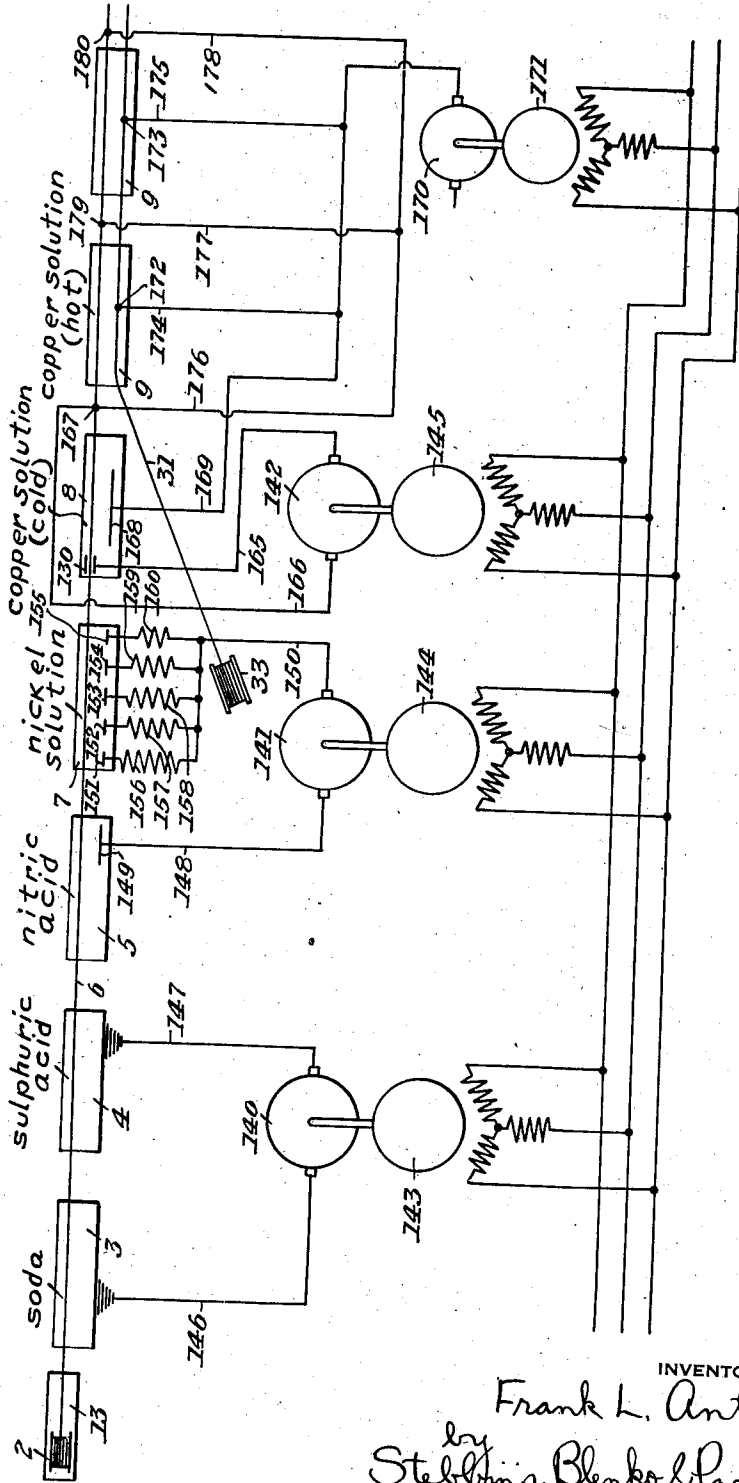
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APPARATUS FOR THE ELECTRODEPOSITION OF METAL

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9 Sheets-Sheet 9

Fig. 21.



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# UNITED STATES PATENT OFFICE

2,075,332

## APPARATUS FOR THE ELECTRODEPOSITION OF METAL

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Application June 4, 1936, Serial No. 83,532  
In Great Britain December 24, 1932

43 Claims. (Cl. 204—5)

This invention relates generally to apparatus for the electrodeposition of metal, and more particularly to such apparatus for electrodepositing metal on a core in order to produce a bimetallic article. The invention is particularly described herein as applied to the manufacture of bimetallic articles having a ferrous core or base and a copper coating. Such products supply a large demand in wire, cable, strips, tubes, and the like. They are of great value in that the ferrous core, such as steel, supplies strength and the copper provides electrical conductivity and resistance to corrosion. The invention is applicable, however, to the production of other combinations of metals. A non-ferrous base or core may be coated with copper, nickel or other metal. For trolley wires, a copper core may be coated with iron. Bimetallic articles may be made by depositing nickel or other metal on a core of copper or other metal. The present application is a continuation in part of my copending applications Serial No. 359,624, filed May 1, 1929, and Serial No. 649,532, filed December 30, 1932.

In accordance with my novel method of producing bimetallic wire as disclosed in said applications, a core is passed through a single electrolytic bath or a series of electrolytic baths and metal is deposited thereon. Moreover, the core is passed through the baths under high tension and it is rotated about its axis as it is fed through the bath. The core is fed from a pay-reel and passes through a series of cleaning baths, after which it passes through a series of electrodepositing baths. It is then wound up on a take-up reel. Both the pay-reel and the take-up reel are mounted in frames which are rotatable at substantially a right angle to the axes of rotation of the reels, so that the core is rotated about its axis as it passes through the baths.

The anode used in the principal electrodepositing solutions may be a moving wire, hereinafter termed a "drag wire". This drag wire is fed from a reel, and after passing through the electrodepositing solutions, is wound up on another reel. It moves through the baths alongside of the core which forms the cathode and the metal is deposited from the drag wire onto the core. Instead of or in addition to the moving drag wire, other types of anode may, however, be used. I may use stationary anodes such as slabs of the metal to be deposited, or metallic shot, or I may use an insoluble anode and add the metal to be deposited as a salt or as metal to the electrolyte.

