

Sept. 14, 1954

S. G. BART

2,689,215

METHOD AND APPARATUS FOR PLATING PIPE

Filed July 13, 1949

2 Sheets-Sheet 1

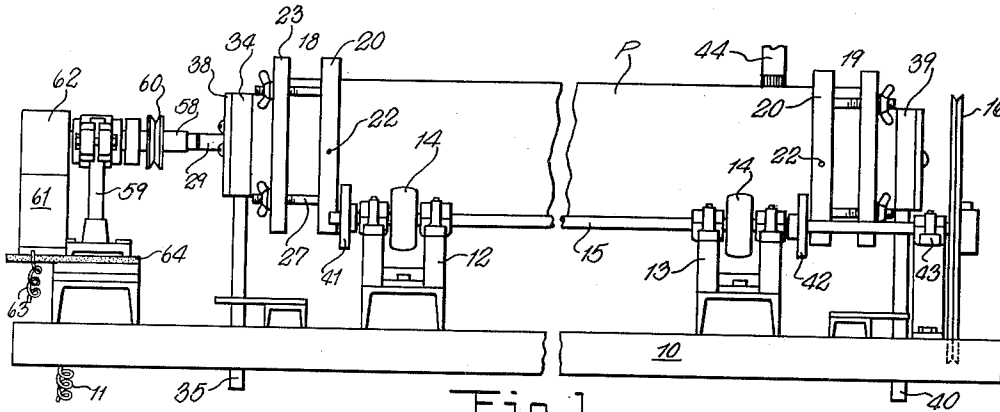


Fig. 1.

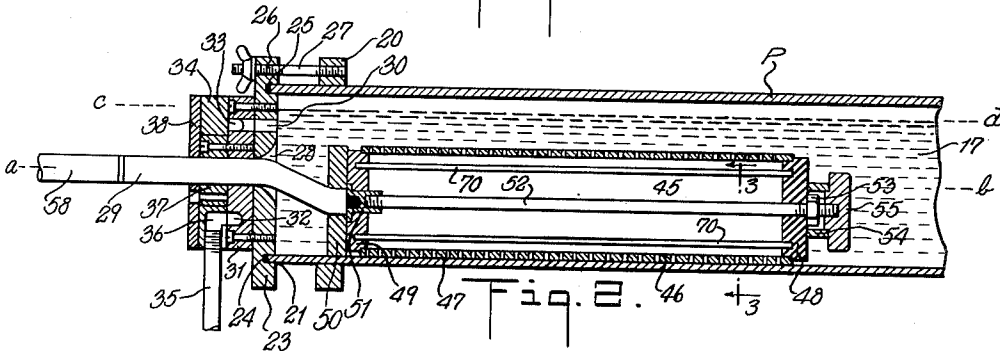


Fig. 2.

Fig. 3.

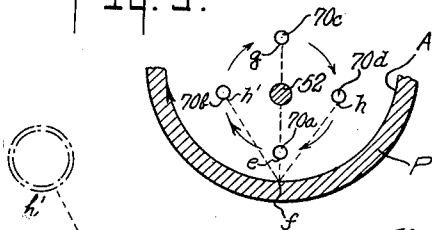
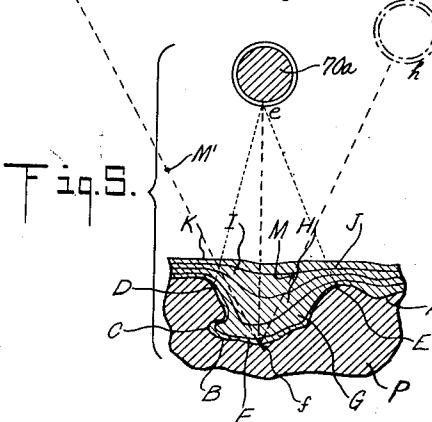
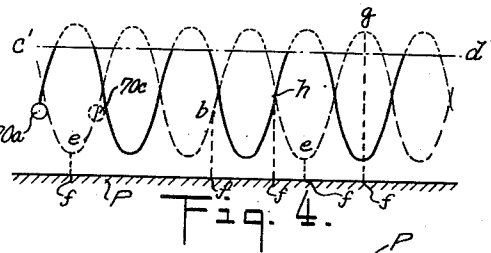
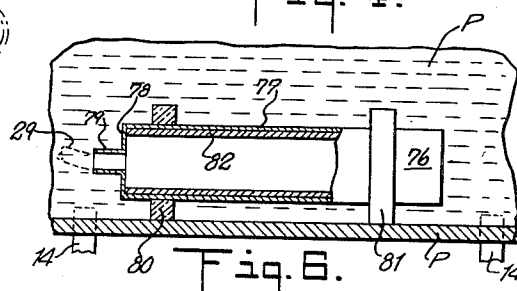


Fig. 4.



Sept. 14, 1954

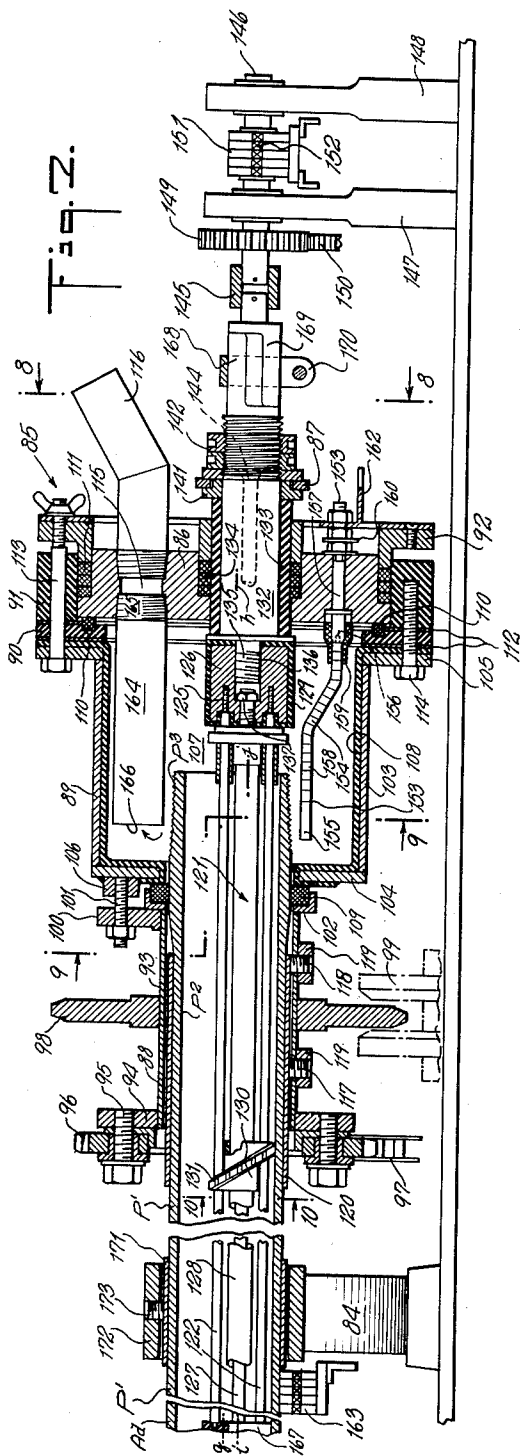
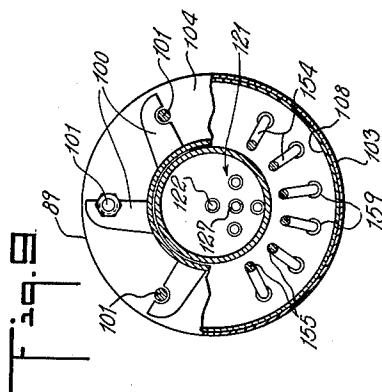
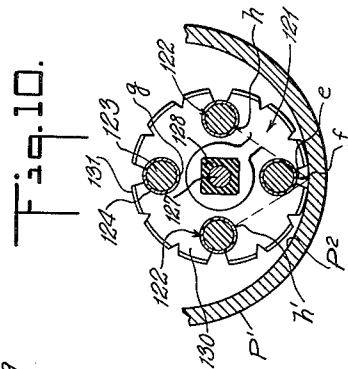
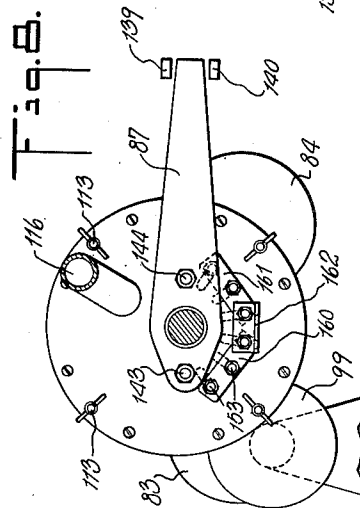
S. G. BART

2,689,215

METHOD AND APPARATUS FOR PLATING PIPE

Filed July 13, 1949

2 Sheets-Sheet 2



INVENTOR.
SIEGFRIED G. BART
BY
Warren S. Orton.
ATTORNEY

UNITED STATES PATENT OFFICE

2,689,215

METHOD AND APPARATUS FOR PLATING
PIPE

Siegfried G. Bart, Essex Fells, N. J.

