Nov. 4, 1958 J. S. CURTISS, JR 2,859,157

METHOD AND APPARATUS FOR ELECTROPLATING THE INTERIOR SURFACE OF CONDUCTIVE MATERIAL APERTURES

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FIG. 2

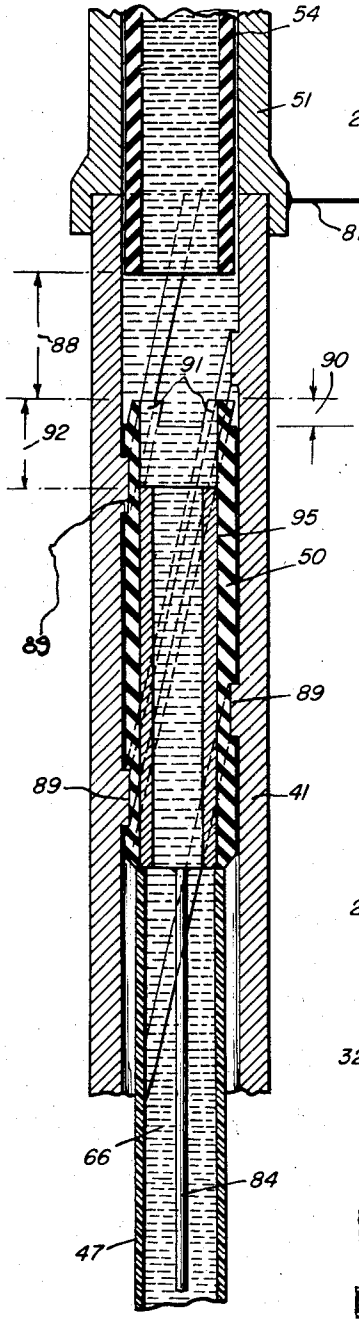

FIG. 1

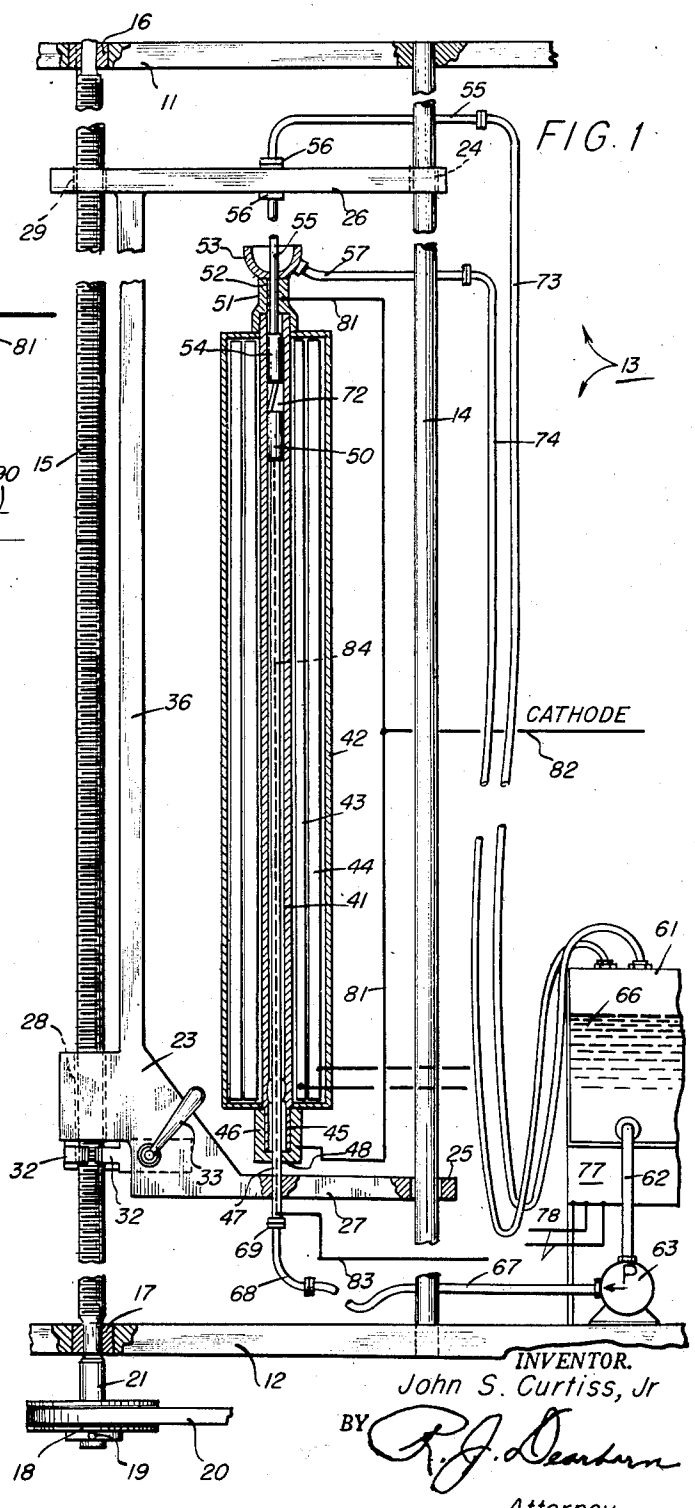

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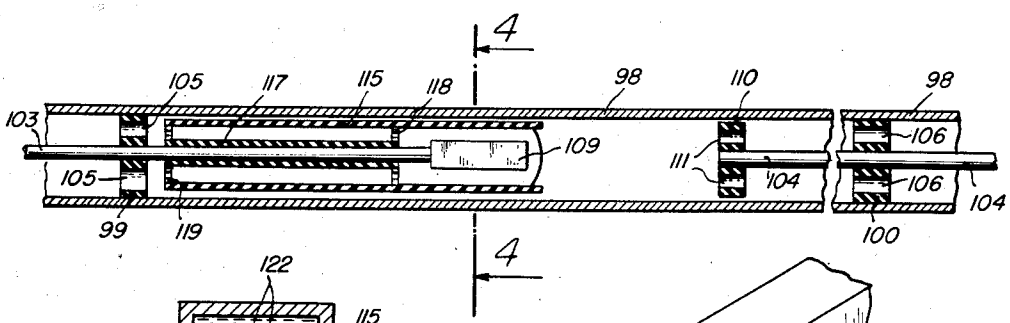
FIG. 3