In the accompanying drawings, which illus-

trate the present preferred embodiment of my invention and also certain modifications,

Figure 1 is a diagrammatic plan view of the whole apparatus, the view being shown in several parts for convenience of illustration;

Figure 2 is a side elevation of a number of the containers or "tronnels" which contain the various solutions through which the core passes, and illustrates the means for filtering and re-circulating the solutions. By "trunnel" I mean a trough-like structure with open ends in which the electrodeposition takes place, the electrolyte being supplied thereto at such rate as to maintain the desired quantity of electrolyte therein.

Figure 3 is a plan view of the mechanism at the entrance end of the apparatus for supplying the core to the baths, and shows the pay-reel and the frame in which it is mounted;

Figure 4 is a side elevation of the mechanism shown in Figure 3;

Figure 5 is a fragmentary plan view showing on a larger scale the bull wheel from which the wire pays out through the trunnion of the rotatable frame;

Figure 6 is a vertical section through the bull wheel adjacent the wobbler ring (the bull wheel has been turned clockwise in Figure 6 through 90° from the position shown in Figure 5);

Figure 7 is a side elevation of the take-up reel and its driving connections;

Figure 8 is a plan view of the apparatus shown in Figure 7;

Figure 9 is a transverse section on the line IX—IX of Figure 3, illustrating the means for mounting the pay-reel and take-up reel in their frames;

Figures 10 and 11 are, respectively, a sectional view and an elevation of a high current density circular anode used to prevent re-resolution of a previously deposited metal;

Figure 12 is a sectional view through one of the tronnels illustrating the contact for the anode or drag wire;

Figures 13 and 14 show in plan and in end elevation respectively a weir in the end of a trunnel for regulating discharge of electrolyte;

Figures 15 and 16 are views in plan and in end elevation respectively of a roller cathode contact;

Figures 17 and 18 are views in plan and in end elevation respectively of supporting and compacting rollers;

Figure 19 is a section on the line XIX—XIX of Figure 8, illustrating a clamping means for preventing release of tension on the core;

Figure 20 is a horizontal sectional view through

the heating furnace for heat treating the coated wire before it is reeled up; and

Figure 21 is a wiring diagram showing the electrical connections for a number of the tronnels 5 which contain the various baths.

Referring more particularly to the accompanying drawings, and for the present to Figure 1, the core or wire to be coated with metal is fed from a pay-reel 2 through a series of cleaning baths 3, 4 and 5. The cleaning baths may be of different compositions, but I have found that in the coating of a steel core with copper, or first with nickel or tin and thereafter with copper, effective cleaning can be accomplished when the bath 3 is a soda solution, the bath 4 is a sulphuric acid solution, and the bath 5 is a nitric acid solution. The core 6 then passes through a solution of a nickel salt, for example nickel sulphate, in the trunnel 7, and after that passes through a copper solution in the trunnel 8, and thereafter through a plurality of tronnels 9, each of which contains an acid solution of a copper salt such as copper sulphate. The character of the grain structure of the electrolytic deposit of copper is materially affected by the temperature of the electrolyte. It is particularly important that the initial deposit of copper be fine grained, as the succeeding grain structure built on the initial deposit cannot be good if the initial deposit was poor. In other words, poor grain structure in the initial deposit carries through the superposed deposit. Accordingly, the temperature of the solution in the trunnel 8 is lower than the temperature of the solutions in the tronnels 9, the temperature of the former being about 85° F., while that of the latter ranges from 150° F. to 180° F. After passing through the last of the tronnels 9, the coated wire is heat treated while passing through a furnace F. It will be noted that while undergoing this heat treatment, the product is under the same high tension as prevails during the deposition of the coating metal. After the relatively short interval during which the product is passing through the furnace F, it is wound up on a take-up reel 10 which is rotatably mounted in a frame 11 driven by a motor and gearing 12, so as to rotate the frame at substantially a right angle to the axis of rotation of the reel 10. The pay-reel 2 at the entrance end of the apparatus is mounted in a similar framework 13 driven by a motor and gearing 14. The construction is such that the core rotates about its axis as it is advanced through the various baths.

The tronnels which contain the various solutions are U-shaped in cross-section, being open at the top and arranged for the discharge of liquid at their ends. Accordingly, the tronnels do not form closed containers for the baths, but on the contrary are either open at their ends or formed with weirs such as shown in Figures 13 and 14. Accordingly, it is necessary to continuously circulate the solution through the tronnels in order to maintain a desired level of the electrolyte therein. The solution in each trunnel flows out of the ends of the trunnel, is collected, filtered if necessary, and then returned to the trunnel. As shown in Figure 2, the solution flows from the ends of each trunnel into receivers 15 and is conducted by pipes 16 to a sump 17. It is then circulated by a pump 18 through pipes 19 and 20 through a filter 21, and then returned to the trunnel. The solution in the sump 17 is heated by a steam pipe 22 which is connected to a steam line 23. The use of such open end tronnels for

the solutions eliminates the necessity of providing stuffing boxes, which would be required with electrodepositing tanks of the usual closed end construction. The stuffing boxes are objectionable for the reason that the packing scratches the surface of the deposited metal and may introduce foreign matter into the deposited metal. Also, by using a series of spaced tronnels instead of a single bath, different solutions can be used in the different tronnels, and these solutions can be filtered and recirculated back to the tronnels. It will be understood that when reference is made to "open end" tronnels, this does not mean that the ends are absolutely free of any structure impeding the flow of liquid. A weir or baffle 24 such as shown in Figures 13 and 14 and made of porcelain or glass may be employed, the essential thought being that the entrance and exit of the wire is effected without it passing through stuffing boxes or the like.

Located between the tronnels 3, 4 and 5, which contain different cleaning solutions, are steam nozzles 25 and water nozzles 26 connected by pipes 27 and 28, respectively, to a steam line 29 and a water line 29. The nozzles 25 and 26 subject the core between tronnels to jets of steam and water which, taken in conjunction with the various cleaning solutions, produce a very clean wire on which a good deposit of metal can be made. Another steam jet 26 is also used between the tronnels 5 and 7 to further clean the core before it passes into the nickel solution in the trunnel 7.