Application July 13, 1949, Serial No. 104,406

18 Claims. (Cl. 204-26)

1

The invention relates in general to a new technique in the art of electrolytic deposition and specifically relates to an improvement in the method of operating the anode and cathode elements of an electrolytic cell. Still more specifically, the invention relates to a novel method for electroplating the insides of tubes such as fluid-conducting pipes and pipe fittings and similar hollow vessels used in chemical and other industries.

The invention also relates to apparatus particularly designed for practicing said method and of which apparatus two different forms are disclosed.

In so far as the method aspects of this disclosure are concerned, the invention is in part a division of my application entitled, "Apparatus for Electroplating the Insides of Pipes," Serial No. 510,768, filed November 18, 1943, now Patent No. 2,503,863, April 11, 1950, and, in so far as the apparatus is concerned, this application is a continuation in part of said prior application.

The primary object of the invention is to provide an improved technique by means of which higher current densities with incidental faster plating and without danger of peeling or cracking, higher temperatures and improved throwing powers may be had, and by the practicing of which technique a better character of metallic liner for pipes and like hollow articles may be obtained than has been possible heretofore, with incidental economy in manufacturing costs in the anode material, in the electrolyte and in the amount of electric current consumed in effecting the necessary density of lining herein featured.

There has been and is at present a demand on the market for corrosion-resistant tubing, pipes, pipe fittings and like hollow bodies. However, and particularly in the case of long pipe, and even in the case of relatively short pipe, say, twenty feet or less in length, it has been quite difficult in a commercial way to develop by electrolytic deposition a smooth, pore-free, homogeneous metallic lining deposit, free of any evidence of laminations, which will tenaciously adhere to the base metal of which the pipe is made and which will be uniform throughout the length of the pipe.

While the disclosure is not limited to any particular combination of metals usually used in electrolytic deposition, one such tubing or pipe in current market demand for service in situations which are liable to create corrosive and contaminating action in the pipe is a carbon steel pipe lined with nickel, which pipes are com-

2

cially required to be of twenty, thirty, or even forty feet in length. Such pipe is, of course, correspondingly heavy, often weighing many tons, and thus difficult to manipulate as herein suggested.

Despite the fact that the stock steel pipe has what appears to the eye to be a smooth bore wall, still when examined microscopically the apparent smooth surface of the interior wall is quite definitely pitted and irregular. Such surfaces resist the adhesion thereto of electrolytically deposited metals when subjected to conventional depositing processes and under such conditions develop a deposit which is not as dense nor pore free as desired and under severe operating conditions is apt eventually to peel or corrode.

Accordingly, another object of the invention is to effect a dense, smooth and, in effect, a uniform metallic deposition which will adhere permanently and, in effect, become locked or bonded to such pitted surface.

Broadly, I attain this objective by causing a plurality of separate anodes, preferably in the form of rods, periodically to approach and then to recede from the electrolyte wetted surface being plated, with what might be called a multiple-phase sine wave effect, so that the surface being plated is subjected to a series of rapidly repeated impulses of maximum current-plating densities, with relative inactive dwells of little, or at least materially less, current-plating densities between the succeeding points of maximum plating densities.

Broadly considered, this method is practiced by causing a first anode of a set of anode rods moving in an electrolytic bath periodically to approach and then to recede from a point of nearest approach to the surface being plated and then, as the first anode is receding from said point, to cause a second anode similarly and periodically to approach and then to recede from said point, simply by swinging at least two anodes, preferably four or more anodes, in the electrolyte to and from the cathode surface. The invention features the locating of each moving anode to operate in a limited orbital field with its point of nearest approach to the cathode surface being plated so that the layer of electrolyte therebetween will be so small as to effect a high current plating density, so high, in fact, as to cause a resulting high degree of polarization and thus relatively little metal deposition on what may be called the too-near points of the immediately adjacent cathode surface. From this point of maximum polarization and minimum

metal deposition each anode as its distance from the cathode surface increases effects a corresponding increase in metal deposition and, of course, a decrease in polarization until a maximum is reached. Beyond this point of maximum metal deposition any increase in spacing between anode and cathode and thus increase in resistance by the layer of electrolyte therebetween progressively reduces the amount of metal thrown down by the remotely spaced anodes, and, accordingly, in the dimensioning of the anode structure herein featured it is simply necessary to insure the maximum possible metal deposition in any particular situation. Arranging the anodes to so move cyclically in their field of operation with the point of nearest approach well within the point of maximum metal deposition develops unexpected results. The anode and cathode can be brought closer together than heretofore and thus a current density of higher plating strength can be used than has been possible by known practices; the adhesion of the deposited metal to the base is permanent; the deposit is free of pores and thus denser than has been known heretofore. Of even greater importance, it has been found that in the case of pitted surfaces the deposit fills up the depressions, recesses or cavities in the surface even though the cavities be of extremely small, even microscopic, dimensions; the deposit fills in re-entrant angles and overlapping recesses as shown enlarged in Fig. 5 of the accompanying drawings to give an effective pore-free and corrosion-resistant protective coating to such roughened or pitted surface.

Considering the known prior art and assuming the usual pitted condition of the surface to be plated, as shown exaggerated in Fig. 5, and assuming the anode to be fixed, it is well known that under normal conditions the metal deposits form on the points nearest the anode, for instance, on the two high or nearest points D and E of Fig. 5, gradually building up on these points with relatively little deposition on the bottom of the cavity until the high points so built up actually touch and often merge into each other and not infrequently leaving holes or vacant spaces in the deposition.

Thus, under known practices and where the anode is at what might be called ideal plating distance from the surface being plated, the points on the surface being plated nearest to the anode become covered quickly and the less the bottoms of the recesses become plated, if at all. However, by following the method herein featured a reversal of this condition occurs in that it is the deep pocket surfaces which first receive the major portion of the deposition, with the high points receiving relatively less depth of deposit until the pockets are more or less level with the balance of the deposition.

One theory which may account for this phenomena is that, when the anode and the cathode surface being plated are close together as herein contemplated, there is one prefixed distance between them under otherwise the same conditions at which the current-plating density results in the maximum possible deposition of metal and the least production of hydrogen for the particular electrolyte used. For progressively less distances than this ideal metal spacing and thus with decrease of resistance from the intervening electrolyte the percentage of deposition of metal ions rapidly decreases as the percentage of formation of hydrogen ions or polarization correspondingly rapidly increases.

In the situation where the anode moves rela-

tive to the cathode surface being plated, as herein featured, such movement is had as will bring each anode when in its position of nearest approach to the cathode surface within the region where there is relatively little metal depositing action and relatively high polarization. This means that, contrary to the known practice, there is relatively little deposition on the surface being plated by the anode in its nearest approach position and, on the contrary, the high hydrogen releasing action at this time defeats the usual accumulation of metal on the adjacent surface, and this is particularly true of the high points.

However, as the spacing between the anode and cathode increases and thus the resistance interposed by the electrolyte increases, both during the approach and retreat of the anode from its point of nearest approach, that condition is reached in both instances where the metal deposition reaches its maximum and, as the distance between the anode and the bottom of the cavity is greater than the distance between the anode and the high points adjacent the cavity, the greater metal deposition occurs at what may be the then bottom of the cavity. In this way the cavities fill from their bottoms upwardly with uniformity in density of the deposited metal.

Apparently, the best results are obtained where the anodes are caused to approach and recede from the point of nearest approach in synchronous relation and each with a rhythmic motion best exemplified by a sine wave foundation as shown developed in Fig. 4. Differently described, the lining metal is discharged from the electrolyte at points near but not at the point of nearest approach of each anode, in spurts or puffs of maximum possible deposition action, and each of which maximum action is of short time lapse duration. It is apparently also necessary for the best results that the spurts be rapidly repeated. Also, the fact that short time intervals of hydrogen formations occur and are sandwiched in between the relatively longer time periods of metal deposition apparently contributes to the resulting dense metal deposition.

As shown in the accompanying drawings of two forms of electrolytic cells by means of which this method is most conveniently practiced, especially in the situations where the pipes to be plated are long, the best results are obtained by using two or more anode rods, preferably from four to sixteen, or even more. In the case of four rods illustrated they are disposed ninety degrees apart to form a squirrel cage anode with the rods extending lengthwise of a cylinder of reference formed by the revolving anodes. The cylinder has its axis eccentrically related to the axis of the pipe, and one side of the cylinder is disposed as close as is practically possible to the surface being plated and at the same time, of course, spaced therefrom to avoid short-circuiting between anode and cathode.

With reference to the apparatus feature of the disclosure, and particularly referring to the showing in Figs. 7-10, as an improvement over the Figs. 1-3 showing, the primary object of the invention is to provide apparatus particularly designed to perform the method herein featured with exactness and otherwise with mechanical efficiency.

Contributing to this objective is the intent to provide in an electrolytic cell of the type wherein the pipe to be plated coacts with plating heads temporarily fixed thereto to form the container for the electrolyte, an arrangement of inter-fitting parts organized to insure automatically

when fabricated a pre-set close relation of the anode and cathode elements best suited to obtain the desired deposition of lining material.

