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3,429,787

PROCESS AND APPARATUS FOR ELECTROLYTICALLY TREATING METAL TUBES

Filed June 15, 1964

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FIG. 1A

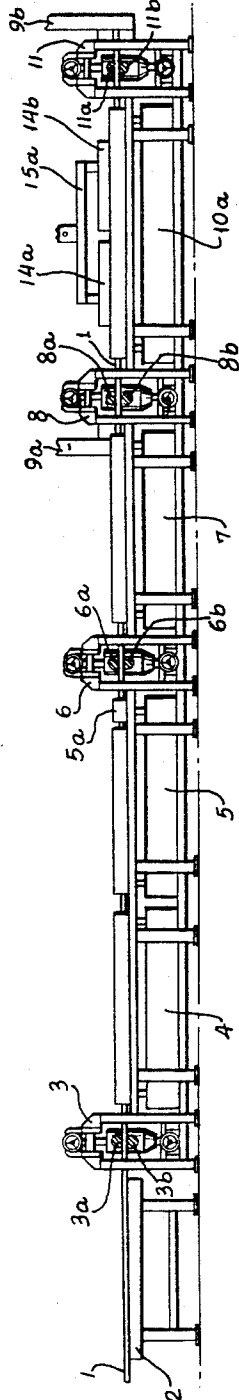
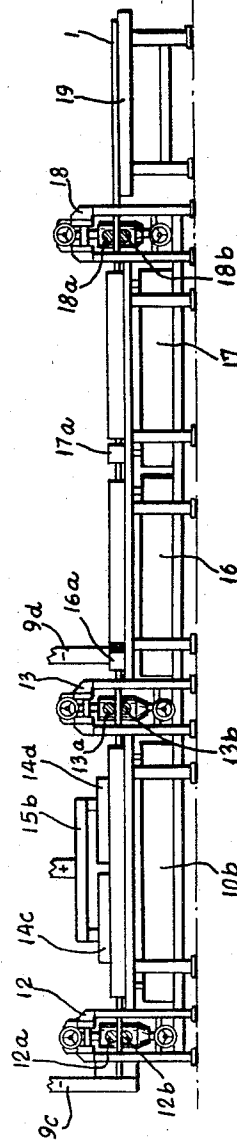


FIG. 1B



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FIG. 2

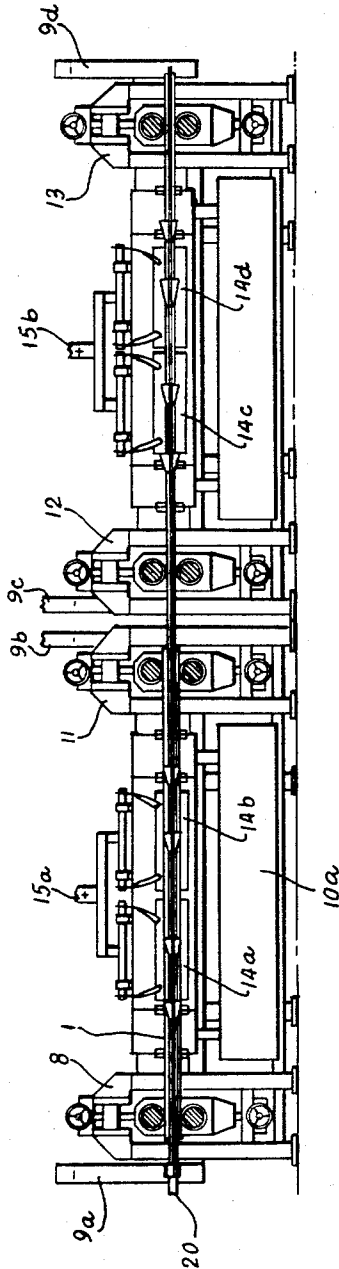
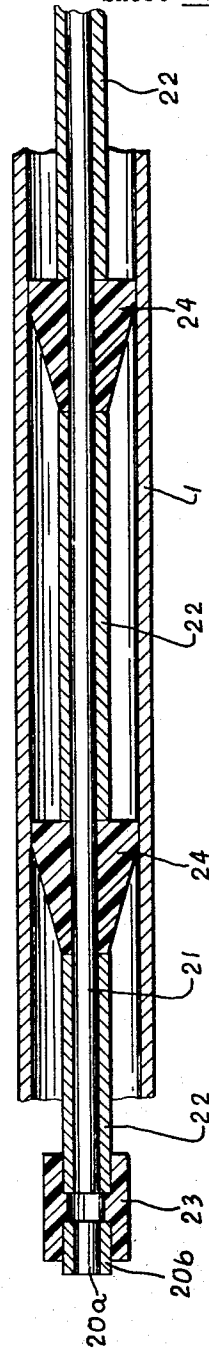


FIG. 3



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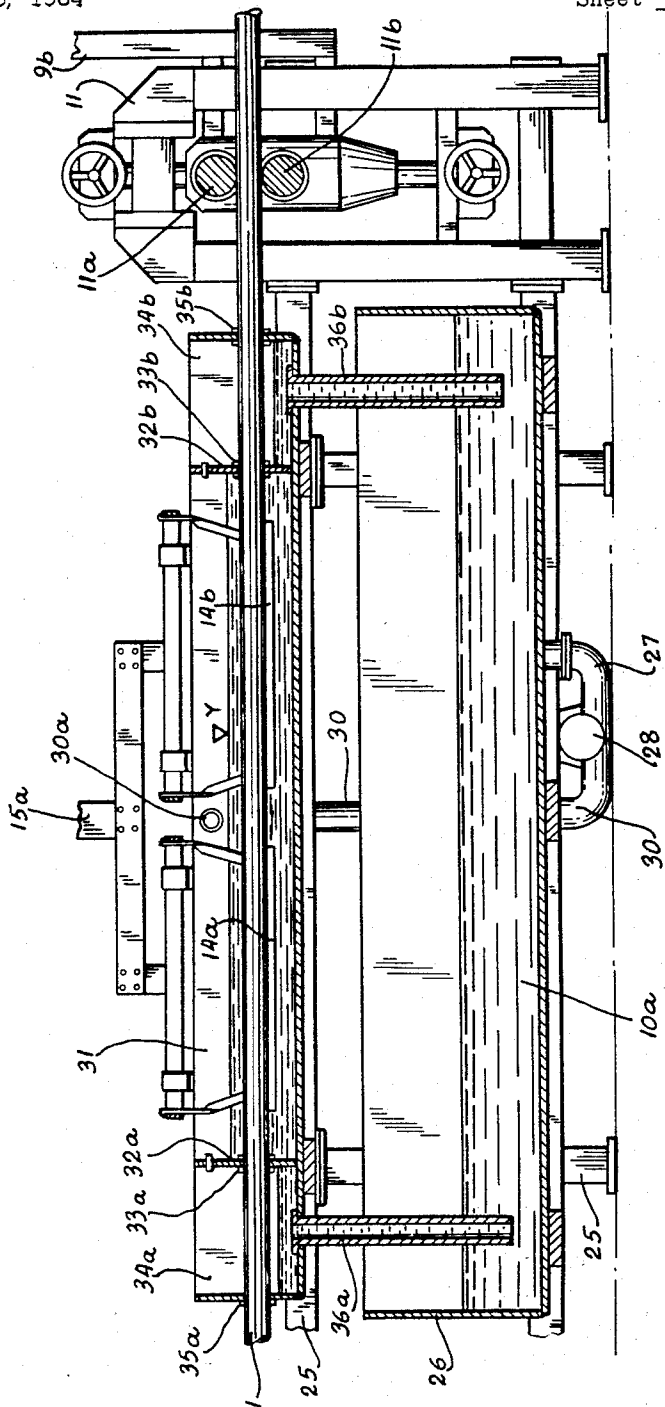
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FIG. 4