It is advantageous in general to coat the core first with a deposit of another metal such as nickel or tin before applying the copper coating. Nickel, which is preferred, readily forms an alloy both with the steel core and with the copper coating.

The deposition of copper on the core which has previously been coated with nickel begins in trunnel 8 and is continued in tronnels 9. A copper drag wire 31 is unwound from a reel 32 and travels parallel to the core 6 but in the opposite direction through the tronnels 9. The anodes in trunnel 8 are stationary, and of any suitable type, as rods, casting, shot, etc. The drag wire 31 is wound on a reel 33 located adjacent the entrance end of the apparatus. During the deposition process, the core 6 and the drag wire 31 both move through the depositing baths but in opposite directions. In addition to this, the core which is maintained under great tension is also rotated about its own axis, so that the deposition will be uniform. The tension on the core is preferably from 15,000 to 50,000 pounds per sq. in., or approaching the yield point of the base material.

The means for supplying the core to the baths is illustrated in Figures 3 to 6. The reel 2 is rotatably mounted in a frame 13, so that as the reel is rotated about its axis, the core unwinds from the reel. The frame 13 is rotatable about its longitudinal axis, which axis is at substantially a right angle to the axis of the reel 2. The frame is rotated through a gear 14 driven by the pinion 34 on an extension of the shaft of synchronous motor 35. The pay-reel 2 is mounted for easy removal from the frames 13; and as shown in Figure 9 is provided with hubs 36 which are secured in place by rods 37. The hubs are supported by cone-shaped bearing sleeves 38 which are internally threaded for reception of screws 39. The sleeves 38 are slidable within housings 40 secured to the frame and are adjusted by rotation of the hand wheels 41.

With this construction, it is an easy matter to remove an empty reel from the frame and insert a full reel.

The core or wire 6, after leaving the pay-reel 2, passes between a pair of rollers 43 and is then wound around a bull wheel 44 from which the wire passes over guide rollers 45 and through the hollow trunnion 46 of the frame 13. In order to assist in straightening and centering the wire on the axis of rotation of the frame I prefer to mount a roller 47 at the end of the series of rollers 45 by means of an adjustable clevis 47a (see Figure 4).

Means is provided for delivering the core from the bull wheel so that it will be in alinement with the guide rollers 45. For this purpose a wobblers ring 48 fits around the periphery 49 of the bull wheel 44. The periphery 49, that is the cylindrical surface about which the turns are wrapped, has a transverse slot 50 which receives the returned or hooked end of the wobblers ring 48 with sufficient looseness so that the ring 48 may slide transversely of the periphery 49 while being entrained with the rotating bull wheel. A separate frame 51, which is stationary, carries a plurality (herein there are five, spaced equally about the circumference of the frame) of bearing wheels or rollers 52 mounted on radial axes and tangential to a helical path. It is this helical path which these rollers 52 force the wobblers ring 48 to follow as the bull wheel rotates, the frame 51 being disposed at one side of the bull wheel so as to maintain the rollers 52 against the wobblers ring.

During paying out of the wire 6 over the bull wheel 44, the turn of the wire in contact with the wobblers ring 48 is gradually forced away from the frame 51, due to the helical path followed by the wobblers ring, until the ring passes over the last or most extended roller, when the ring falls back to begin the helical path all over again. The turns of wire 6 do not, of course slip back with the wobblers ring; and therefore as the periphery 49 again approaches the place for the next turn to be laid on, there is space for it to be laid between the last turn and the wobblers ring. This arrangement delivers the wire from the bull wheel in alinement with the guide rollers.

It has been stated that the core is fed through the bath under high tension. This tension is accomplished by driving the mechanism of the pay-reel by one motor, driving the mechanism of the take-up reel with another motor, and so relating the speeds of the two motors as to impart the desired tension to the wire 6. The pay-reel 2 carries a lug 54 which is adapted to be engaged by a lug 55 on the side face of a gear 56 mounted coaxially with the reel 2. The gear 56 is driven through a gear train 57 and a sprocket shaft 58, this shaft having interposed therein a slip clutch 59 which slips so that when the reel is full and must turn more slowly than toward the end of the unreeling, excessive strain on the train of gears is avoided. The sprocket 61 on the shaft 58 is driven by a sprocket chain 62 from the sprocket 63 on the driven shaft 64. A direct current motor 66 drives through a speed reducer 67 having a pinion 68, a gear 69 on the driven shaft 64. The current for this motor is led in through the collector rings 71. The driven shaft 64 carries a pinion 72 meshing with a gear 73 carried on the side of the bull wheel 44 so as to rotate the latter.

The arrangement for feeding the wire 6 which has just been described is preferable for wire of

relatively large diameter which is quite stiff. For wire which pulls more readily from the reel, it may be found desirable to hold back rotation of the reel 2 by means of a friction brake as described in my prior application Serial No. 649,532, filed December 30, 1932. The operator, therefore, will be guided by circumstances in selecting the arrangement shown herein according to which the reel 2 is driven, or the arrangement shown in my prior application according to which a brake is applied to the reel 2, so as to obtain the proper tension on the wire 6 as it passes through the electrolyte. I have found this tension feature to be highly important in obtaining a satisfactory and uniform deposit.

The take-up reel 10 and its driving connections are illustrated in Figures 7 and 8. The reel is rotatably mounted in the frame 11 in the same manner that the pay-reel 2 is mounted in its frame 13. The frame 11 is rotated about its longitudinal axis by the synchronous motor 75 and gearing 12 illustrated in Figure 1. The motors 35 and 75 for revolving the frames 13 and 11 are synchronous so as to rotate the core about its axis at the same speed at both ends of the apparatus. The core 6, after passing through the last trunnion 9, and then through the furnace F, passes over a shoe 77, then around a bull wheel 78, and is then wound on the take-up reel 10. The curvature of the shoe 77 approximates the curvature of the wire passing over the rollers 45 on the pay reel. The bull wheel 78 is substantially identical with the bull wheel 44 of the pay reel, it being noted that the bull wheel 44 delivers the wire in alinement with the axis of rotation of the frame 13 while the bull wheel 78 receives the product of the process in alinement with substantially the same axis.