Another object of the invention is to provide a simple form of electrolytic cell to which can be fitted the different lengths of pipe to be lined without necessity of dismantling very much of the balance of the equipment and by means of which apparatus in either of the two forms illustrated the method herein disclosed and claimed may be practiced economically.

Pipes of the character herein contemplated to be lined are of extremely large size, usually about forty feet in length, sometimes as much as two feet in diameter, and when made of steel often weigh two-three tons. Any attempt to rotate this heavy pipe simply by virtue of its frictional engagement with power driven rollers on which it rests, as disclosed in the Figs. 1-2 form of the invention, would cause a very indifferent form of driving connection between the rollers and the pipe by reason of the inertia of the heavy rotating parts.

Likewise, in the Fig. 1 showing the means at 41 and 42 for resisting endwise creeping of the pipe, while satisfactory for light work, was ineffective to resist end play in the case of large rotating masses when formed of long, heavy pipe.

The later and improved Figs. 7-10 form of the invention herein featured provides as part of the closure heads temporarily secured to the opposite ends of the pipe, a rugged pipe mounting which can be made of heavy steel tubing flanged to give it additional strength and provided with driving means capable of receiving the requisite power turning torque to rotate the head and therethrough to rotate the pipe. Instead of engaging the pipe over a relatively short length thereof, the improved disclosure features a long and somewhat cushioning engagement with an extensive length of the pipe, thereby to grasp and then to rotate the heavy pipe without marring it at any place or places which may be engaged by the driving elements. Also, the Figs. 7-10 form features a guide roller carried by and in itself tending to additionally reinforce the pipe mounting, which guide roller in its engagement with rugged rotating stops forming a part of the stationary parts of the apparatus can effectively resist any possible inertional tendency to end play of the pipe.

In other words, torsional strains are transmitted primarily through the rugged pipe mounting particularly designed to receive and transmit such strains and organized to distribute the strains along a material length of the pipe at one, or preferably at opposite ends thereof.

Still another object of the invention is to provide such a form of apparatus organized to have controls associated therewith and by means of which the character and flow of the electrolyte in the container may be regulated and varied to meet particular environmental operative conditions. Another object is to provide apparatus designed to utilize the available electric energy to do its deposition work efficiently; to minimize possibility of short-circuiting between the anode and cathode elements and thus to avoid as far as possible electrical or ionization losses during the operation.

Among the other objects of the invention are to provide certain basic structural parts of the electrolytic cell designed to accommodate pipes of different lengths to function as cathode elements together with their associated long anode

construction and thus to provide apparatus especially designed to operate on pipes of unusual lengths; to plate the pipes to and even around their ends without necessity of reciprocating the anode as in the Fig. 1-3 showing; and above all to insure an accurately prefixed and incidentally and abnormally close approach of the anodes to the surface being plated, as featured by the method aspects of the disclosure.

Various other objects and advantages of the invention will be in part obvious from a consideration of the method features of the disclosure and from an inspection of the accompanying drawings and in part will be more fully set forth in the following particular description of one method of practicing the invention on either one of two forms of apparatus, and the invention also consists in certain new and novel modifications of the preferred method and other features of construction and combination of parts of the apparatus hereinafter set forth and claimed.

In the accompanying drawings:

Fig. 1 is a view in side elevation of one form of apparatus for forming a lining for a pipe shown in operative position thereon with the mid-portion of the pipe and apparatus broken away and the anode reciprocating mechanism omitted to save space.

Fig. 2 is a vertical sectional view taken axially through the left hand portion of the pipe shown in Fig. 1 and showing positioned therein one form of squirrel cage anode structure rolling on the bottom of the bore of the pipe under treatment;

Fig. 3 is a transverse and explanatory sectional view of the anode construction and the bottom side of the pipe taken on the line 3-3 of Fig. 2, omitting the end mounting for the anode rods;

Fig. 4 is a developed showing in the form of a two-phase sine wave of the reciprocal movements of an opposing pair of the four anode rods shown in Fig. 3;

Fig. 5 is a highly magnified showing (not to scale) and in full lines of the lowermost anode rod of Figs. 3 and 10 and the adjacent portion of the surface being plated, with the said anode rod in ghost outline in two other positions and also showing succeeding stages of the deposition in a cavity by wavy lines and a final line which tends to become straight;

Fig. 6 is a view largely in vertical section of a modified form of the anode construction of Fig. 2 and featuring a wheel-like form of spacing and insulating ring;

Fig. 7 is a vertical axial sectional view of the right end of an electrolytic cell showing a modified form of apparatus by means of which the method aspects of the invention may be practiced; showing an improved form of the apparatus aspect of the invention, and showing a wobble type of spacing ring as an improvement over the spacing rings shown in Fig. 6;

Fig. 8 is a right end view of the disclosure in Fig. 7 as viewed from the plane 8-8;

Fig. 9 is a transverse sectional view taken on the broken line 9-9 of Fig. 7, and looking in the direction indicated by the arrows; and

Fig. 10 is a detail in end elevation of one of the wobble plate anode spacers, taken on the line 10-10 of Fig. 7 and looking in the direction indicated by the arrows.

Referring first to the disclosure in Figs. 1 and 2, there is disclosed a metallic support or long frame 10 connected conventionally to the negative side of a source of electric energy through a cable 11. Mounted on the support 10 are four roller

supporting brackets, two marked 12 and 13 in Fig. 1, on each side of the apparatus. Each of the brackets carries a pipe supporting roller 14, the four rollers coacting to form a cradle support for the pipe P. The rollers on one side as shown in Fig. 1 are mounted on and are rotated by a drive shaft 15 extending lengthwise of and located to one side of the pipe under treatment. The shaft 15 is provided at its right end with a drive pulley 16 which rotates the shaft and the two rollers carried thereby.

The pipe P which is to have its inner bore lined is located on the four supporting rollers and the parts are arranged so that when pulley 16 rotates it operates through the drive shaft and active rollers to rotate the pipe about its own longitudinal axis indicated by the line *a—b* in Fig. 2.

The opposite open ends of the pipe are temporarily closed so as to maintain a pool 17 of electrolyte therein with the pool maintained at all times at about the level *c—d* well above the anodes therein described. The left closure 18 and the right closure 19 for temporarily closing the opposite ends of the pipe P are of substantially the same construction so that the detailed description of one will be sufficient for the other.

Referring specifically to the left closure 18 as illustrated in Fig. 2, there is disclosed an annular strap 20 which is slipped on the adjacent end of the pipe, located by the stops hereinafter described and secured in spaced relation from its adjacent end 21 by set screws 22. A flat, disc-like plate 23 of insulating material, insoluble in the electrolyte present, is provided on its inner face with an annular recess 24 in which is received the adjacent end 21 of the pipe with a gasket 25 seated in the recess to prevent leakage of the electrolyte out of the pipe. Externally of the pipe, the end plate is provided with four bolt holes 26 extending therethrough and clamping bolts 27 are passed through strap 20 and through these bolt holes to securely anchor the closure considered as a whole in place on the pipe. The end plate is provided centrally thereof with a funnel-shaped opening 28 for receiving a flexible anode cable 29 and is provided outwardly therefrom with an inlet port 30 for passing the electrolyte into the pipe.

Secured to the outer face of the end plate 23 is a channel plate 31 provided on its outer face with an annular groove 32 open through passageway 33 therein to the inlet port 30. Abutting the channel plate is a fixed plate 34 so designated as it forms a fixed part of the apparatus and is provided with an intake pipe 35 for supplying a stream of electrolyte to the left end of the pipe. An L passageway 36 leads from the pipe 35 to groove 32 in all rotative positions of the end closure.

Secured to the outer face of the channel plate at its center is a cylindrical hub 37 which is journaled for rotary movement in a bearing therefor provided in the center of the fixed plate and held against axial movement by a face plate 38. It is understood that the anode cable 29 extends snugly through an opening provided therefor in the axial centers of the channel plate, the hub and the face plate to avoid leakage of the electrolyte out of the pipe past the cable.

The right closure 19 is of similar construction to the closure thus described except that the several plates and the hub are solid at their centers as there is no anode cable at the right end of the apparatus. The fixed plate 39 at the right end of the showing corresponding to the fixed

plate 34 at the left is provided with a discharge pipe 40, opening from the interior of the pipe by passageways similar to those shown at the left of Fig. 2. It is understood that the electrolyte is pumped by means not herein disclosed through the inlet pipe 35 and flows from left to right through the pipe P, and through the discharge pipe 40 back to the source of supply.

In order to provide a gauge for locating the straps 20 as they are inserted on pipe P and, incidentally, to prevent subsequent inward creeping of the same, a pair of stops in the form of discs 41 and 42 is mounted on, rotates with the drive shaft 15, and engages the inner faces of the straps. A supporting journal 43 for the shaft 15 is shown in close relation to the drive pulley 16. It has been found that as the rollers 14 and associated parts are connected electrically through frame 10 and the cable 11 to the source of electrical energy there has been a sufficient electric contact and the entire pipe P becomes the cathode of the system. As a matter of precaution, there is disclosed a brush 44 in bearing engagement with the rotating pipe P engaging the same adjacent its right end or electrolyte discharging end. It is understood that brush 44 is conventionally supplied from cable 11 and supplements the application of current through the four supporting rollers 14.