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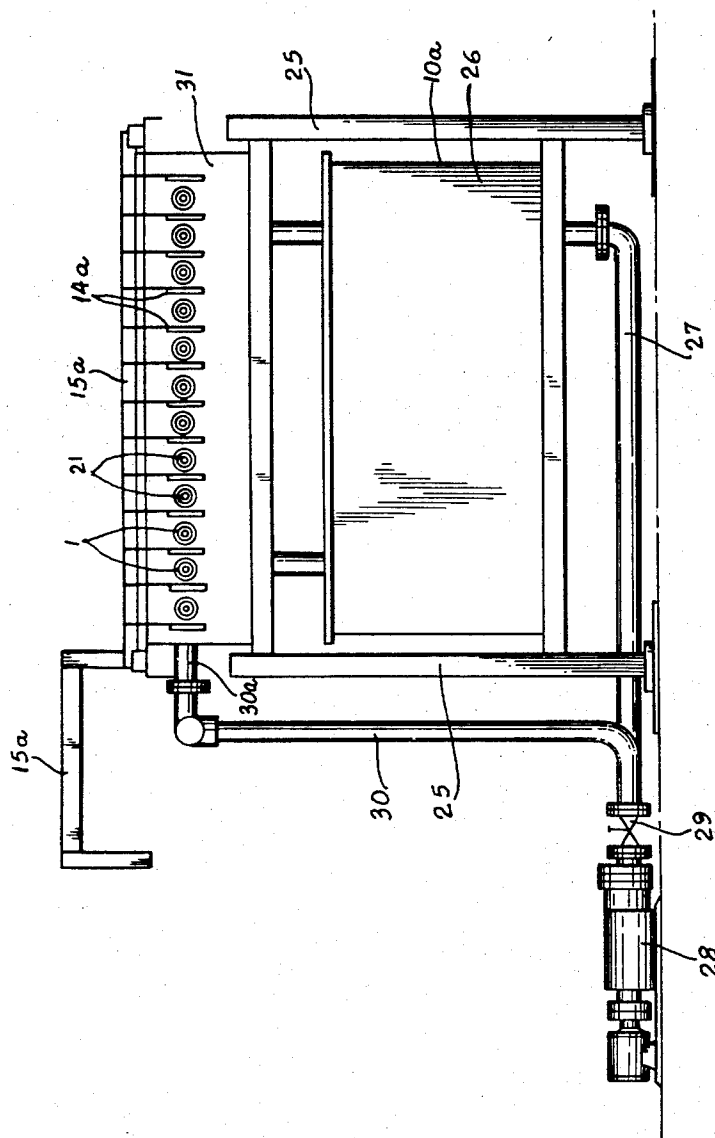


FIG. 5

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PROCESS AND APPARATUS FOR ELECTROLYTICALLY TREATING METAL TUBES

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Int. Cl. C23b 5/56

12 Claims

ABSTRACT OF THE DISCLOSURE

A process for electrolytically depositing on the interior and exterior surfaces of elongated metal tubes a metal coating while passing the tubes successively through an electrolytic bath in which an elongated conductor located in the bath passes coaxially through the tubes without touching the latter, in which a metal anode is located in the bath while the tubes are connected as cathodes and in which the tubes are advanced through the bath in such a manner as to maintain at all times one-half to one-third of the conductor uncovered so that the conductor will have a dipole function receiving metal from the anode while the conductor is uncovered by a tube and giving up the metal thus received from the anode to the interior surface of the tube while the conductor is covered thereby, and an apparatus for carrying out the process.

The present invention relates to the electrolytic treatment of articles.

More particularly, the present invention relates to the electrolytic treatment of elongated metal tubes.

It is already known to electrolytically deposit on the inner surfaces of elongated metal tubes, which may have an inner diameter small as approximately 3 mm., metals such as zinc, copper, cadmium, or the like, while continuously advancing the tubes one after the other through the apparatus. The tubes are transported along a generally horizontal path and are connected into an electrical circuit in such a way that the tubes themselves form the cathode while there is maintained in the interior of the tubes an elongated conductor in the form of a wire which acts as an anode, and with such an apparatus the tubes are successively advanced through several treating baths in one of which of course the metal coating will be electrolytically deposited on the inner surface of the tubes. The elongated wire which passes coaxially through the interiors of the several tubes as they are advanced through the several treating baths may carry a plurality of plugs which act in the manner of pistons in that they slidably engage the interior surfaces of the tubes as they are transported through the apparatus, and these plugs are made of plastic or other electrically non-conductive material, and they result in positively sucking the treating liquids into the tubes and positively displacing the treating liquid out of the tubes as they are continuously advanced through the apparatus, so that in this way the plugs provide a pumping action to guarantee thorough contact of the tubes with the treating liquids. With an apparatus of this type it is possible to achieve a practically uninterrupted coating on the inner surfaces of relatively long tubes even if they are of relatively small inner diameter. This known apparatus and process is highly economical and have the advantage of providing exceedingly uniform coatings on the metal tubes. Moreover, the plugs by providing the above-mentioned pumping action guarantee complete flooding of the surfaces of the tubes with treating liquids while also guaranteeing that

there is no undesired intermixing of the several different treating liquids.