The take-up reel 10 is driven from a motor 79 which is mounted on the frame 11 and rotates therewith. The drive from this motor to the bull wheel 78 and to the reel 10 has substantially the same arrangement as that for the pay reel, except that here the coated wire is being wound up. In addition there is a sprocket 81, driven in common with the reel 10, which is connected by a sprocket chain 82 to a sprocket wheel 83 secured to a screw 84. A traveling guide 85 moves back and forth across the screw 84 which has a return thread cut therein. The guide fingers 86 of the guide 85 are disposed one to either side of the wire 6, and accordingly the wire is caused to lay in a smooth coil on the reel 10. A rod 88 fits into the notches 89 formed in the outer ends of arms 90 of the guide so as to prevent the guide from rotating with the screw.

The axles 92 of the frame 11 are mounted in bearings 93. The left-hand axle, as viewed in Figure 7, extends beyond the bearing for some distance and is provided with contact rings 94. These rings make contact with brushes 95 which are connected by wires 96 to a source of direct current. The D. C. motor 79 is connected to the rings 94 by wires 97 which extend through the axle 92. In the construction just described, the frame is rotated about its longitudinal axis by the motor 75 and driving connection 12, and the take-up reel is rotated so as to wind up the core wire by the motor 79 which is mounted on the frame and which rotates therewith. It is preferred to have separate motors and driving means for the frame and for the reel.

It will be noted that both the motor 66 and the motor 79 are direct current motors. By rotating the two motors at precisely the same speed, the

tension on the wire 6 as it travels through the tronnels is maintained constant. Short of ideal conditions as to friction in the bearings and source of current, it will be found necessary to regulate the relative speed of the two motors 66 and 79 so as to maintain this tension within limits. By maintaining the speed of the motor 79 substantially constant and by speeding up the motor 66, the tension may be decreased; while by reducing the speed of the motor 66 (the speed of the motor 79 meanwhile being substantially constant) the tension in the wire 6 may be built up. In order to avoid requiring the services of an attendant for supervising the speed of the motor 66, I prefer to employ an automatic regulating device such as is shown schematically in Figure 4 of the drawings. The thrust bearing 99 for the trunnion at the outer end of frame 13 is linked by chains 100 and bolts 101 (which permit adjustment) to a yoke 102 having knife-edge contact with a lever member 103 pivoted at 104 to a vertical frame 105. This lever 103 constitutes substantially a scale beam mechanism, and carries at its outer (lower) end a segmental rack 107 meshing with a pinion 108 fixed to a pendulum 109. This pendulum carries a contact 110 forming a part of a control for resistance in the circuit to the motor 66. By arranging the change in resistance in steps, or by other suitable expedient, the control arrangement is prevented from "hunting". The bearing for the other trunnion of the frame 13 affords sufficient play longitudinally of its axis so that the entire frame 13 is movable slightly along the axis of rotation in conformity to changes in tension in the wire 6. The amount of travel is extremely small due to the long lever arm of the scale beam mechanism 103. In this manner, changes in tension in the wire automatically bring about changes in the speed of the motor 66, this regulation having the effect of keeping the tension on the wire 6 within predetermined limits.

Figure 19 illustrates a device for preventing the release of tension on the coated core. It comprises a head 112 which, in the embodiment shown, is of truncated cone-shape secured to the axle 92 of the frame by screws 113. The head is provided with openings 114 arranged at an angle to each other and converging in a direction opposite to that in which the core travels. A clamping jaw 115 is arranged in each of the openings, and a spring 116 disposed within each opening abuts against the end of each jaw 115, tending to force them toward each other. When the core 6 moves to the right, as viewed in Figure 19, the springs are compressed and the jaws are forced into the openings and moved apart a distance sufficient to allow the core to move between the jaws. However, the core is prevented from moving to the left since in this direction the springs force the jaws together, so that they grip the core. This arrangement prevents loss of tension on the core when a full take-up reel is removed and is replaced by an empty reel. I have found that in certain cases it is possible to provide sufficient frictional resistance in the working parts of the take-up reel that this resistance alone is sufficient to keep the wire under tension when the motor is stopped.

Roller contacts arranged between the tronnels are employed for making the electrical contact with the core wire 6 which forms a cathode in the process. A preferred form of contact roller is shown in Figures 15 and 16. A copper roller 117 is mounted between the arms of a yoke 118 which

is mounted in such angular relation to the wire 6 that the roller 117 rolls on the wire without side slippage. In other words, the contact between the wire 6 and the roller 117 must be helical due to the simultaneous advance and rotation of the wire; and the axis 119 of the roller 117 is maintained at such an angle to the wire 6 that if the roller bodily rolled about the wire 6, the latter being stationary, the resulting helical path would coincide with the aforementioned helical contact. Thereby sliding contact is avoided.

I preferably form the yoke 118 with a broad flat bearing surface for the side of the roller 117 which is pushed thereagainst by the forward travel of the wire 6. The slots 120 in which the axes 119 are received are deep enough to cause substantially the entire weight of the roller 117 to bear on the core 6 so as to make good electrical contact.

An anode contact is illustrated in Figure 12. The drag wire 31 which forms the anode is supported on a porcelain base 121 resting on the bottom of the trunnel which has a lead lining 122. A contact brush 123 contacts with the drag wire.

The core 6 is treated between tronnels with a jet or spray of slightly acidulated water. One part of sulphuric acid to one thousand parts of water may be used, and it has been found that in this manner the formation of a dark colored stain which otherwise would be formed on the core is prevented.