Located within the pipe P and in rolling contact with the bottom thereof is an anode construction 45 composed primarily of a hollow thin-walled cylindrical shell 46 formed of any insulating material, insoluble in the electrolyte present. The shell is provided with a large number of apertures 47 extending therethrough to permit passage of the electrolyte into contact with the anode material. The right end of the cylinder is closed by an end plate 48 of insulating material and the opposite end by an end plate 49 of conductive material to the outer face of which is secured a cable guiding plate 50 of insulating material for spacing the end plate 49 away from the pipe.

Fitted in the end plate 49 is a metallic cable connector or thimble 51 in the outer end of which is intruded one end of the conductor elements of the insulated anode cable 29. A combined tie rod and anode rod 52 is threaded into the inner end of the connector 51 and is passed through the end plate 48. The end plates 48 and 49 are firmly secured in place by nut 53 engaging the right end of the tie rod bearing on plate 48 and periodically moving the anode element, when in its uppermost position and thus most remote from said place of nearest approach, into said free gas space and thus into an inoperative position while so free of the electrolyte. The protruding end of the tie rod is protected from the deposition of metal thereon by a sleeve 54 and cap 55 both of insulating and insoluble material.

It has been suggested in the above-identified patent that a mass of loose particles forming anode material, specifically, fine nickel particles, be contained in the shell 46. It has been found necessary, however, in practicing the method herein featured, to use separate nickel anode bars 70 with their ends inserted in the end plates 48—49, as shown in Figs. 3 and 4 of the patent, instead of the loose particles. It has also been suggested to omit the shell 46 as unnecessary when using the squirrel cage type anode formed by the rods 70 and their end mountings 48—49.

It is understood that the anode cable 29 is sufficiently flexible to assume the different positions imposed thereon by variations in the internal

diameter of the pipe for the time being located in the apparatus and to permit some shifting of the construction incidental to the rotation of the pipe. The outer end of the cable 29 is connected mechanically and electrically with an anode shaft 58 journaled in the shaft bracket 59 and rotated by connection with some suitable form of motor through anode pulley 60. Current from the positive side of the source of electric energy is conveyed to the shaft 58 through a wide brush 61 and bearing on a cylinder or armature 62 secured to the shaft and supplied through cable 63. A sheet of insulation 64 insulates the shaft bracket 59 and parts carried thereby from the electrically charged support 10.

In operation, and assuming that the parts are assembled as shown in Figs. 1 and 2, and that through the drive pulley 16 the pipe P is caused to rotate bodily about its own axis and that a flow of liquid electrolyte, such as a nickel solution, is being pumped through the pipe, an electrolytic action will be set up in the apparatus. In the instant case an extremely thin layer or nickel will be deposited on whatever may be the bottom of the pipe for the time being as hereinbefore outlined. The frictional engagement between the pipe and the cylindrical anode construction rolling on the same will tend to rotate the construction even in the absence of any outside power acting thereon through the armature pulley 60. The peripheral speeds of the pipe and anode structure will be about the same.

As the inner surface of the pipe P receives its lining deposit, it is raised up with the rotation of the pipe out of the pool of electrolyte and for a period of time during the rotary movement of the pipe while the deposit is uppermost the freshly deposited layer is raised free of the electrolyte. At this time, there is permitted an escape of hydrogen and other gases adhering to the precipitated layer of metal. This discharged gas accumulates in the space above the level *c-d* of the pool and is carried off more or less by the stream of electrolyte as it is discharged from the apparatus.

After passing through this period of gas discharge, the previously deposited portion of the lining re-enters the electrolyte and the depositing action is repeated with an additional film of nickel on the previously deposited nickel film. The deposition is thus continuously applied until the desired thickness of lining is attained. After the pipe has thus been lined, it is demounted from the apparatus and a new section of pipe inserted in place thereof and the operation continued.

In those cases where it is desired to roll the anode construction independently of whatever rolling effect may be imposed thereon by the rotating pipe, the anode pulley 60 may be connected to a source of power as hereinbefore suggested and the anode structure rotated by power independent of the rotation of the pipe.

Reference is made to Figs. 3-5 for a more detailed explanation of the method as practiced on either of the two forms of apparatus herein disclosed and for convenience the anode rods 70 are separately identified and marked counter-clockwise as 70a, 70b, 70c and 70d in Fig. 3.

Considering any one of the anode rods 70, such as the rod 70a shown at the instant of its lowermost point of its cycle of movement and at its nearest approach to the cathode surface being plated, it will be understood that the disclosure features the bringing of the separated anodes,

one after the other, as close as is possible to the cathode surface under treatment. As is well known, the resistance interposed by the electrolyte between the cathode and each anode varies directly as the square of the shortest distance between anode and cathode at any instant of time, it is apparent that reducing the distance to a minimum causes an enormous surge of current at the point of nearest approach between the adjacent anode and the surface nearest the same, as along the short line *e-f* in Figs. 3, 4 and 10. Assuming for a moment that all the anode rods are at all times within the electrolyte as is the case in Fig. 2, this would mean that in the six o'clock position of each anode the current is of maximum density, and at the twelve o'clock position it is at the least depositing density, and that therebetween the density of the depositing current gradually increases from the twelve o'clock to the six o'clock position and then gradually decreases from the six o'clock to the twelve o'clock position with a sine wave formation.

In Fig. 4 the wave formations of two of the anodes 70a and 70c, one hundred and eighty degrees apart, are shown one in full lines and the other in dash lines, the other two rods of the four-anode system being omitted to save crowding of the wave lines on this figure. This means that the anodes in their periodic approach and recession from the point of nearest approach will throw from the electrolyte onto the surface at *f* being plated a succeeding series of throws of maximum electric density with dwells therebetween, at the point of nearest approach of densities too high to produce metal depositions and during the arc of swing most remote from the cathode surface of highly reduced electric densities—in fact, too weak to provide any material amount of metal deposition.

In the showing in Fig. 5 there is disclosed a portion of the surface of the steel pipe P at any point *f* at any instant of time located at the bottom of Fig. 3. The showing has been enlarged about one hundred diameters. In such a showing the apparently smooth surface A of the bore wall of the pipe P actually is not smooth, but is rough or pitted; for instance, it might show a recess or pocket or other irregularity or imperfection B, which recess may even possess a re-entrant cavity C overlapped by a portion D of the material forming the surface A.

As previously noted, if an attempt were made to electroplate such a surface by conventional processes the deposits would pile up most actively on the points D and E and little if any deposition would form on the deep surfaces of the cavity.

However, by periodically moving each of the anode rods to and from the pitted surface herein featured a different result follows. Considering any one rod in Fig. 3 in its twelve o'clock position, such as the rod 70c in Fig. 3, then at its greatest distance from the cathode surface being plated and thus with a long line *g-f* to the cathode surface under consideration, the line *g-f* being long and thus the resistance interposed by the electrolyte being high, very little metal deposition will be along the line *g-f* and, as a matter of fact, very little hydrogen is formed. Consider this anode rod as it moves into its three o'clock position, the line *h-f* will be shorter than the line *g-f*; the resistance decreased, and the current density directly increased so that proportionally more metal ions are passed along the line *h-f* than when the

anode was in its twelve o'clock position, and this increase in metal deposited will continue to that point where the current density has increased to such an extent that more hydrogen ions rather than metal ions are being released. Eventually, as the anode rod reaches its six o'clock position the hydrogen released reaches its maximum and relatively little metal is deposited along the line of nearest approach $e-f$ and, incidentally, there is even less metal deposit on the high points D and E for the dotted lines $e-E$ and $e-D$ between the anode in its six o'clock position and these high points are even of less length than the line $e-f$. It follows that in the six o'clock position there is almost an absence of any metal deposition on the high points D and E, but a little more deposition is had on the bottom surface of the cavity. With anode 70a in the six o'clock position and thus depositing only a very little metal along the line $e-f$, the real depositions at the point f at this instant of time come from the 70d and 70b anodes at or near their three and nine o'clock positions, respectively, which are a little further away from the instant point f , and therefore the current density is more nearly at that point where maximum metal ions are formed with the least polarization results.

While there is very little metal deposited along the short line $e-f$, however, any greater spacing between anode and cathode will progressively deliver more and more metal until a maximum is reached and from this point, with further spacing of anode and cathode, the rate of metal deposition decreases. In Fig. 5 the distance $h-M$ on the line $h-f$ is equal to the distance $e-f$ so that the additional and relatively short distance $M-f$ may be regarded as the real metal deposition area.