Of course, it is essential with an apparatus of the above type to maintain the inner conductor connected into the electrical circuit so that it will act as an anode, even when the tubes are initially introduced into the apparatus with the conductor extending coaxially into the interiors of the tubes, so that special switch assemblies are required which will provide at one place a switch which opens in order to permit a tube to be introduced into the apparatus while simultaneously a second switch closes so as to maintain the inner conductor connected in the circuit, and then when a tube has been started through the apparatus the first switch closes and the second switch automatically opens, and with such a known switching arrangement it is possible to maintain the inner conductor connected in the electrical circuit so that it will uninterruptedly act as an anode.

Of course, it is also possible to provide electrolytic coatings on the exterior surfaces of the tubes by locating in the electrolyte metal electrodes made of a metal which is to be deposited on the exterior surfaces of the tubes and these electrodes are also connected into the circuit so that they will act as anodes. The above principle can also be used for electrolytically treating metals without depositing coatings thereon. For example, the above principle may be used in electrolytic degreasing or polishing of tubes. In order to polish the tubes it is only necessary to reverse the polarity so that the tubes become the anodes and the inner and outer electrodes become the cathodes.

Although the above-discussed method and apparatus for continuously treating both the inner and the outer surfaces of elongated metal tubes is extremely simple and quite practical, there is a disadvantage not only in the necessity of providing a complex switching arrangement as discussed above but also in the fact that during deposition of a coating on the inner surfaces of the tubes it is necessary to replenish the inner anode from time to time, and particularly when dealing with tubes of small inner diameters this requirement is extremely inconvenient since it requires a long period of time and is of considerable disadvantage. The smaller the inner diameter of the tube the more time is required for replenishing the inner anode. The reason for this is that the thickness of the inner anode which is surrounded by the tube as it passes through the electrolyte is of necessity smaller with tubes of smaller inner diameters, so that when dealing with tubes of relatively small inner diameters the anodes become consumed at a faster rate.

It has already been proposed to alleviate this latter problem by providing anodes in the form of suitable sleeves which are mounted on a conductive core made of copper wire, for example, but with the convenience of simply slipping sleeves onto a copper wire there goes the disadvantage of a smaller time between the periods of when the anode must be replenished while on the other hand there is always the danger that after the sleeve has become consumed the copper core itself will become consumed and can lead to undesired breakage of the copper core in the electrolytic bath. Thus, while there are indeed certain advantages from a known method and apparatus of the above type, as compared to structures where tubes are maintained stationary while they are treated, nevertheless particularly when dealing with tubes of small inner diameters, the advantages which can be achieved are greatly diminished by the requirement of frequent replenishing of the anode.

It is accordingly a primary object of the present invention to provide a method and apparatus of the above general type which will make it possible to completely avoid

the necessity of replenishing the anode from time to time.

In particular, it is an object of the present invention to provide electrolytic deposition of a suitable metallic coating on the interior and exterior surfaces of elongated metal tubes, particularly tubes of relatively small diameter, while obtaining the metal coating solely from a plate which is situated at the exterior of the metal tubes in the electrolytic bath so that while such a plate will of course be consumed at a rate which is faster than in conventional electrolytic processes and apparatus, nevertheless since the plate can be made quite thick and can be easily replaced the elimination of the necessity for replenishing the inner electrode provides a great advance in the art.

It is furthermore an object of the present invention to provide a method and apparatus of the above type which makes it possible to provide the desired coatings of the desired quality on the metal tubes from the very beginning of the operation so that the first tube is coated as effectively as all of the subsequent tubes while at the same time automatically compensating for variations in the operations resulting from variations in the distances maintained between the successive tubes as well as variations in the concentration of the electrolyte, etc.

It is also an object of the present invention to provide the above advantages achieved with the present invention not only for the coating of tubes but also for other electrolytic processes such as the polishing of coated tubes.

It is also an object of the invention to provide a process and apparatus of the above type which makes it possible to provide a predetermined relationship between the thicknesses of the coatings deposited on the exterior and interior of metal tubes.

It is furthermore an object of the present invention to provide a process and apparatus according to which a plurality of metal tubes can be treated simultaneously with a structure where a series of treating baths are arranged one after the other with a transporting structure for efficiently transporting the tubes successively through the several baths while at the same time maintaining the liquids particularly of the electrolytic bath circulating between a reservoir and a container through which the tubes pass while compensating for any leakage which may occur and while at the same time providing an efficient electrical structure for maintaining the desired electrical circuit with the various parts which are to act as anodes and cathodes maintained at the proper polarities.

With the above objects in view the invention includes, in a process for electrolytically treating elongated metal tubes which are advanced through an electrolytic bath in which there is located an elongated conductor which is not connected to any source of current and which passes coaxially through the tubes without contacting the latter as they are advanced through the electrolytic bath while there is also maintained in the electrolytic bath a plate of a suitable metal from which the metal for the coatings is derived, the step of advancing the tubes successively through the electrolytic bath while maintaining between the tubes a spacing which will uncover at any one time preferably one half of the electrical conductor which is in the electrolytic bath but at a maximum not more than two-thirds of this electrical conductor.

Also, the invention includes, in an apparatus for electrolytically treating elongated metal tubes, an electrolytic bath means adapted to contain an electrolyte and carrying an elongated conductor which extends through the electrolyte and which is not connected to any source of current. A transporting means transports the metal tubes through the bath one after the other with the conductor extending coaxially through but not contacting the metal tubes, and a metal plate which is in the electrolyte is connected electrically with the metal tubes to a source of direct current which provides for the metal tubes, on the one hand, and the plate, on the other hand, opposite polarities.