Contamination of the anode 31 (herein termed the drag wire) by cuprous oxide, if permitted to go on unchecked as the drag wire is pulled toward the entrance end, will have a deleterious effect upon the deposition of metal upon core 6. The effect of the accumulation of cuprous oxide is particularly damaging to the quality of the deposition during the first part of the travel through the electrolytic bath or baths. I have found that a high pressure jet of water is effective for removing the accumulation of cuprous oxide from the drag wire between tronnels. Such a jet is shown at 124, and impinges upon the anode in the air gap between tronnels, so that the anode enters the next trunnel cleansed of adherent impurities.

In a commercial installation, and particularly where a relatively thick deposit of metal on the core wire is desired, the span between the pay-reel and the take-up reel will be too long to avoid sagging, unless intermediate supports are provided. The type of support which I at present prefer is illustrated at 125 in Figures 17 and 18, it being understood that the position of a support is intermediate the adjacent ends of two tronnels, i. e. not in the electrolyte but in the air gap between tronnels. It is preferable to stagger the supports, placing one on one side of the core 6, and the next on the other side, and so on, as indicated in Figure 17.

The rollers 125 are preferably made of a hard corrosion resistant alloy, such as iron containing about 14½% silicon, each roller being mounted on a non-corrosive stud or pin 126.

As indicated in Figure 18, the supports 125 are not directly below the wire but are staggered so that the wire due to its weight tends to wedge itself in between. Moreover, the type of roller shown provides point contact with the core, so that the combined result of the wedging effect and of the point contact is a compacting action on the electrodeposited metal in the helical paths taken by the supporting rollers 125 on the revolving wire or rod 6. In order to provide the point contact, each roller 125 is tapered away in both directions from a rounded ridge which alone makes contact

with the core 6. The shape of roller is substantially such as would be obtained by placing together the bases of two truncated cones one of which is more nearly cylindrical than the other.

5 The pins 126 are disposed substantially in a horizontal plane and at such an angle to the direction in which the core 6 is advancing that a helical path is produced without slippage, in the manner explained in connection with the contact roller 10 117.

A great deal of difficulty has been experienced in obtaining a good deposit of copper on the core which had previously been coated with nickel in the tronnel 7. It is important to bear in mind 15 that the over-voltage on the wire 6 entering the copper solution in the tronnel 8 is much greater than the over-voltage between a copper-coated surface and a copper electrolyte. If a rod, say five feet long, were copper-coated on one end and nickel-coated on the other end (no 20 etching or buffing of the nickel coating being resorted to), and if such a rod were inserted in a copper plating system, it would be found that the current would flow instantly through the copper-coated end of the rod but would be delayed in flowing through the nickel-coated end. Spongy copper of poor bonding quality would be deposited on the rod in such a case. In order 30 to prevent this happening when the wire 6 enters the tronnel 8, I impress a current of high density upon the core 6 where it first comes in contact with the copper electrolyte, thus ensuring that the nickel coated core is instantly struck with a uniform crystalline nucleus on which the remaining copper deposit may form. An excellent union is thus effected between the copper and the nickel.

In order to impress such a current density upon the entering and revolving cathode, I provide 40 a local anode, preferably of the type illustrated in Figures 10 and 11. This anode I position at the point where the cathode enters the copper electrolyte; and as shown in Figure 21 I control the flow of current therethrough, connecting this anode in its own individual circuit. Preferably, 45 an ammeter and a voltmeter are arranged in this circuit so that the operator can control the impressed current at this point.

Although it is obvious that the anode just referred to may take several forms other than truly 50 annular, I have had excellent results with the anode 130 of the form illustrated. This anode is insoluble, being made of a metal such as lead which is not dissolved by the electrolyte. This anode surrounds most of the cathode 6 and extends for only a short distance at the entrance 55 of the tronnel 8. It is supported by straps 131 which fit over the sides of the tronnels.

Current for carrying out the electrodeposition of the metals is supplied by a series of generators 140, 141 and 142 connected, respectively, 60 to motors 143, 144 and 145, and a generator 170 connected to a motor 171. The tronnels 3 and 4 are connected in series with the generator 140 by conductors 146 and 147. The negative conductor 148 of the generator 141 is connected to an iron anode 149 in the tronnel 5. The positive conductor 150 of the generator 141 is connected in parallel to a plurality of nickel anodes 151, 152, 70 153, 154 and 155. The anodes 151 and 155 are connected to the conductor 150 through resistances 156, 157, 158, 159 and 160, respectively. The resistance 156 is the greatest and 160 is the least, the intermediate resistances decreasing 75 from 156 to 160 as indicated on the drawings.

This arrangement tends to produce a uniform current density throughout the length of the core wire within the tronnel 7. If varying resistances are not employed, the tendency is to have the greatest current density at the entrance end of the tronnel, which results in uneven deposition of the nickel. The varying resistances 156 to 160 counterbalance the resistance of the core wire, thereby equalizing the current densities along the whole length of the wire and causing deposition of metal throughout 10 substantially the whole length of the tronnel.

The circular high current density anode 130 which is illustrated in detail in Figures 10 and 11 is connected by a positive conductor 165 to the generator 142. The negative conductor 166 15 is connected at the point 167 by a roller contact of the type shown in Figure 16 to the core wire 6. An anode 168 is connected by a positive conductor 169 to a generator 170 which is driven by a motor 171. The drag wire 31 is connected at points 172 and 173 within the tronnels 9 by positive conductors 174 and 175, respectively. Negative conductors 176, 177 and 178 connect the generator with points 167, 179 and 180, respectively, on the cathode wire. 25