Tracing the path of the anode in Fig. 5 as it moves counter-clockwise, past its six o'clock position and in its approach to its nine-o'clock position, the line of deposition, in so far as the point f is concerned is along the line $h'-f$. Again assuming the distance $h'-M'$ to be the limit within which there is no, or practically no, metal deposition, the remaining distance $M'-f$ is still within the field of possible high metal deposition. Accordingly, in both of the ghost outline positions of the anode as shown in Fig. 5 metal deposits will be had at the point f . For the purpose of this description it may be assumed that the point of maximum deposition, in so far as point f is concerned, is when the anode is on one side of the vertical through point f and between its three and five o'clock positions and on the other side when between its seven and nine o'clock positions, and that at the bottom of its swing, i. e., when between its five and seven o'clock positions, the anode is approaching and then receding from its least metal depositing action at its six o'clock position.

As the point f was selected arbitrarily it follows that this detailed description will eventually fit every other point on the rotating cathode surface under treatment facing the anode rods.

The deposition at point f will in time cause an initial deposit to form on the bottom surface of the recess or pocket B, say, to form an initial and, of course, extremely thin, in fact barely visible layer F, very much exaggerated proportionally in depth in Fig. 5. It can be assumed that at this point there is a high polarization and relatively little metal deposit at the high points D and E. In general, the deposition takes

place most intensely at the place of greatest depression in the pocket or, differently expressed, at a place where the line $e-f$ is slightly longer than its least length. As the depositing proceeds the length of the line $e-f$ becomes gradually shorter as the pocket fills up. Considering what may be referred to arbitrarily as a second layer, it is noted that the layer G intrudes into the cavity C, spreading a little more laterally than in the case of the initial layer somewhat as does a dentist filling a tooth cavity, to form an underlapping interlock at C. As shown, the outer edges of layer G as it rounds into the recess begin more definitely to overlap the high points D and E initially with extremely thin coatings. In due time the next succeeding layers H and I continue to fill in the recess always at the points of greatest depth of depression and gradually increase the thickness of deposition on the high points and in the balance of the pipe bore. Eventually, the last layer J more or less completely fills the recess and is of substantially uniform thickness of material and forms the apparently smooth facing K characterizing electrolytically deposited metal such as the nickel herein suggested.

In those conditions where the distance $e-f$ is made sufficiently longer than the distance $h-m$, to minimize the liberation of hydrogen, then maximum metal deposition is more or less confined to the lengthwise plane defined by the line $e-f$.

While the lining deposit is shown in Fig. 5 as distinct layers to facilitate this description at different stages of the depositing action, it is to be understood the deposited metal is of one piece and is apparently homogeneous and without evidence of laminations at all levels of deposition.

It is understood that, while each of the anode rods is thus successively approaching and then receding from the surface being plated, the surface itself is also moving counter-clockwise as indicated by the arrows in Fig. 3. This means that any point f on the pipe which may be opposite one anode rod in its nearest approach to the surface being plated is displaced to the left slightly as its associated anode rod moves away, and another point on the surface faces the next succeeding anode in its nearest approach thereto.

Assuming a condition which sometimes exists due to the use of anodes of large diameter compared to the pipe, that the level $c-d$ of the electrolyte is below the top of the cylinder of reference formed by the revolving anodes, then, of course, each anode as it approaches its twelve o'clock position will be out of the electrolyte for a short period of time as indicated by the dots forming the crown of the sine waves and thus inactive in so far as any plating activity is concerned. Accordingly, in Fig. 4 the level $c'-d'$ of the electrolyte is assumed to be at the faint, long dash-and-dot line and, of course, the otherwise complete sine curves are interrupted to form what might be called a mutilated multiple phase sine curve. However, the disclosure contemplates that in actual practice the pipe will be filled to about eighty per cent of its capacity with the electrolyte and thus form a gas-receiving space in the container with the entire anode construction submerged in the electrolyte. Under any condition the level of the electrolyte 17 is maintained sufficiently high in the pipe P to maintain at least two of the anode bars 70 submerged in all rotative positions of the anode construction.

In following the method herein featured all drawn marks, tool and die scores tend to be eliminated and there is eventually formed a smooth-faced lining to the pipe P.

Referring to the modified form of structure shown in Fig. 6, the pipe P is supported on rollers 14 as in the Fig. 1 form, and anode structure 76 likewise rolls on the bottom of the pipe under treatment. In this case, which cannot be used to practice the method herein featured, the anode structure is formed of an outer nickel anode shell 77 provided at one end with a closure head 78 in the center of which projects a nipple 79 designed to receive an end of the exposed conductors of the anode cable 29 as disclosed in Fig. 2. In place of the insulating shell shown in Fig. 2, the anode structure 76 is encircled adjacent opposite ends by a pair of solid spacing rings 80 and 81 of insulating material which likewise roll on the inner surface of the pipe. It is the intent here, as in the Fig. 2 disclosure, to bring the anode structure close to the surface being coated and thus permit the use of a current density greater than would be possible where the anode is spaced a greater distance from the surface being plated than in the case here illustrated. Fitted within the nickel shell 77 is a rugged copper liner 82 designed to give structural strength to the thinner nickel shell anode and to assist in carrying the current.

As was the case in the Figs. 1-3 form of the apparatus, there is likewise disclosed in the later Figs. 6-10 form of the invention certain structural parts of the completed machine which may be regarded as fixed or permanent parts. These parts include the base structure which, in turn, supports a cradle for receiving the fabricated and replaceable parts herein featured, together with certain power transmission elements for rotating the cathode and anode elements of the electrolytic cell; certain liquid handling mechanism such as supply sources and pumps for supplying the electrolyte to the apparatus; and certain electric current supplying sources connected to the anode and cathode elements, all as is usual in devices of this character.

Referring first to so much of the fixed parts as are illustrated, it will be understood that sets of pipe supporting-rollers, as many as may be necessary, and of which two, numbered 83 and 84, are outlined in Fig. 8, are spaced along the length of the apparatus to form a cradle fashioned to support the pipe to be plated for rotation about its fixed horizontal axis *g-h*.

In Fig. 7 there is disclosed the right end of the pipe P' whose bore wall P² is to be plated. A plating head 85, particularly constituting the novel feature of this disclosure and forming the right end of so much of the apparatus as is illustrated, is temporarily secured to and is carried by the pipe. It is understood that a somewhat similar form of head, but without the anode driving mechanism hereinafter described, closes the other end of the pipe. The two heads with the pipe therebetween form a container for the electrolyte.

The head includes mainly a rugged, thick, flat, fixed closure plate 86 and a five-piece unit temporarily secured to, supported by the pipe and acting to rotate the pipe. The plate 86 is held from rotating by means of an anchor strap 87 (see Fig. 8) hereinafter described. The five-piece rotatable unit which turns with the pipe includes, in order from left to right, a rugged steel tubular mounting 88, a steel dome or bell

89 of larger diameter than the mounting, a packing ring support 90 of insulating material, an external ring bearing 91 of insulating material and a retainer ring 92 of steel between which and the packing ring 90 the fixed closure plate 86 is sandwiched.

The pipe mounting 88 includes a long, steel cylinder 93, which is provided at its extreme left end with an outstanding flange 94 to which is secured by bolts 95 an external chain sprocket wheel 96 of large diameter designed to be driven by chain 97 from a source of rotative power (not shown) to rotate the unit and with it the pipe. The cylinder 93 is provided mid-length with a guide roller 98 of large diameter engaging in a rotatable, spool-like guideway 99 carried by the base of the apparatus and operating through the roller 98 to resist axial shifting of the pipe.

The cylinder 93 is provided at its right end with a series of outstanding hook lugs 100 for engaging with bolts 101 projecting from bell 89 to form an easily separable bayonet joint connection between the mounting 88 fixed to the pipe and the bell 89 rotated thereby. Secured to the lugs 100 and to the adjacent end of the cylinder 93 is a thin, metal, L-shaped gasket retaining ring 102.

The bell 89 includes a cylindrical mid-portion 103 of materially greater diameter than the mounting 88 and co-axially related thereto. Opposite ends of the mid-portion 103 are transversely reinforced by flanges of which the left flange 104 is inturned and the right flange 105 is outturned from the cylindrical mid-portion. Projecting outwardly towards the left from inturned flange 104 is a series of circumferentially spaced-apart bosses 106 in which the inner end of the bolts 101 are fixedly threaded.

The outstanding flange 105 at the right end of bell 89 forms a bolting flange and faces the packing ring support 90. The space within the bell 89 and packing ring 90 forms a large plating chamber 107 closed at its outer end by the closure plate 86 and at its left or inner end by flange 104. The adjacent end of pipe P' extends through the flange 104 and projects for a short distance into the plating chamber 107. A thin layer 108 of insulating material, preferably rubber, faces the right side of flange 105, the inner wall of the mid-portion 103, the right face of flange 104, and laps the inner edge of flange 104 as it faces the pipe. In this way, insulation 108 completely lines the plating chamber 107.

In order to avoid leakage from chamber 107 towards the mounting 88, an annular packing or gasket ring 109 of relatively large, square cross section is fitted within ring 102 and snugly encircles the pipe in the position thereof between the lugs 100 and the inturned flange 104.