Thus, according to the process of the invention, there is provided an electrolytic bath through which the elon-

gated metal tubes are successively advanced one after the other. An elongated metal electrical conductor, in the form of a suitable wire, for example, is maintained in the electrolyte and in accordance with the invention is not connected to any source of current so that the problem of providing a switching arrangement for connecting the conductor to a source of current is eliminated. The tubes are successively advanced through the electrolyte with this elongated conductor extending coaxially through the interiors of the tubes without contacting the latter, and a metal plate is situated in the electrolyte and connected electrically with the tubes in such a way that, for the purpose of deposition of coatings on the interior and exterior surfaces of the tubes, this metal plate acts as an anode while the tubes themselves act as cathodes. According to the process of the invention the tubes successively transported through the electrolyte are advanced in such a way that not more than two-thirds of the electrical conductor is covered by the tubes at any one time, and preferably one half of the electrical conductor remains uncovered at all times, which is to say the spacing between the successive tubes ideally will be such that the distance between the successive tubes will be equal to the lengths of the tubes themselves.

In order to appreciate how the results of the invention are achieved, it is necessary to take into consideration the following explanation:

Assuming that the electrolyte is zinc sulfate and contains an anode in the form of a metal plate of zinc as well as a cathode made of iron, with the anode and cathode provided with current through suitable metallic conductors and a suitable source of current, then in the metallic conductors at the exterior of the electrolyte, assuming that there is a sufficiently high voltage, there will be a flow of electrons from the anode to the cathode. Simultaneously there will be in the electrolyte as a result of the applied voltage the formation of ionized zinc atoms at the anode which go into the solution as doubly charged positive zinc ions, and as a result of the diffusion and voltage drop they wander off into the electrolyte while at the cathode the zinc ions, as a result of diffusion as well as the voltage drop, are neutralized by the negative charge resulting from the presence of the electrons, and thus metallic zinc is deposited at the cathode. Thus, as a result with this known process there will be within the electrolyte a transportation of ions from the anode to the cathode and a transportation of electrons in the reverse direction. If an ammeter is connected to the metallic conductors at the exterior of the electrolyte than the flow of electrons can be shown by the ammeter, the magnitude of the current being determined on the one hand by the applied voltage as well as the electrical resistance of the metallic conductors and on the other hand from the inner resistance of the electrolyte. This inner resistance of the electrolyte will depend upon, among other things, the size of the exposed electrode surfaces and the speed of diffusion of the zinc ions.

Assuming now that the relatively high internal resistance of the zinc sulfate electrolyte, as compared to metallic zinc, is reduced by introducing into the electrolyte a metallic conductor of a metal such as zinc, for example, then this conductor will have the character of a dipole, and the above-described process will then take place in a manner similar to the operations which occur when a pair of cells, each including an anode and a cathode, are connected together in series. In other words when a zinc conductor, in the above example, is introduced into the electrolyte, it acts as a dipole in that the negative pole of the zinc conductor in the electrolyte will have deposited thereon zinc from the zinc anode plate, while the positive pole of the zinc conductor which has been introduced into the electrolyte will act as an anode with respect to the iron cathode and zinc will flow from the positive pole of the dipole zinc member to the iron cathode to be deposited thereon.

The above principle is used in the process and appa-

ratus of the invention by providing the inner electrical conductor which is not connected to any source of current but which extends through the electrolyte and which extends coaxially through the metal tubes without contacting the latter as the metal tubes are advanced through the electrolyte. With the invention there is of course an anode located in the electrolyte at the exterior of the metal tubes, and the elongated conductor in the interior of the metal tubes acts as a dipole in the manner described above. Thus, although it is not connected to any source of current, when the inner conductor is not covered by the metal tube it acts as a negative pole and there is deposited upon the conductor metal from the anode in the electrolyte at the exterior of the metal tube, while when the conductor is covered by the metal tube the coating previously deposited on the conductor for the anode will flow from the conductor to the interior surface of the metal tube. Of course, it is assumed that the metal tube is electrically connected into the circuit as the cathode, and in addition it must be assumed that there is no electrical circuitry which will disturb the dipole function of the inner conductor or which will interrupt this function and also the anode plate which is in the electrolyte and the metal tube which is coated respectively form the anode and cathode of an electrical circuit which is provided with a source of direct current. In other words the metal tubes are electrically connected to the negative pole of the source of direct current while the anode plate is connected to the positive pole of the source of direct current.

Of course, ideally the successive metal tubes should be spaced from each other by a distance equal to their length, so that in this way one half of the inner electrical conductor which has the dipole function is uncovered and thus there is an equal opportunity for metal to become deposited on the inner conductor when it is uncovered and for the metal to flow from the inner conductor to the inner surface of the metal tubes. However, the process and apparatus of the invention function very well even if two thirds of the inner conductor remains covered so that only one third thereof is uncovered at any given time, the only difference being in that this latter case the exterior surface of the metal tube will receive a somewhat thicker coating than the interior surface thereof. Moreover, the inner conductor which may be made of copper, for example, can initially be provided with sleeves of zinc mounted thereon, so that in this way there is an initial reserve of metal to be deposited on the inner surface of the metal tubes and in addition such a reserve of metal will automatically compensate for variations in the lengths of the tubes and the distances therebetween as well as in the concentration of the electrolyte, etc. However, it will be seen that with the invention it becomes completely unnecessary to replenish the anode in the interior of the metal tubes from time to time. Because the outer anode plate supplies the metal for the interior as well as the exterior coating, relatively long periods will elapse before it is necessary to change the exterior metal plate which in any event is very quickly and easily changed, and the necessity of changing either the inner conductor or mounting new sleeves thereon to replace consumed sleeves is completely avoided with the process and apparatus of the invention.

Of course, the process and apparatus of the invention can be used for polishing an already coated tube simply by reversing the polarity so that the coated tube is the anode and the plate becomes the cathode.

Of course, in order to guarantee that at least one third of the inner conductor remains uncovered at all times it is necessary for the inner conductor to be longer than the metal tubes on which the coating is to be electrolytically deposited. Ideally the inner conductor will of course be twice as long as the metal tubes so that at all times one half of the conductor is exposed.

The novel features which are considered as characteristic for the invention are set forth in particular in the

appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1A and FIG. 1B, which is a continuation of the right end of FIG. 1A, schematically illustrate the entire installation for electrolytically treating the elongated metal tubes;

FIG. 2 schematically illustrates on an enlarged scale, as compared to FIGS. 1A and 1B, that part of the installation which includes the electrolytic baths in which the metal is electrolytically deposited on the metallic tubes;

FIG. 3 is a longitudinal sectional view, on a scale which is still further enlarged as compared to FIG. 2, fragmentarily illustrating the manner in which a metal tube is transported with the inner conductor passing coaxially therethrough;

FIG. 4 is a sectional schematic elevation showing details of the electrolytic bath and structure associated therewith; and

FIG. 5 is a transverse end view of the electrolytic structure of FIG. 4.