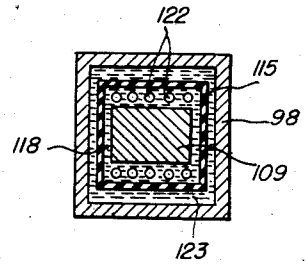


FIG. 4

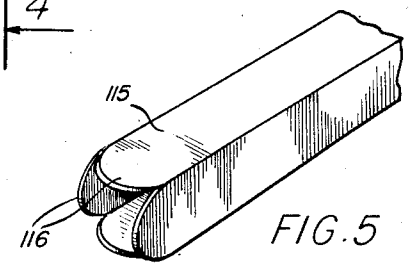


FIG. 5

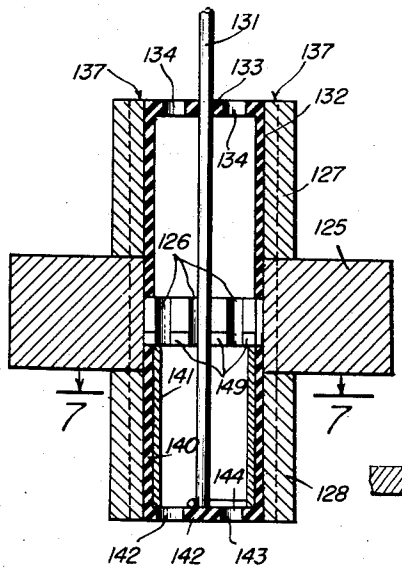


FIG. 6

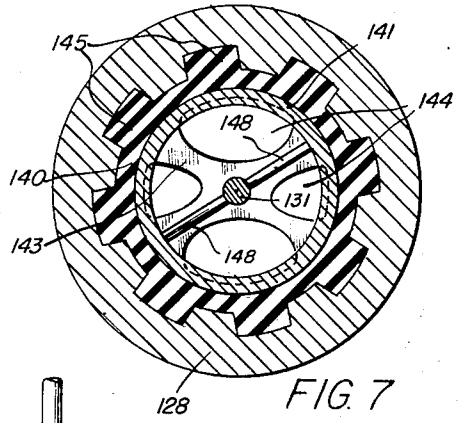


FIG. 7

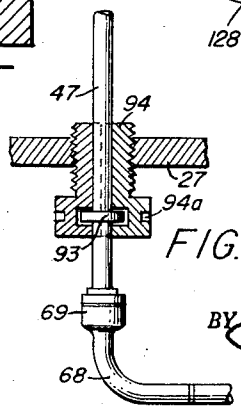


FIG. 8

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METHOD AND APPARATUS FOR ELECTROPLATING THE INTERIOR SURFACE OF CONDUCTIVE MATERIAL APERTURES