The packing ring support 90 is provided on the side facing the fixed closure plate 86 with an annular packing 110 to defeat leakage from the right end of chamber 107 at this place. A three-ring set of packing 111 is interposed between the fixed closure plate 86, the external ring bearing 91 and the retainer ring 92 to prevent leakage at this point. Thin washers 112 of insulating material are interposed between the packing ring 90 and both the bearing 91 and that part of the insulation 108 which faces the outstanding flange 105. A circle of through bolts 113 with wing nuts are passed through the flange 105, the packing ring support 90, the ring bearing 91 and the retainer ring 92 to place the gasket, packing and the washers therebetween

under a squeeze load. Also, bolts 114 passing through the flange 105, the packing ring support 90 and in screw engagement with the bearing 91 secure the bearing 91 and packing ring 90 to the flange 105 to cause the bell 89 to turn the bearing 91.

The closure plate 86 is provided off center thereof with a discharge opening 115 for discharging the electrolyte from the chamber 107. A hose connection 116 leads from opening 115 to a source of electrolyte (not shown) and forms a discharge from the chamber 107. A similar inlet opening is carried by the corresponding closure plate at the other end of the pipe, except that in this case the inlet pipe is at the axis of the left closure plate.

The pipe P' is secured to the pipe mounting 88 by means of a pair of jam screws 117 and 118 working in nuts 119 secured to the outside of the mounting. In one form of the apparatus the screws are caused to bear on and bite directly onto the pipe exterior. Where high power torque forces are involved, as in those cases where heavy pipes are to be rotated, the inner ends of these screws preferably bear on a soft metal wear or cushioning tube 120 into which the pipe is inserted before it is inserted in the steel cylinder 93. The cushioning pipe 120 may also be used as a shim or as a means for centering the pipe P'.

A squirrel cage anode construction 121 is mounted to extend through the bore of the pipe and to project beyond opposite ends thereof into the plating chambers, such as the chamber 107, and is disposed to rotate about an axis $i-j$ eccentrically relative to the axis $g-h$ of the pipe.

The anode construction features the use of long anode rods 122, preferably four or more in number, arranged to extend lengthwise of a cylinder of reference disposed as close as is possible to the pipe surface P² to be plated and otherwise conforming functionally to the anode rods 70 in the Figs. 1-5 form of the apparatus disclosure. In the illustrated case, the anode rods 122 distinguish from the rods 70 in that they are insoluble in the electrolyte used and are formed as shown in Fig. 10 of a core 123 of copper electroplated with a covering 124 of platinum. This forms, in effect, an all-platinum anode not soluble in the Watts type electrolyte herein featured. The copper core extends beyond the platinum coating and is reduced and the reduced ends threaded as shown at 125.

The right or front end of the anode construction is formed by a copper anode head 126 into which the threaded ends 125 of the anode rods are screwed. The left or back end of the anode construction is formed of a flat cylindrical head 167 of insulating material, similar to the spacers 130, and into which head the rear ends of the anode rods 122 are threaded and to which the tie rod 127 is bolted as shown at 137, thus protecting the rear end of the anode construction as the front end is protected.

The head 167 rides on a surface which may be the rear end of the pipe bore P². In this case the bore surface traversed by the head 167 is not coated or, perhaps, imperfectly coated, and in practice the unplated end of the pipe is simply cut off and thrown away. Where the rear end of the pipe is threaded, it is a usual practice to utilize a tubular adapter to form an extension from the rear end of the pipe and which adapter may be screwed on to the threaded rear end of the pipe. In such case, of course, the left plating head is carried by the adapter rather than by

the pipe itself. Such an adapter is suggested at Ad at the left of Fig. 7. Sometimes this adapter is made several feet in length and the anode construction is dimensioned to extend variable distances into the adapter, and in this way a single relatively long anode construction can be utilized with pipes of different lengths. A tubular pipe-extending adapter has been used with the unthreaded pipe P of the Figs. 1-2 disclosure, with a liquid sealing pipe joint connection between pipe and the adapter. In this case, of course, the right closure 19 is secured to the adapter rather than to the pipe P itself. The two heads are tied together by a steel tie rod 127 enclosed in and keyed to a tube 128 of insulating material to form a skeleton or squirrel cage of anode construction of the necessary length to extend through the pipe for the time being under treatment. The exposed faces of the copper head 126 are covered by a layer 129 of insulating material, preferably rubber.

A plurality of roller spacers 130 of insulating material are spaced along the length of the tie rod insulating tube 128, are keyed thereto as shown in Fig. 10 and act to prevent the anode rods from touching the surface P² being plated.

In Fig. 6 it is suggested that the insulating spacing rings be of wheel-like construction. However, in those cases where the anode construction was not shifted, areas or bands of insufficient plating occurred where the spacing wheels engaged the pipe surface. In order to avoid these insufficiently plated areas in the instant disclosure and still avoid shifting of the long heavy anode construction, the peripheries of the spacers 130 define rings 131 inclined to the axis of the anode construction. This forms a wobble plate form of engagement with the pipe, so that the point of engagement of the spacers with the pipe moves back and forth axially of the pipe length as the anode construction rotates and thus exposes all portions of the pipe to the deposition action.

While the disclosure features the driving of the anode construction by reason of the frictional engagement between its wobbling spacer rings 131 and the chain driven pipe, it is suggested that the right end of the anode construction be rotated from an external source of power and at the same time to avoid the wearing of the spacers 130 by reason of their slipping against the rough surface of the pipe. This is most conveniently attained by driving the anode construction through a driving connection turning about an axis fixed relative to the fixed closure plate 86. For this purpose an anode shaft 132 of conductive material, preferably copper, is journaled in a bushing 133 of insulating material carried by and extending through the fixed closure plate 86. A set of three-ring packing 134 fitted into a recess provided therefor in the closure plate 86 defeats leakage of the electrolyte from chamber 107 along the outside of the bushing 133. The anode shaft 132 has its inner end reduced and the reduced end 135 threaded and reversely screwed into a threaded socket 136 provided in the adjacent anode head 126. A nut 137 in socket 136 secures the adjacent end of the tie rod 127 to the copper anode head 126. A similar connection at the left end of the tie-rod secures that end to its adjacent anode head 167. The shaft 132 drives the anode head 126 through the screw-threaded connection at 135 and therethrough rotates the entire anode construction 121 as a unit.

17

The fixed closure plate 86 is held from rotating by means of the long anchor strap 87 whose outer end is held by engaging loosely between fixed stops 139 and 140 as shown in Fig. 8. A ring 141 loose on shaft 132 rides in strap 87 and is held in place by a set of take-up rings 142 threaded on shaft 132. A pair of long bolts 143 and 144 (see Fig. 8), of which one is shown in dotted outline in Fig. 7, are passed through the strap 87, and engage in the fixed closure plate to defeat any tendency of the closure plate to turn by reason of the turning parts 90, 91 and 92 which engage the closure plate.

The anode shaft 132 is connected by means of a flexible coupling 145 to a drive shaft 146 journaled in fixed bearings 147, 148, forming a portion of the permanent part of the machine beyond the plating head 85. Drive shaft 146 is provided with chain sprocket wheel 149 driven from a source of rotative power through a chain drive 150. In this way power from chain 150 drives shaft 146 and through the flexible coupling 145 and anode shaft 132 drives the squirrel cage anode construction 121. Shaft 146 is also provided with an armature 151 on which bears a fixed brush 152 for supplying positive current through the rotating parts to the anode construction.

The plating heads as thus far described are intended to line only the bore wall of the pipe, which pipe usually terminates at about the gasket 109. When it is not intended to plate any part of the pipe exterior, the bell 89 then used in the assembly may be much shorter than is shown in Fig. 7.

In the case illustrated, the pipe is provided at one or both ends and in the portion extending into the chamber 107 with an end externally threaded at P³. The instant apparatus is designed to externally plate the threads on the pipe. For this purpose a group of fixed external anodes 153, shown to be six in Fig. 8, are arranged in a semi-cylindrical form grouped beneath and extending parallel to the threaded end of the pipe and to each other.

Referring to the detailed showing of one of these external anodes as shown in Fig. 7, there is disclosed a stiff platinum rod or wire 154, the end 155 nearest the threads on the pipe being exposed thereto and the other end 156 threaded into a fixed bar conductor 157 carried by the fixed closure plate 86 and extending through the same. Insulation 158 and a nipple 159 of insulating material at the threaded end of the anodes covers all of the platinum wire 154 in the electrolyte except its exposed anode-forming end 155. The outer ends of the several conductors 157 are connected by two bus bars 160, 161 and the bus bars connected by a terminal 162 to the positive side of the source of current which supplies the fixed brush 152. The negative side of the source is connected directly to the pipe by means of one or more brushes 163 shown bearing on the pipe at the left end of Fig. 7.

In this case, instead of the electrolyte flowing directly into the discharge opening 115, a long discharge tube 164 is located in the chamber 107; has its discharge end 165 fitted in the opening 115 with a driven fit therein; and has its intake port 166 in overlapping relation to the pipe and located close to the pipe and on the side of its threads P³ opposite the group of external anodes 153.