The entire installation which is shown in FIGS. 1A and 1B includes a plurality of individual units and containers arranged one after the other in the direction of movement of the tubes 1 and adapted to contain the various treating liquids for treating the tubes prior to the electrolytic treatment thereof for depositing metal thereon, for example, as well as for treating the tubes subsequently to the electrolytic deposition of metals thereon. The first unit in the direction of movement *x* of the tubes is the table 2 on which the several tubes are arranged beside each other so as to move simultaneously through the apparatus. Next to the table 2 is located the transporting unit 3 which is provided with a plurality of pairs of rollers 3*a* and 3*b* driven in any suitable way and adjustable to the diameter of the particular tubes, the pairs of rollers 3*a* and 3*b* equalling the number of tubes and engaging the latter to transport the tubes in the direction of the arrow *x*. A bath 4 follows the transporting unit 3, and this bath contains a known degreasing solution for preliminarily degreasing the tubes as they move through the bath 4. Subsequent to the bath 4 is a further treating container 5 which in a known way electrolytically degreases the tubes. At 5*a* there is indicated a container which immediately follows the electrolytic degreasing bath 5 and which is simply a water bath for the purpose of washing the tubes as they advance out of the bath 5 and through the bath 5*a*. Then the tubes are engaged by a further transporting unit 6 which may be constructed identically with transporting unit 3 and which has a plurality of pairs of rollers 6*a* and 6*b* for respectively engaging and continuing the movement of the tubes 1 through the apparatus to the pickling bath 7 where the tubes are descaled with a suitable pickling solution which may be, for example, 10% sulfuric acid solution.

The treating bath 7 is followed by a further transporting unit 8 which is provided with a plurality of pairs of rollers 8*a* and 8*b* which on the one hand serve to continue to transport the tubes in the same way as the rollers of the other transporting units and which on the other hand are electrically conductive and are connected into the electrical circuit so as to supply cathode current for the tubes 1. For this purpose the rollers 8*a* and 8*b* are engaged by electrically conductive slip contacts which are not illustrated in the drawing and which are electrically connected with a copper bus bar 9*a* which is connected to the negative pole of a source of direct current which is not illustrated in the drawing.

Subsequent to the electrically conductive transporting means 8 is located a bath means 10*a*, 10*b* which is the electrolytic bath means in which the metal coating is

electrolytically deposited on the inner and outer surfaces of the tubes, and in accordance with one of the features of the invention this bath means is divided into a pair of electrolytic bath units **10a** and **10b**. After passing through the electrolytic bath unit **10a** the tubes are engaged by a further transporting unit **11** provided with a plurality of pairs of rollers **11a** and **11b** which engage and continue the transportation of the tubes **1**. The transporting means **11** is also electrically conductive, and the rollers **11a** and **11b** are engaged also by unillustrated slip contacts which are electrically connected with a bus bar **9b** which is also connected to the negative pole of the source of direct current so that the connection of the tubes into the circuit so as to form cathodes is maintained by the transporting means **11**.

Referring now to FIG. 1B which forms a continuation of FIG. 1A, it will be seen that there is located immediately subsequent to the transporting unit **11** a transporting unit **12** which is provided with the pairs of rollers **12a** and **12b** for engaging and continuing the transportation of the tubes **1**, and these rollers are also engaged by unillustrated slip contacts which are electrically connected with the bus bar **9c** which is in turn connected to the negative pole of the source of direct current, so that the negative polarity of the tubes is maintained by the transporting unit **12**.

Immediately subsequent to the transporting unit **12** is located the second bath unit **10b** of the electrolytic bath means, and this bath means **10b** is followed by a further transporting unit **13** provided with pairs of rollers **13a** and **13b** for engaging and continuing the transportation of the tubes, and these rollers also are engaged by slip contacts which are electrically connected with a bus bar **9d**, and again this latter bus bar is connected to the negative pole of the source of current so that the negative polarity of the tubes is still maintained by the transporting unit **13**.

The conducting of the anode current to the electrolytic bath means **10a**, **10b**, and in particular to the metal electrodes **14a**, **14b**, **14c** and **14d** located in the electrolytic baths and being in the illustrated example zinc plates, can take place also by copper bus bars, these bus bars **15a** and **15b** both being electrically connected to the positive pole of the source of direct current which is not illustrated in the drawings. The electrolytic baths **10a** and **10b** which are filled with zinc sulfate are followed by a pair of passivation baths **16** and **17** which contain among other things chromic acid and which are immediately preceded, respectively, by water baths **16a** and **17a**. The passivation baths **16** and **17** are followed by a further transporting unit **18** provided with the pairs of rollers **18a** and **18b** which engage and continue the transportation of the tubes **1** and which serve to deliver them to the discharge table **19**.

The pair of electrolyte containers **10a** and **10b** are shown on an enlarged scale in FIG. 2, partly in section, while FIG. 3 shows on a further enlarged scale the structure of the inner anode assembly.

Throughout the entire length of the entire installation shown in FIGS. 1A and 1B there are arranged a plurality of elongated conductors **20**, in the form of wires, the number of which are equal to the number of tubes **1** which are arranged beside each other and which move simultaneously through the apparatus so that each tube **1** will have this elongated conductor passing coaxially there-through as the tube **1** is advanced through the installation. The elongated conductors **20** have an exterior diameter substantially smaller than the inner diameter of the tubes, this latter inner diameter being as small as three or four millimeters for example, so that the wires **20** of course have a relatively small diameter. With the exception of the portions of each wire **20** which pass through the bath **5** and the electrolytic baths **10a** and **10b**, each wire **20** has the construction shown at the left of FIG. 3, namely an inner core **20a** made of metal and surrounded by a

covering of plastic **20b**, which is of course electrically non-conductive. Inasmuch as the electrolytic baths **10a** and **10b** and the bath **5** form a minor fraction of the total length of the installation shown in FIGS. 1A and 1B, it is clear that the wire **20** for the most part has this construction according to which it is in the form of an inner metal wire **20a** surrounded by a plastic coating **20b**.