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Application October 4, 1956, Serial No. 613,869

14 Claims. (Cl. 204—26)

This invention is concerned with electroplating of the inside surface of tubes or passages through solid articles, and the like. More specifically the inside surfaces to be electroplated in accordance with this invention, are those which fall into the category of being relatively difficult to plate evenly or satisfactorily, e. g. long, small bore tubes, or passages having sharp corners or similar difficult surface configurations on the inside surface thereof.

It has been found that the wear resistance of rifle barrels can be greatly increased by plating the inside surface thereof with corrosion resistant materials having increased hardness, e. g. by chromium plating. Experience has shown, however, that whereas such plating of relatively large sized rifle barrels has been successfully accomplished, problems arise in connection with smaller sized rifle barrels which heretofore became practically insurmountable. Consequently, while the successful chromium plating of naval guns in the order of 16 inch size has been quite successfully carried out, attempts to similarly plate small arms rifle barrels, e. g. 50 caliber rifles or smaller, have been at best unsatisfactory.

It appears that the reasons for the difficulty in plating such small diameter tubes on the inside, include the fact that during the electroplating process gas bubbles are emanted from the electrolyte at the surface being plated, and as these form inside the tube there is a tendency for them to become trapped and set up local areas where the plating is not carried out, or is very poorly accomplished. This is true even where the tube is disposed vertically, because the concentration of bubbles near the top of the tube becomes much greater than it is near the bottom. In addition, where the tube to be plated on the inside is a rifle barrel, having lands and grooves therein, there is a tendency for the current flow to be uneven in its density at the sharp edges of the lands as well as along the corners where the lands and grooves meet. This fact is well known in electroplating generally and it involves the proposition that there is an inincreased density of current flow (and plating taking place) at any unstanding sharp edges or exposed surfaces; while the opposite effect is had at depressions or corners. In the latter case the density of current flow and consequently the plating which is accomplished, becomes less than the average density of plating current over the area being treated. An additional problem that is created in small sized tubes is that of unevenness in the plating effects over the length of the tube where an anode is employed in the form of a centrally disposed wire or the like that extends for the full length of the tube. The unevenness in such instance has many factors which tend to cause it, among which is the fact that as the gas bubbles rise inside the tube the number of bubbles become cumulatively greater near the top of the tube so that the amount of electrolyte maintaining contact with the anode and with the tube surface being plated, is much reduced near the top of the tube. Another factor involved is the electrical resistance of the anode which is created by reason of the relatively long configuration

for the anode, along with a relatively small diameter (so as to leave sufficient space for clearance of the gas bubbles as formed). This relatively high electrical resistance of the anode, tends to cause an uneven distribution of the density of current flow during the plating operation.

Consequently, it is an object of this invention to provide a system for plating tubes or other passages which overcomes the above mentioned diffiulties.

Another object of this invention is to provide an arrangement for plating the inside surface of tubes such that the exposed area on the inside surface of the tube is limited to a predetermined size having a definite relationship to the location of the anode. In this manner an even and adequate plating operation for the entire inside surface of a small bore, or otherwise difficult to plate, tube may be successfully carried out.

Another object of this invention is to provide a plating system for the inside surface of metallic tubes or other passages such that a hollow anode is employed for circulating the electrolyte therethrough and wherein the anode is surrounded by an insulating shroud which limits the path of the plating current to the inside surface of the tube to be plated, all the way around the inside circumference thereof. In this manner, as the electrolyte is circulated through the anode and inside the shroud, it makes effective contact with the inside surface of the tube to be plated, only above the shroud so that the distance or length of path of current flow from the anode to the metallic tube surface is positively controlled at all points around the inside surface being plated.