In order to facilitate breaking of driving connection between the anode shaft 132 and the

18

permanently mounted drive shaft 146 when it is desired to demount the parts, it is suggested that the end of the shaft 132 in the part thereof between the rings 142 and the coupling 145 be formed of two overlapping and interfitting driving parts 168 and 169 normally secured against accidental separation by an encircling band clutch 170. It is also suggested, especially where sleeves or shims 120 are used, that a similar thin metal cylindrical shim 171 encircle the pipe P' at each of the rollers 84 and that the shim 171 be contained in a rugged cylindrical steel roller 172 resting on the perimeter of the pipe supporting roller 84 and free to turn thereon. If desired to protect or center the pipe at this point, the shim 171 may be pressed into engagement with the pipe by means of a screw 173 threaded through the roller 172 as shown to the left of Fig. 7.

For an illustration of one situation where the Figs. 7-10 form of the disclosure functioned effectively, the pipe P' was thirty-two feet long, had an internal diameter of twenty-four inches, weighed three tons, and the over-all current supplied to the brushes at 157, 162 and 163 had a substantially constant voltage of twelve volts and a substantially constant amperage of six thousand amperes. In this case the anode approached the cathode with about one-eighth of an inch clearance. In other words, the line e-f has a length of about one-eighth of an inch.

In operation, and assuming the parts are in the position shown in Fig. 7, with the electrolyte being pumped into the left end of the assembly at a rate to maintain the interior of the pipe about eighty per cent filled and the liquid in the end chambers at the same level and thus below the discharge tube 164 and with the squirrel cage anode construction and the cathode pipe rotating in the same direction and at the same peripheral speed, the surface P² of the pipe, the exposed end of the pipe and the threaded portion P³ will be plated, as described in considering Figs. 3-5, with a single, continuous, uniform and pore-free layer of the deposited metal. The operation is continued with the anode and cathode rotating in epicyclic relation as above described until the desired depth of deposit is attained, at which point the operation is terminated. As there is no electrolyte engaging the outer surface of the pipe between the gaskets 109 at opposite ends of the pipe the mid-portion of the pipe exterior will, of course, not be plated.

When finished the plated pipe is removed from its position in the apparatus to permit the mounting of a fresh stock pipe in place on the more or less permanent parts of the machine. This is most easily done by removing the left chain drive 97, if one be present, and the electrolyte supply source from the left plating head. The left bell is rotated to cause a break at its bayonet joint connection and removed from the pipe. Then the anode driving connection at 168-169 is broken by releasing the split clamp 170. The right bell 89 is then reversely rotated about its own axis to break the bayonet joint connection between the several hook lugs 100 and their associated bolts 101. The bell 89 and associated parts, together with the entire anode construction is withdrawn as a unit from the pipe and laid on a suitable support ready for re-insertion in the stock pipe next to be treated. This leaves the pipe with mounting 88 and shim 171 in position thereon and with the pipe and mounting 88 momentarily resting on the supporting

rollers 83—84. By loosening the screws 117, 118 and 173 the finished pipe, together with the shims 120 and 171 may be withdrawn axially from the mounting 88 and from the roller 172 towards the right of Fig. 7, leaving the mounting 88 and associated parts, like the chain drive 97, guide roller 98, and guideway 99, remaining in place as part of the permanent structure of the machine and ready to receive a fresh pipe.

Usually, it will not be necessary to demount the squirrel cage anode construction from the right head, but, if necessary for any reason, as to facilitate resetting of the pipe or repair or replacement of the anode rods, it can be separated from the anode shaft simply by unscrewing the copper head 126 away from the anode shaft 132 in the closure plate.

To continue the operation, a fresh pipe, without the shims if not needed, is passed through the fixed mounting 88 and through the roller 172 and the screws 117, 118 and 173 tightened. The anode construction is then fed axially into the pipe, if not already in place; the bell 89 is located in position telescoping the end of the pipe and is rotated to lock it to the mounting 88. The driving connection at 168—169 and the fluid and electric circuits are restored and the plating operation repeated as above outlined.

By means of apparatus such as is described in Figs. 7—10 there is avoided any necessity for using the flexible anode cable 29 of the Figs. 1—2 device, which cable was liable to mechanical breakage and current losses after it had been in use for a while.

Rotating the pipe by means of the chain drive acting through the rugged heads rather than to depend upon the frictional engagement of the heads with its supporting rollers provides a more positive form of drive than is possible with the Figs. 1—2 device.

The anode construction with its associated plating head 85 becomes in effect a fixed unit which, once having been carefully fabricated with its multiplicity of separate parts, can be replaced in one pipe after the other without necessity of rearranging their component parts. In mounting a fresh pipe in position on the relatively fixed parts of the machine it is necessary only to manipulate a few readily accessible clamps and screws.

It is particularly noted that the main strain-transmitting parts of the heads, that is, the mounting 88, the bell 89, and retaining ring 92, are made of steel reinforced by outstanding or instanding end flanges and thus capable of rotating without becoming distorted or otherwise strained out of their initial shape even when holding particularly heavy pipe. At the same time, the parts which might otherwise be exposed to electrolytic action are insulated and the parts so required to be insulated are confined largely to the interior of the bell, thus saving the cost of expensive insulating material.

By following the method herein featured, there is formed on the pipe a deposit of nickel which is dense, non-porous, homogeneous, which fills to microscopic exactness the recesses, pockets and like pitted surfaces on the stock steel pipe, and which deposited layer is permanently bonded to the pipe in interlocking relation. The exposed surface of the deposit has the smoothness characterizing semi-bright electrolytically deposited nickel.

I claim:

1. In an electrolytic cell for electroplating the

bore of pipes when rotating about their own axes and horizontally disposed, the combination of a pipe to be plated forming the cathode element of a cell, a plating head into which an end of the pipe projects and which head includes a closure plate fixed in space, a hollow anode construction of squirrel-cage type located in the bore of the pipe, of materially less external diameter than the internal diameter of the pipe and rotatable about an axis offset from the axis of rotation of the pipe, means for mounting the pipe with its axis of rotation fixed in space, said anode construction including end members, a plurality of anode rods having their ends carried by the end members and the balance of the rods being exposed to the pipe and to the electrolyte of the cell, and means for rotating the cathode element and the anode element, said rotating means including a drive shaft journaled in the fixed closure plate directly engaging one of the end members in axial prolongation of the same and having said offset axis fixed in space to turn the squirrel cage anode construction about its own axis.

2. In a device for electroplating the inner walls of pipes, the combination of a pipe constituting the cathode element of an electrolytic cell and mounted for rotary movement about its own axis and horizontally disposed, hollow heads temporarily secured to the pipe at opposite ends thereof, projecting therefrom and coacting with the pipe to form therewith a container for all of the electrolyte present, one of said heads including a fixed part and a rotatable part, one of said parts journaled on the other to turn about the axis of the pipe, with the rotatable part secured to the pipe to be turned thereby, said fixed part including a shaft mounting with its axis offset from the axis of the pipe, an anode construction of the squirrel-cage type within the container mounted for turning about an axis parallel to and offset from the axis of the pipe, said construction including an anode head and a plurality of anode rods extending through the pipe and defining when revolving a cylinder of reference located closer to one side of the pipe than to the opposite side, and said anode rods being each replaceably mounted at one end in the anode head and insulated from the pipe, and an anode shaft journaled in the shaft mounting in the fixed part and operatively connected for driving the squirrel cage anode, and power means for supporting the pipe and the rotatable closure parts fixed thereto.

3. In a device for lining the interior of pipes by electrolytic deposition, the combination of the pipe to be lined forming the cathode element of an electrolytic cell, hollow heads temporarily secured at opposite ends of the pipe to close the same and coacting therewith to form a container for the electrolyte of the cell, each of said hollow heads including a relatively fixed part and a relatively movable part journaled one on the other for relative movement about the axis of the pipe, means for temporarily securing the rotatable part of each head to the pipe to be supported thereby and to turn therewith, an anode construction having its axis parallel thereto and offset from the axis of the pipe, said anode construction including end supports one journaled for rotary movement in one of the fixed parts and including anode rods revolvable about the axis of the anode construction contained within the container, insulated therefrom and having their ends mounted in the end supports.

4. In a device for lining the bore wall of a pipe

by electrolytic deposition, the combination with the pipe to be plated acting as the cathode of an electrolytic bath, an anode of the squirrel-cage type within and extending lengthwise of the pipe and including at least one anode rod mounted to move in a generated cylinder of reference of materially smaller diameter than the diameter of the pipe, with the axes of pipe and cylinder parallel to and offset from each other, said anode being longer than the pipe and projecting beyond opposite ends thereof thereby to plate the bore wall complete to its ends, and power means to rotate the same about its axis, and another power means detachably engaging an end of the anode in the part thereof projecting beyond the pipe for rotating the anode about its axis.