In the degreasing bath **5** which electrolytically degreases the tubes each of the wires **20** is composed only of the inner portion **20a**, the plastic covering **20b** being omitted in the bath **5**, so that the bare wire **20a** is uncovered and exposed in the electrolytic degreasing bath **5**, and this uncovered portion of the wire is connected by suitable contacts to the anode current so that the degreasing can be carried out in an electrolytical manner.

In the electrolytic baths **10a** and **10b** the structure of the inner conductor changes in that in these baths there is also located an electrical conductor, but not an electrical conductor covered by a coating of insulation. Instead there extends through the baths **10a** and **10b** a copper core **21** which is surrounded by a plurality of rigid metal sleeves **22** made of zinc, and the copper wire portion **21** of the wire **20** in the baths **10a** and **10b** is not supplied with any current and is not connected into any circuit so that it can perform the above-described dipole function in the electrolytic baths, enabling the wire **21** to have at one time the function of a cathode with respect to the exterior anodes **14** and at another time to have the function of an anode with respect to the tubes **1** which surround the conductor **21**. For this purpose the wire portion **21** of each wire **20** is in the form of a completely separate and independent insert introduced into the length of the wire **20** at a suitable interruption in the portion **20a** thereof, and this insert **21** for each wire **20** is independent of the remainder of the wire **20** and is separately mounted and interchangeable, and in addition it is insulated from the remainder of the wire **20** as by being connected thereto by way of sleeves **23** (FIG. 3) made of any suitable electrically non-conductive material such as a suitable plastic, rubber, or the like. The exposed portion of the wire which is in the degreasing bath **5** is also separate from the remainder of the wire **20** and connected thereto by suitable insulating sleeves, but of course this exposed wire portion of each wire **20** in the bath **5** is supplied with current from the exterior by the anode conductors.

As is apparent particularly from FIG. 3, the core **21** carries between the several zinc sleeves **22** the plugs **24** which act similarly to pistons and which have a frusto-conical configuration, these plugs **24** being made of any suitable resilient, elastically deformable plastic, and plugs have their largest outer diameter slightly greater than the inner diameter of the tubes **1** so that they can perform a piston-like sealing function at the interior of the tubes **1** which move along the conductors, respectively, with the latter passing coaxially through the tubes **1**. These plugs in addition serve simultaneously for centering the conductors in the interior of the tubes so that in this way they promote the efficient deposition of a metal coating on the inner surfaces of the tubes. The plugs **24** are rigidly fixed to and immovable with respect to wire core **21** and they are additionally provided on the wire **20** at every container of the installation in the region of the entrance and discharge of the tubes into and out of the several containers, so that only in the electrolytic deposition baths **10a** and **10b** as well as in the electrolytic degreasing bath **5** are there additional plugs so as to provide in these baths the centering of the anode wire with respect to the interiors of the tubes, and thus in these baths even a very slight sagging of the inner conductor will be reliably prevented.

The several baths through which the tubes successively pass while moving along the installation shown in FIGS. 1A and 1B are identically constructed, and thus the details of only one of these baths are illustrated in FIGS.

4 and 5 where by way of example the detailed structure of the electrolytic bath 10a is illustrated.

Thus, it will be seen that each of the baths includes a frame 25 which carries a lower container or reservoir 26 which has an open top, which is of a relatively large size, and which contains the treating liquid of the particular bath, in this case the electrolyte. As is apparent from the lower portions of FIGS. 4 and 5, a pipe 27 provides communication between the lower interior of the reservoir 26 and a motor-driven pump 28 which sucks the treating liquid out of the reservoir 26, and a pipe 30 is connected to the outlet of the pump 28, this pump 30 carrying a valve 29 and having an upper outlet end 30a through which the treating liquid is discharged into an upper container 31 which is shallower than the reservoir 26 and in which the actual treatment of the tubes 1 takes place.

As is shown most clearly in FIG. 4, the interior of the container 31 of the bath 10a, and of course also of the bath 10b, accommodates the exterior anode plates, and thus the exterior anode plates 14a and 14b are shown in FIG. 4 in the interior of the container 31. Moreover, the container 31 is limited by a pair of end walls 32a and 32b through which the tubes 1 pass at an elevation lower than the liquid level γ of the treating liquid. For this purpose the end wall 32a is provided with a row of openings 33a, through which the several tubes 1 respectively pass into the bath 31, and the wall 32b is provided with a row of openings 33b through which the tubes move out of the treating bath 31, and each of these entrance and discharge openings 33a and 33b is provided with a suitable sealing ring which extends along the edge of each opening and which engages the exterior surface of the tube in a substantially fluid-tight manner, so that in this way discharge of the treating liquid into the liquid-collecting chambers 34a and 34b situated directly before and after the container 31 is very greatly reduced. A certain steady leakage of the treating liquid does take place into the overflow chambers 34a and 34b which are respectively provided with openings 35a and 35b through which the tubes also pass and these latter openings are also provided with suitable sealing rings which slidably engage the exterior surface of the tubes. The overflow collecting chambers 34a and 34b communicate with conduits 36a and 36b, respectively which direct the excess treating liquid back into the reservoir 26, so that in this way the liquid level in the interiors of the overflow chambers 34a and 34b are always at an elevation lower than the inlet and outlet openings 35a and 35b.

In the region of each entrance opening 33a and discharge opening 33b of each container 31 a plug 24 is located so that as the leading open end of each tube enters into a particular container the plug 24 in the tube will suck the treating fluid into each tube so as to reliably fill the latter with the treating fluid while at the same time reliably preventing the several treating fluids from becoming mixed with each other, and as the trailing end of each tube moves beyond the plug 24 at the entrance opening of the particular bath the plug 24 at the discharge opening will guarantee that the treating liquid in each tube is reliably displaced out of the latter, so that in this way the plugs also serve to suck the treating fluids into and displace the treating fluids out of the several tubes to guarantee intimate contact between the inner tube surfaces and the treating liquids.