The proper spacing of the cathode contacts affects both the quality of the deposit and the cost of the process. High current densities decrease the total length of tronnels needed to produce 30 a deposit of a certain thickness, but the current density cannot exceed a certain amount without injuring the quality of the deposit. This maximum current density will prevail adjacent the cathode contacts only, and will drop down 35 until a point midway between cathode contacts is reached. With the entering wire carrying little or no copper, the drop in current density toward this midpoint is rapid; but toward the delivery end the drop in current density between cathode contacts becomes slower and slower due to the greater conductivity of the heavily coated wire. In order to keep the current density within the limits which will give a good deposit, I preferably increase the distance between cathode 40 contacts in the direction of travel of the core. If separate baths are employed, the length of the containers or tronnels 9, and the distance between cathode contacts can both be increased. The increased resistance due to the increased 45 length of the coated core between cathode contacts compensates for the decreased resistance per unit of length resulting from the increased diameter of the coated core as the deposition continues. 50

The gradual depletion of the anode wire 31 in moving from the exit end toward the entrance end has a beneficial effect in promoting the desired distribution of current density along the length of the core 6. As the drag wire 31 approaches the entrance end, the cross section of wire 31 has decreased; and the corresponding lowering of its conductivity promotes the lower current density which should prevail in the earlier portions of the deposition process. Of course, near the exit end the conductivity of anode 31 is near its maximum, which accords with the desire for relatively high current densities in the later portion of the process. Moreover, the depletion of the anode 31 tends toward 65 a purer anode. Such purity of anode is of considerably greater importance toward the entrance end.

A number of rollers 125 of the point contact type are preferably used in staggered relation 75

in carrying out the process. The use of supports in this relation to the core 6 is highly advantageous as it permits of handling the wire expeditiously and without any deleterious effects upon the product. The guiding of the wire by means of the supports insures accurate positioning thereof at all times, thereby insuring that proper conditions will be maintained in the apparatus.

I prefer to use all of the different types of contacts for the core which I have described, the different types of contacts being used at different points in the process. Thus, in the tronnels, 3, 4, 5, 7 and 8, it is preferred to use solution contacts, that is, to avoid any mechanical contact with the core, as it has been found that minute scratches which are made by the use of mechanical contacts will be carried through the whole process and the defects may actually increase as the process progresses. In passing through the first tronnel 9 containing a hot copper solution, a relatively heavy deposit is made, so that a roller contact of the type shown in Figures 15 and 16 may be employed here and throughout the rest of the process. During most of the process, it is preferred to use the compression rollers shown in Figures 17 and 18 to accomplish the compression and refinement in grain structure which has been described.

After the coating of the core 6 is completed, I pass the product through a heat treatment zone before it is wound up on the reel 10. A furnace F of refractory blocks for accomplishing this heat treatment is shown in horizontal section in Figure 20. The heat may advantageously be supplied by a gas burner 185, and the hot gases are caused to flow in a direction opposite to the direction of travel of the product 6 to a stack 186. The product 6 is somewhat heated by the gases; and is finally highly heated by the flame from the burner 185. This flame (preferably a reducing flame) can play directly on the product due to the rotation of the product and its forward travel.

A troublesome phenomenon which frequently accompanies the heating of a copper-coated rod or wire is the formation of blisters. Defects which are not apparent during or at the completion of the electrodeposition process show up as blisters when a heat treatment is applied. Such heat treatment may become necessary, for instance, when drawing the rod or wire through dies to obtain finer gauge wire. I have found that by heat treating the product 6 at the end of the electrodeposition process while it is still under tension and before it is reeled up, the danger of formation of blisters is materially decreased.

I have illustrated and described the present preferred embodiment and manner of practicing my invention, but it should be understood that the invention may be otherwise embodied or practiced within the scope of the following claims.

I claim:

1. Apparatus of the type described which comprises an electrolytic bath, means for passing a wire through said bath, means for rotating said wire about its axis while passing through said bath and while maintaining it under tension, and means for depositing metal from said bath onto said wire.

2. Apparatus of the type described which comprises a bath for depositing metal, a reel for supplying wire to said bath and a reel for receiving wire from said bath, said reels being ro-

tatable in a direction to cause said wire to rotate in the same direction on entering and leaving said bath, and means for depositing metal on said wire while passing through said bath.

3. Apparatus of the type described which comprises a bath for depositing metal, a reel for supplying wire to said bath and a reel for receiving wire from said bath, said reels being rotatable in a direction to cause said wire to rotate in the same direction on entering and leaving said bath, an anode in said bath, and means for passing electric current from said anode to said wire while the wire is passing through said bath.

4. Apparatus of the type described which comprises a bath for depositing metal, a reel for supplying wire to said bath and a reel for receiving wire from said bath, said reels being rotatable in a direction to cause said wire to rotate in the same direction on entering and leaving said bath, means for depositing metal on said wire while passing through said bath, and means for supporting said wire.

5. Apparatus of the type described which comprises an electrolytic bath, means for passing a wire through said bath under tension, means for rotating said wire about its axis while passing through said bath, means for depositing metal from said bath onto said wire, and rotatable means for supporting the wire.

6. Apparatus for the electrodeposition of a coating metal on a metallic base, comprising an electrolytic bath through which the base may extend, means for feeding the base metal through the bath, means for rotating the base metal about its axis during such movement, and an anode extending alongside the path of movement of the base.

7. Apparatus for the electrodeposition of a coating metal on a metallic base, comprising an electrolytic bath through which the base may extend, means for feeding the base metal through the bath, means for rotating the base metal about its axis during such movement, an anode extending alongside the path of movement of the base, and means for maintaining the base under tension during such movement.

8. Apparatus of the type described, comprising a plurality of baths for depositing metal from solution, the different baths being of different character, means for passing a wire through said baths, and means for rotating the wire about its axis while it passes therethrough and while maintaining it under tension.

9. Apparatus for electrodepositing metal on a core, comprising an electrolytic bath, means for passing the core as a cathode through the bath from an entrance end to an exit end, means for rotating the core about its axis while passing through the bath, means for passing an anode wire through the bath in the opposite direction to the direction of movement of the cathode, and means for reeling up the depleted anode wire at said entrance end.