5. In a device for electroplating the bores of pipes and the like, means for mounting the pipe to rotate about its axis when horizontally disposed, a closure head for closing one end of the pipe, comprising a bell having means at one end for temporarily securing it to one end of the pipe to be plated to rotate therewith, a fixed plate overlapping the other end of the bell to close the same, packing between the bell and plate to defeat leakage from the interior of the bell, a retaining ring between which and the bell the fixed plate is squeezed to place a load on the packing, an anode mounted for rotation within the pipe about an axis parallel to and offset from the axis of the pipe, a support for one end of the anode journaled in the fixed plate for rotation about a fixed axis in offset relation to the conduit and to the axis of rotation of the pipe, and a gasket between the fixed plate and the rotating anode support.

6. In an apparatus for plating pipe, the combination of a pipe constituting the cathode element of an electrolytic cell, means for supporting the pipe, heads for opposite ends of the pipe temporarily secured thereto and supported thereby and coacting therewith to form a container for the electrolyte, power means acting directly on the heads for rotating the same and there-through for rotating the pipe, an anode construction of the squirrel-cage type including a plurality of anode rods in the container located in a cylinder of reference whose axis is parallel to and offset from the axis of the pipe, means for spacing the anode rods from the adjacent surface of the pipe, said spacing means including a wabbling ring of insulating material secured to the anode construction to turn therewith and at all times with its pipe-engaging perimeter disposed in a plane inclined to a plane perpendicular to the axis of rotation of the anode construction.

7. In an apparatus for plating pipe, an article of manufacture constituting a plating head for installation on the end of a rotating pipe to be plated and comprising three major parts, to-wit, a tubular pipe mounting formed of steel, a hollow bell formed of steel with a layer of insulating material facing its inner side and a relatively fixed closure plate formed of insulating material and closing the outer end of the bell, a bayonet joint driving connection between the mounting and the bell, said mounting provided with means for temporarily securing the same to the pipe whereby the mounting and bell turn with the pipe, means for mounting the closure plate in the bell for relative rotary movement, and packing means between the relatively moving

parts of the bell to prevent leakage from the interior of the same.

8. The article defined in claim 7 and in which the mounting is provided with means for rotating the same and with it the bell, the closure plate being provided with means for holding it fixed in space and thus resisting its tendency to rotate.

9. In an apparatus for plating pipe, an article of manufacture for installation on a pipe to be plated when the pipe is mounted for rotary movement about its axis horizontally disposed, comprising a head provided with means for securing the same temporarily to an end of the pipe to rotate therewith, said head including a bell provided with an electrolyte-containing chamber, a fixed closure plate journaled in the bell for relative rotary movement and closing the outer end of the chamber, an anode driving shaft journaled in the fixed closure plate for rotation about a fixed axis parallel to and offset from the axis of the pipe and provided with means for rotating the same and with means for attaching a replaceable anode construction to the same.

10. The device defined in claim 9 and in which one anode construction is connected to said attaching means for plating the interior of the pipe and another anode construction is carried by and supported from the fixed closure plate and extends into the chamber for plating a part of the exterior of the pipe.

11. In an electrolytic cell for forming on a pipe an integral layer of electrolytically deposited metal extending along the bore and lapping the ends thereof and extending for a short distance along the outer side of the pipe from said lapped ends, the combination of the pipe to be plated, hollow heads temporarily secured to the pipe each in spaced relation to its adjacent end and each head including a hollow bell into which the adjacent end of the pipe extends, said pipe and bells coacting to form a container for the electrolyte, one of the heads provided with an intake for the electrolyte and the other head provided with a discharge for the electrolyte, an internal anode construction extending through the bore of the pipe insulated from and in rolling contact with the bore wall and projecting therebeyond at opposite ends thereof into the bells to deposit the layer on the bore of the pipe from end to end thereof and each of said bells also provided therein with an external anode construction overlapping the adjacent end of the pipe to plate the outside of the pipe adjacent said end, and said anode constructions coacting to continue the plating integrally about the ends of the pipe, means for rotating the pipe to cause its ends to pass the fixed external anode constructions, and means for supplying a current of plating density to the cathode-forming pipe and to both of the anode constructions.

12. The device defined in claim 11 and in which the inlet and outlet for the electrolyte have their respective intake and discharge ports located adjacent the inner ends of the bells and about mid-length of the portions of the adjacent pipe which extend into the respective bells to cause the electrolyte to pass in an S-shaped path about the ends of the pipe.

13. In apparatus for lining a pipe by electrolytic deposition, the combination of a pipe mounting fashioned to receive one end of the pipe, a readily replaceable hollow unit providing an electrolyte-containing chamber adapted to receive the end of the pipe which is in the mounting and open to its bore, said unit including a bell open at

its outer end and a closure for the open end, said bell and its closure mounted for relative rotary movement, means for fixing the closure in space, a quickly detachable connection between the bell and the pipe mounting, an anode construction adapted to be located in the pipe to plate its bore, and said fixed closure provided with current-conducting means for supplying the anode construction with current and for locating one end of the anode construction in said chamber in prefixed relation to the pipe to be lined.

14. The apparatus defined in claim 13 and wherein the anode construction includes anode rods detachably secured electrically and mechanically to the current-conducting means carried by the closure and located thereby in position to position the portion of the anode construction within the pipe in rolling engagement with the bore wall of the pipe.

15. In a machine for electroplating the bores of pipes and the like, the combination of a cradle, an assembly of structural elements forming an electrolytic cell demountable supported on the cradle, said elements including a tubular mounting and a hollow head at one end of the mounting and removably secured thereto, power means engaging the mounting to rotate the same and with it the part of the head secured to the mounting, the pipe to be plated adapted to be supported on the cradle constituting the cathode element of the cell and adapted to be inserted in the mounting to support the same, means for closing one end of the bore of the pipe with the other end of the pipe opening into the hollow head, said pipe and hollow head coacting to form a closed container for the electrolyte, said hollow head including a closure plate fixed in space, said head and closure plate mounted one on the other for relative rotary movement, readily detachable fastening means for securing the closure plate temporarily to the head, a rotatable anode construction for insertion into the bore of the pipe, projecting at one end into the hollow head and journaled for rotary movement in the closure plate, and said anode construction and closure plate being removable as a unit from the assembly and from the cradle supported pipe on the separation of the closure plate from the hollow head.

16. Apparatus for use in forming an electrolytic cell for plating the interior of pipes and wherein the pipe constitutes the cathode of the cell, said apparatus including a support for the pipe, a mounting receiving the pipe and supported by the pipe, conductive current carrying means including in order and in substantial coaxial driving relation an anode construction, a rigid anode shaft and a drive shaft, the anode construction adapted to be inserted into the pipe in rolling engagement with the bottom thereof and including expendable anode rods replaceably connected at one end to the anode shaft, means for supporting the anode shaft from the mounting for rotation about an axis fixed relative to the mounting, a flexible driving coupling between the anode shaft and the drive shaft, means for supporting the drive shaft for rotation about a fixed axis, an armature carried by the shaft, and a brush engaging the armature for supplying current to the carrying means.

17. An electrolytic cell for plating the bore of a pipe and for plating the exterior of the pipe at one end thereof and wherein the pipe is the cathode of the cell, including a plating head provided with a container for a body of electrolyte and adapted to be open to one end of the bore of the pipe, said head provided with an opening for receiving an end of the pipe and with means for locating the pipe end within the container, said container also provided with an anode support facing the opening, an anode construction having one end carried by the support, extending across the chamber and fashioned for intrusion into the bore of the pipe for plating its bore up to the end within the chamber, and a second anode construction within the chamber having one end carried by the support and disposed for plating the exterior of the pipe at the end within the chamber, and means extending through the support for supplying current of plating density to both of said anode constructions from a source exterior to the cell.

18. In the art of operating an electroplating cell having an electrolyte capable of liberating metal and hydrogen in varying amounts at the cathode, the method which consists in imposing on the cell an electric current of plating density and of substantially constant all-over voltage and amperage while causing a plurality of spaced-apart anodes one after the other each to traverse a closed path and in doing so to approach the cathode periodically through the intervening electrolyte from a point remote from the cathode and thus from a point of least metal deposition through a point of maximum deposition of metal and least production of hydrogen to a point of nearest approach to the cathode with production of hydrogen at said point of nearest approach; then reversing the direction of movement of the anode, moving it away from the cathode to cause the anode to pass again through a point of maximum deposition of metal to a point most remote from the cathode, while regulating the relative time sequence of anode movements to obtain the maximum metal deposition in puffs of relatively short time lapse duration, sandwiched in between intervals of maximum hydrogen formation, and simultaneously displacing the cathode to cause the point thereon at said point of nearest approach of any one of the anodes to provide a different point thereon at the point of nearest approach of the next succeeding anode.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
615,940	Wright	Dec. 13, 1938
1,733,404	Fahrenwald	Oct. 29, 1929
1,850,426	Tyrrell	Mar. 22, 1932
1,904,432	Fink	Aug. 13, 1933
1,927,162	Fiedler et al.	Sept. 19, 1933
1,931,704	Moore et al.	Oct. 24, 1933
2,198,267	Lind et al.	Apr. 23, 1940
2,453,668	Marisic et al.	Nov. 9, 1948
2,503,863	Bart	Apr. 11, 1950

FOREIGN PATENTS

Number	Country	Date
22,289	Great Britain	of 1907
416,086	France	July 29, 1910