As is particularly apparent from FIG. 5, the width of the installation, from front to rear, is great enough so that, in the illustrated example, twelve tubes 1 can be arranged beside each other on the entrance table 2 and can simultaneously move through the installation. It is of course immaterial to the operation how many tubes are arranged beside each other so as to move simultaneously through the apparatus, but in the illustrated example there will be groups of twelve tubes moving at predetermined intervals one after the other through the

apparatus, and in addition it is immaterial whether all twelve tubes are aligned with each other so as to receive the same treatments during precisely the same time intervals. In other words as long as a series of tubes are transported at predetermined intervals along a given conductor, it makes no difference whether the movement of tubes along one conductor is synchronized with the movement of tubes along another conductor. Thus, the several tubes which move along several conductors can have any desired relationship with respect to each other. The several conductors which are arranged across the installation operate completely independently of each other. Thus, each conductor in the electrolytic baths 10a and 10b, for example, must have at least one third of its length uncovered at any one time, as pointed out above, but since the several conductors 21 operate completely independently of each other with their particular polarity of any instant determined by which portion of a given conductor 21 is surrounded by a tube 1, it is clear that it is immaterial whether the several tubes 1 move with any particular synchronization along the several conductors.

The electrolytic bath means 10a, 10b will have a single continuous conductor 21 passing therethrough and insulated from the remainder of the wire 20, as described above, and it is preferred to have a pair of separate baths 10a and 10b than a single continuous bath, since in this way the length of each bath and of course the portion of the conductor 21 located therein can correspond to the length of a tube 1, and thus in this way in one bath the conductor 21 will be completely uncovered at a given time, as shown in the bath 10b in FIG. 2, so that according to the dipole function the deposition of metal from the plates 14c and 14d can take place on the portion of the conductor in the bath 10b while as the tube 1 advances into and through the bath 10b the dipole function will cause the metal to then be transferred from the conductor onto the inner surface of the tube 1 while the conductor in the bath 10a now becomes progressively uncovered to an increasing extent so as to receive metal from the plates 14a and 14b in the bath 10a.

Remembering that ideally the spacing between the tubes will be equal to the lengths of the tubes, then where each of the baths 10a and 10b has a length corresponding to that of the tubes, it is clear that one tube will be completely located in the bath 10b before the next tube enters into the bath 10a, and on the other hand a tube will have been entirely transported out of the bath 10b before the next tube enters into the bath, so that in this way the required extent of uncovering of the inner conductor can be maintained.

With the ideal arrangement shown in FIG. 2 and according to which the spacing between the tubes equals their lengths and the tubes are equal to the lengths of the baths 10a, on the one hand, and 10b, on the other hand, there will be practically no consumption of the zinc sleeves 22 inasmuch as according to the dipole function precisely the amount of metal deposited on the inner conductor from the anode plates will be removed therefrom to be deposited from the inner surfaces of the tubes.

Of course, the number of electrolytic baths can be increased to any number in the interest of enlarging the entire length of the region where electrolytic position takes place, the only requirement being that the total length of the tubes is not greater than two thirds of the total length of the inner conductor which has the dipole function, and preferably the tube should only be one half of this length, as pointed out above. Otherwise, the enlarging of the effective length of the installation along which electrolytic deposition takes place, which is to say elongating the electrolytic baths with respect to the lengths of the tubes, makes it possible to increase the speed with which the tubes are moved through the installation without undesirably influencing the quality of

the deposition of the zinc coating on the inner and outer surfaces of the tubes.

As an example of particular tube lengths, in a particular installation according to the invention the tubes have a length of 15 meters while the conductor 21 which is not connected to any source of current and which has the dipole function has a length of 30 meters, and preferably the arrangement is such that each bath 10a and 10b has a length of 15 meters providing the total length of 30 meters for the conductor 21 and of course as the tubes are transported through the apparatus they are maintained spaced from each other, in the ideal case, by a distance of 15 meters, so that in this way the rate of deposition of zinc onto the inner conductor when it acts as a cathode will equal the removal of the coating therefrom when surrounded by the tube 1 when the inner conductor acts as an anode.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of electrolytic installations differing from the types described above.

While the invention has been illustrated and described as embodied in electrolytic process and apparatus, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a process for electrolytically treating elongated metal tubes which are longitudinally advanced one after the other through an electrolytic bath in which is located an elongated conductor which extends coaxially through each tube without engaging the latter as each tube is advanced through the bath and in which there is located a metal electrode connected electrically with the metal tube through said electrolytic bath at a polarity opposite to that of the tube while the elongated conductor is not connected to any source of current, the step of advancing the metal tubes through the bath one after the other with a spacing therebetween which will provide a covering of the conductor by the tubes which at a maximum is approximately two thirds of the length of the conductor in the electrolytic bath.

2. In a process for electrolytically treating elongated metal tubes which are successively advanced longitudinally through an electrolytic bath in which is located an elongated conductor which extends coaxially through the tubes without touching the latter as they are advanced through the bath and in which there is an electrode electrically connected through said electrolytic bath with each metal tube as it passes through the bath but of an opposite polarity thereto, the step of successively advancing said tubes through said bath while maintaining the distance between the successive tubes substantially equal to the length of said tubes.

3. In a process for electrolytically depositing on the interior and exterior surfaces of elongated metal tubes a metal coating while passing the tubes successively through an electrolytic bath in which is located an elongated conductor which passes coaxially through the tubes without touching the latter as they are advanced through the bath with a metal anode located in the bath and the tubes themselves acting as cathodes while the elongated conductor is not connected to any source of current, the step of successively advancing the tubes through the bath in a manner

which maintains at all times from one half to one third of the conductor uncovered, so that said conductor will have a dipole function receiving metal from said anode while said conductor is uncovered by a tube and giving up the metal thus received from the anode to the interior surface of the tube while the conductor is covered by the tube.

4. In an apparatus for electrolytically treating metal tubes, in combination, elongated electrolytic bath means adapted to contain an electrolyte through which the tubes to be treated are longitudinally passed; an elongated electrical conductor carried by said bath means in the interior of said bath means; means operatively connected to said bath means for transporting therethrough the metal tubes one after the other and spaced in axial direction from each other through said bath means with said conductor passing coaxially through the tubes without touching the latter and so that at any instant at least one third of the length of said electrical conductor in said bath means is uncovered by the metal tubes; and electrical means for electrically interconnecting a source of direct current only with a metal plate which is located in said bath and said tubes with opposite polarities therebetween.