10. Apparatus for electrodepositing metal on a core, comprising a series of spaced open ended containers adapted to hold electrolytic baths, means for passing a core as a cathode in a substantially straight path through the baths, means for rotating the core axially while passing through the baths, and electric contacts for the cathode located between containers.

11. Apparatus for electrodepositing metal on a core comprising a series of spaced open ended containers adapted to hold electrolytic baths

adapted for the deposition of the same plating metal, means for passing a core as a cathode successively through the baths, means for passing an anode successively through the baths, and jets for impinging jets of water on the anode between baths.

12. Apparatus for electrodepositing metal on a core, comprising a series of spaced open ended containers adapted to hold electrolytic baths adapted for the deposition of the same plating metal, means for passing a core as a cathode successively through the baths, means for passing an anode successively through the baths, electric cathode contacts located between containers, and electric anode contacts located in the containers.

13. Apparatus for electrodepositing metal on a core comprising a series of spaced open ended containers adapted to hold electrolytic baths adapted for the deposition of the same plating metal, means for passing a core as a cathode successively through the baths, means for passing an anode successively through the baths, electric contacts for the anode located in the containers, and jets for impinging jets of water on the anode between the containers.

14. In combination, an electrolytic bath, means for supplying a core to said bath, said means comprising a frame rotatable about its longitudinal axis, a pay-reel mounted in the frame and rotatable about an axis which is at substantially a right angle to the longitudinal axis of the frame, and means for rotating the frame to cause rotation of the core in the bath about its axis.

15. In apparatus for the electrodeposition of metal, the combination of an electrolytic bath and means for winding up and rotating a core about its axis, comprising a frame rotatable about its longitudinal axis, a take-up reel mounted in the frame and rotatable about an axis which is at substantially a right angle to the longitudinal axis of the frame, means for rotating the frame about its longitudinal axis, and means for rotating the reel about its axis.

16. In apparatus for the electrodeposition of metal, the combination of an electrolytic bath and means for winding up and rotating a core about its axis, comprising a frame rotatable about its longitudinal axis, a take-up reel mounted in the frame and rotatable about an axis which is at substantially a right angle to the longitudinal axis of the frame, means for rotating the frame about its longitudinal axis, and means mounted on the frame and rotatable therewith for rotating the reel about its axis.

17. Apparatus for winding up and rotating a core about its axis, comprising a frame rotatable about its longitudinal axis, a take-up reel mounted in the frame and rotatable about an axis which is at substantially a right angle to the longitudinal axis of the frame, means for rotating the frame about its longitudinal axis, an electric motor mounted on the frame and rotatable therewith, said motor having a driving connection with said reel, and means for operating said motor.

18. In apparatus for treating wire in which the wire is paid out from a pay-reel, treated, and wound on a take-up reel, the wire being pulled under tension from the first reel by being wound on the second reel, the combination of a frame having at its opposite ends trunnions for rotatably supporting the frame on a horizontal axis extending longitudinally of said apparatus, a pay-reel rotatably mounted in said

frame intermediate said trunnions on a transverse axis, and guiding means on the rotatable frame for straightening and feeding the wire from the reel through one of said trunnions along said longitudinal axis.

19. In apparatus for treating wire in which the wire is paid out from a pay-reel, treated, and wound on a take-up reel, the wire being pulled under tension from the first reel by being wound on the second reel, the combination of a frame having at its opposite ends trunnions for rotatably supporting the frame on a horizontal axis extending longitudinally of said apparatus, a pay-reel rotatably mounted in said frame intermediate said trunnions on a transverse axis, and guiding means for straightening and feeding the wire from the reel through one of said trunnions along said longitudinal axis comprising a series of rollers mounted in said frame.

20. In apparatus for treating wire in which the wire is paid out from a pay-reel, treated, and wound on a take-up reel, the wire being pulled under tension from the first reel by being wound on the second reel, the combination defined in claim 19 in which the series of rollers is so arranged as to reverse the curvature of the wire passed thereto.

21. In apparatus for treating wire in which the wire is paid out from a pay-reel, treated, and wound on a take-up reel, the wire being pulled under tension from the first reel by being wound on the second reel, the combination of a frame having at its opposite ends trunnions for rotatably supporting the frame on a horizontal axis extending longitudinally of said apparatus, a pay-reel rotatably mounted in said frame intermediate said trunnions on a transverse axis, and guiding means on the rotatable frame for straightening and feeding the wire from the reel through one of said trunnions along said longitudinal axis, said guiding means reversing the curvature of the wire passed thereto and comprising an adjustable roller engageable with the wire on the outside of said reverse curvature substantially where it reaches said longitudinal axis.

22. In apparatus for treating wire in which the wire is paid out from a pay-reel, treated, and wound on a take-up reel, the wire being pulled under tension from the first reel by being wound on the second reel, the combination of a frame having at its opposite ends trunnions for rotatably supporting the frame on a horizontal axis extending longitudinally of said apparatus, a pay-reel rotatably mounted in said frame intermediate said trunnions on a transverse axis, and guiding means for straightening and feeding the wire from the reel through one of said trunnions along said longitudinal axis comprising a series of rollers mounted in said frame for engaging one side of the wire and an adjustable roller for engaging the other side of the wire substantially where it reaches said longitudinal axis.

23. In apparatus for treating wire in which the wire is paid out from a pay-reel, treated, and wound on a take-up reel, the wire being pulled under tension from the first reel by being wound on the second reel, the combination of a frame rotatably mounted on a horizontal axis extending longitudinally of said apparatus, a pay-reel rotatably mounted in said frame on a transverse axis, guiding means on the rotatable frame for straightening and feeding the wire from the reel along said longitudinal axis, and means retarding and controlling the feed of wire to

control the tension of the wire between the two reels of said apparatus.

24. In apparatus for electrodepositing metal on a core, the combination with an electrolytic bath and means for feeding the core through the bath under tension, of means for preventing release of tension on the core.