5. In an apparatus for electrolytically treating metal tubes, in combination, elongated electrolytic bath means adapted to contain an electrolyte through which the tubes to be treated are longitudinally passed; an elongated electrical conductor carried by said bath means in the interior of said bath means; means operatively connected to said bath means for transporting therethrough the metal tubes one after the other and spaced in axial direction from each other through said bath means with said conductor passing coaxially through the tubes without touching the latter and so that at any instant at least one third of the length of said electrical conductor in said bath means is uncovered by the metal tubes; electrical means for electrically interconnecting a source of direct current only with a metal plate which is located in said bath and said tubes with opposite polarities therebetween; and a plurality of resilient, electrically non-conductive, elastically deformable plugs carried by and distributed along said conductor for yieldably engaging the interior surface of the metal tubes as they are transported through the bath to center said conductor in said tubes.

6. In an apparatus for electrolytically depositing metal from a given plate onto the interior and exterior surface of elongated metal tubes, in combination, elongated bath means adapted to contain an electrolyte; an elongated electrical conductor extending through and carried by said bath means and being electrically insulated at opposite ends thereof; transporting means for transporting the metal tubes one after the other and spaced in axial direction from each other through the bath means with said conductor located coaxially within and out of contact with said tubes and so that at any instant at least one third of the length of said electrical conductor in said bath means is uncovered by the metal tubes; electrical means electrically interconnecting a source of direct current only with the tubes and the plate in a manner rendering said plate which is in said bath an anode and said tubes a cathode; and sleeve means of the same metal as said plate covering said conductor and also maintained out of contact with the tubes as they are transported through the bath means.

7. In an apparatus for electrolytically treating metal tubes, in combination elongated bath means adapted to contain an electrolyte as well as a plate of metal in said electrolyte; an elongated electrical conductor extending through said bath means and being electrically insulated at opposite ends thereof; transporting means for transporting the tubes one after the other and spaced in axial direction from each other through said bath means with said conductor extending coaxially through but not contacting said tubes and so that at any instant at least one third of the length of said electrical conductor in said bath

means is uncovered by the metal tubes; electrical means for electrically interconnecting a source of direct current only with said tubes and plate while providing opposite polarities for said tubes and plate, respectively; and a plurality of electrically non-conductive resilient, elastically deformable plugs of frustoconical configuration carried by and distributed along said conductor for slidably engaging the interior surface of the tubes as they are transported through the bath means.

8. In an apparatus for electrolytically treating elongated metal tubes, in combination, elongated bath means adapted to contain an electrolyte and a metal plate, said bath means being divided into at least two identical units each containing electrolyte and each containing a metal plate; an elongated electrical conductor electrically insulated at opposite ends thereof and passing through said electrolyte in said bath means; transporting means for transporting the tubes one after another and spaced in axial direction from each other through the bath means with said conductor passing coaxially through the tubes without contacting the latter and so that at any instant at least one third of the length of said electrical conductor in said bath means is uncovered by the metal tubes; and electrical means electrically interconnecting only said tubes and said plates with a source of direct current while providing said plates on the one hand and said tubes on the other hand with opposite polarities, respectively.

9. In an apparatus for electrolytically treating elongated metal tubes, in combination, elongated bath means adapted to contain an electrolyte as well as a metal plate, said bath means including an upper electrolyte container, a lower reservoir for the electrolyte located beneath said container, conduit means providing communication between said reservoir and container, pump means for pumping electrolyte from said reservoir into said container, overflow chambers respectively located before and after said container for receiving electrolyte which is not retained in said container, and additional conduits providing communication between said chambers and reservoir for directing to the latter electrolyte which reaches said chambers; an elongated electrical conductor electrically insulated at opposite ends thereof and carried by said bath means and passing therethrough in said container thereof; transporting means for transporting one after the other through said container and spaced in axial direction from each other, said metal tubes with said conductor passing coaxially through but not contacting said tubes and so that at any instant at least one third of the length of said electrical conductor in said bath means is uncovered by the metal tubes; and electrical means interconnecting a source of direct current only with said tubes and plate while providing opposite polarities for said tubes and plate, respectively.

10. In an apparatus for electrolytically treating elongated metal tubes, a plurality of bath means arranged one after the other along a predetermined path and respectively adapted to contain different treating liquids, an intermediate one of said bath means being adapted to contain an electrolyte while at least one bath means in advance of said intermediate bath means is adapted to contain a liquid for degreasing the tubes; an elongated conductor extending through all of said bath means and being composed for the most part of an electrical conductor covered with a layer of insulation, said conductor being uncovered in the bath which is located in advance of said intermediate bath for degreasing the tubes and said conductor in said intermediate bath which contains

electrolyte being insulated from the remainder of the conductor; means for advancing the metal tubes successively and spaced in axial direction from each other through the several baths with said conductor passing coaxially through the tubes without contacting the latter and so that at any instant at least one third of said conductor in said intermediate bath means is uncovered by said tubes; means for providing a source of current for the uncovered conductor portion in the degreaser bath for electrolytically degreasing the tubes as they pass through the latter; and electrical means for connecting the tubes, as they pass through the intermediate bath means with a direct source of current which is also connected with a plate in said intermediate bath means which is provided with a polarity opposite to that of said tubes as they pass through the intermediate bath means which contains the electrolyte.

11. In an apparatus for electrolytically treating elongated metal tubes, in combination, bath means adapted to contain an electrolyte and containing a metal plate in the electrolyte; an elongated electrical conductor extending through the electrolyte of the bath means and being electrically insulated at opposite ends thereof; electrically conductive transporting means located adjacent said bath means for transporting therethrough one after the other the metal tubes which are to be treated spaced in axial direction from each other with the conductor passing coaxially through but being out of contact with the tubes and so that at any instant at least one third of the length of said electrical conductor in said bath means is uncovered by the metal tubes; and electrical means connected only to said transporting means and to said plate for electrically interconnecting the transporting means and plate with a source of direct current and for providing said plate and said tubes through said transporting means with opposite polarities.

12. In an apparatus for electrolytically polishing tubes provided with a metal coating at their exterior and interior surfaces, in combination, electrolytic bath means; a metal plate located in the electrolyte of said bath means; an elongated electrical conductor extending through the bath means in the electrolyte thereof but being electrically insulated at opposite ends thereof; transporting means for transporting through the electrolyte in said bath means metal tubes one after the other with the conductor extending coaxially through the tubes without contacting the latter and so that at any instant at least one third of the length of said electrical conductor in said bath means is uncovered by the metal tubes; and electrical means operatively connected only to said tubes and plate for connecting them with a source of direct current while providing them with polarities which cause said tubes to act as the anodes and said plate to act as a cathode.

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