25. Apparatus for electrodepositing metal on a core comprising an electrolytic bath, means for passing the core through said bath, means for rotating said core about its axis while passing through said bath, and means for connecting said core in an electric circuit as a cathode including a roller for contacting the core, the axis of the roller being disposed in such angular relation to the axis of the core that the path of rolling contact with the core is helical.

26. Apparatus for electrodepositing metal on a core comprising an electrolytic bath, means for passing the core through said bath, means for rotating said core about its axis while passing through said bath, and means for connecting said core in an electric circuit as a cathode including a roller for contacting the core and bearing with a substantial portion of its weight on the core, said roller and core angularly contacting each other, the contact of the roller and core defining a helix due to the simultaneous advance and rotation of the wire.

27. Apparatus for electrodepositing metal on a core comprising a series of electrolytic baths, means for passing the core through the baths, means for rotating the core about its axis while passing through the baths, and means for connecting the core in an electric circuit as a cathode including a roller disposed between baths and bearing with a substantial portion of its weight on the core to make electrical contact therewith, the axis of the roller being disposed in such angular relation to the axis of the core that the path of rolling contact with the core is helical.

28. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for passing the core as a cathode through the bath, a plurality of spaced anodes in the bath arranged sequentially along the path of travel of the cathode, said anodes having unequal resistances tending to equalize the current density along the cathode.

29. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for passing the core as a cathode through the bath, a plurality of spaced anodes in the bath arranged sequentially along the path of travel of the cathode, and resistances of different amounts connected to said anodes and tending to equalize the current density along the cathode.

30. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for passing the core as a cathode through the bath, a plurality of spaced anodes in the bath arranged sequentially along the path of travel of the cathode, said anodes being connected in parallel through resistances to one conductor of a source of electric current, said resistances increasing in amount toward the other conductor of the source of electric current so as to equalize the current density along the cathode.

31. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for advancing the core as a cathode through the bath, and spaced anodes arranged sequentially along the path of travel of the cathode and cooperating with said cathode to bring about the electrodepositon of metal thereon, one of said anodes being disposed where electrodepositon on said cathode begins

and being connected in a circuit which permits flow of current at different density from that provided for the subsequent anode or anodes.

32. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for advancing the core as a cathode through the bath, and spaced anodes arranged sequentially along the path of travel of the cathode and cooperating with said cathode to bring about the electrodepositon of metal thereon, one of said anodes substantially surrounding said cathode where electrodepositon on said cathode begins and being connected in a circuit which permits flow of current at different density from that provided for the subsequent anode or anodes.

33. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for passing the core as a cathode through the baths, and supporting means for the core comprising rollers arranged in staggered relation on the two sides of the path of travel of the core and making substantially point contacts with the core.

34. Apparatus for electrodepositing metal on a core comprising an electrolytic bath, means for passing the core as a cathode through the bath, means for rotating said core about its axis while passing through the bath, and rollers arranged to make substantially point contacts with the rotating core so as to form compacted helical paths on the deposited coating of metal.

35. Apparatus for electrodepositing metal on a core comprising an electrolytic bath, means for passing the core as a cathode through the bath, means for rotating said core about its axis while passing through the bath, and supporting means for the core comprising a plurality of rollers which make substantially point contacts with the core, the axes of the rollers being disposed in such angular relation to the axis of the core that the path of rolling contact with the core is helical.

36. Apparatus for electrodepositing metal on a core comprising an electrolytic bath, means for passing the core as a cathode through the bath, means for rotating said core about its axis while passing through the bath, and supporting means for the core comprising a plurality of rollers which are angular in longitudinal section and make substantially point contacts with the core, the axes of the rollers being disposed in such angular relation to the axis of the core that the path of rolling contact with the core is helical.

37. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for passing a core as a cathode through said bath, and spaced cathode contacts arranged along the system, the distance between cathode contacts becoming greater toward the delivery end of the apparatus.

38. Apparatus of the type described which comprises an electrolytic bath, means for passing a wire through said bath, means for rotating said wire about its axis while maintaining it under tension, means for depositing metal from said bath onto said wire, and means for heat-treating said coated wire while still under tension.

39. Apparatus for electrodepositing metal on a core comprising a container for an electrolytic bath, means for passing the core as a cathode from an entrance end through the bath to an exit end, means for rotating the core as it travels through the bath, means for supplying an anode wire to the bath at a point remote from the

entrance end, and means for feeding the anode wire through the bath to a point adjacent the entrance end of the bath, the apparatus being so constructed and arranged that the anode travels in the bath only in a direction opposite to the direction of travel of the cathode.

40. In apparatus for electrodepositing metal on a core, a plurality of baths of different metals, means for passing the core as a cathode through the baths successively, and spaced anodes arranged sequentially along the path of travel of the cathode and cooperating therewith to bring about electrodeposition on said cathode, one of said anodes being an insoluble anode of high current density substantially surrounding said cathode where, having left one bath, it is entering the next.

41. In apparatus for electrodepositing metal on a core, a plurality of baths of different metals, means for passing the core as a cathode through the baths successively, and spaced anodes arranged sequentially along the path of travel of the cathode and cooperating therewith to bring about electrodeposition on said cathode, one of said anodes being an insoluble substantially cylindrical anode of high current density so dis-

posed as to substantially surround the portion of the cathode which is entering a bath for impressing current at high density on that portion of the cathode which is then entering the bath.

42. Apparatus of the type described comprising a pay-out reel and a take-up reel spaced therefrom, means for feeding a wire from the pay-out reel to the take-up reel and maintaining it in tension therebetween, an electrolytic bath arranged in the path of the wire so that the wire passes through said bath on its way from the pay-out reel to the take-up reel, means for rotating the wire while passing through the bath, means for depositing metal from the bath onto the wire, and heat treating means through which the coated wire passes on its way to the take-up reel and while still under tension.

43. In apparatus for electrodepositing metal on a core, an electrolytic bath, means for passing the core as a cathode through the bath, means for rotating the core, and means supporting the core and providing point contacts therewith comprising a plurality of rollers having rounded ridges thereon.

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