Briefly, the invention is concerned with a system for electroplating the interior surface of an aperture in conductive material, and with an improvement in such a system. The improvement includes the combination of an anode adapted to be located inside said aperture; an electrolyte; means for effectively exposing a limited area, preferably offset axially from the anode, of said interior surface at a time to said electrolyte; means for moving said exposed area to cover the entire inside surface to be plated; and means for supplying electric current to said anode and to said tube for causing said electrolyte to plate the inside surface of the aperture at said exposed area.

Some illustrative embodiments of the invention are described in greater detail below, in accordance with the applicable statutes, and are illustrated in the drawings, in which:

Figure 1 shows a schematic view of the entire apparatus that is to be employed in plating a small bore rifle barrel, with the barrel being plated shown in vertical cross section, and with the supporting framework shown broken off to reduce the over-all height of the drawing;

Fig. 2 is an enlarged detail view in vertical cross section illustrating the details of construction of the anode and related insulating shrouds of the Fig. 1 apparatus;

Fig. 3 is a longitudinal elevation partly in cross section of a fragmentary portion of a rectangular wave guide with plating apparatus therein, shown broken off near one end of the drawing in order to reduce the length of the showing;

Fig. 4 is an enlarged, transverse cross section view taken along the lines 4—4 of Fig. 3 looking in the direction of the arrows;

Fig. 5 is a fragmentary perspective view of the anode shroud used in the Fig. 3 apparatus;

Fig. 6 is a longitudinal elevation largely in cross section, showing the apparatus for plating an impeller hub, having deep spline grooves on the interior surface thereof; and

Fig. 7 is an enlarged, transverse cross section view

taken along the lines 7—7 of Fig. 6 looking in the direction of the arrows.

Fig. 8 is an enlarged partially sectional view of an adjustable support and bearing for the insulating tube 47 where it is mounted in the lower member of the frame shown in Fig. 1, together with the swivel shown between the tube and adjacent elbow.

In one particular embodiment illustrated and described herein there is shown a rifle barrel as being the small diameter bore tube that is to be plated on the inside surface thereof. It will be appreciated that this does not limit the invention to the plating of rifle barrels only, but rather it is applicable to many other tubes and passages, or apertures, which are to be plated on the inside surface thereof. Thus it will be appreciated that whereas in the illustrated apparatus, the shroud that surrounds the anode and makes contact with the inside surface of the rifle barrel, has fingerlike extensions covering the lands of the rifle barrel; if the tube to be plated is some other type of metallic tube the configuration of the shroud might take other shapes. The shape of such shroud acts to regulate the distribution of current flow density over the surface by regulating the length of path for the plating current.

Referring to Fig. 1, it will be noted that there is a supporting framework for certain of the elements of the system which framework has a top frame member 11 and a bottom frame member, or base, 12. This framework 13 supports a guide rod 14 in addition to a threaded shaft 15. Shaft 15 is rotatably supported in bearings 16 and 17 at the top and bottom thereof, respectively. Shaft 15 is arranged for rotation in any feasible manner, such as by means of a pulley 18 attached to a lower extremity 21 of the shaft 15. In order to provide for positive rotation of the shaft 15 with the pulley 18, a no-slip coupling may be employed, e. g. a set screw 19 and in addition a key (not shown) may be used if desired. The pulley 18 may be driven by a belt 20 which will extend to another pulley (not shown) that may be attached to an electric motor (not shown) or the like, as a source of power.

Within the outer framework 13 of the apparatus, there is a plating apparatus supporting frame 23, that is slideably guided and positioned by the guide rod 14 which passes through holes 24 and 25 in horizontally extending members 26 and 27, respectively, of the frame 23. On the other side of inner framework 23 from the guide rod 14 there is a pair of holes or passageways 28 and 29 which slideably fit over the threaded shaft 15 and act as guides to prevent lateral movement of the inner framework 23. For determining the vertical positioning of the frame 23 there is an internally threaded split or half-nut element 32 which is arranged in any feasible manner (such as by cam action [not shown] or the like) to be moved horizontally into and out of engagement with the threads of the shaft 15. There is shown a handle 33 for thus moving the half nut elements 32 for engagement or disengagement with the threads of the shaft 15. The frame 23 also includes a vertical panel or integral connecting member 36, which extends between the lower portion of the frame 23 and the upper member 26 thereof, so as to create an integral framework which moves vertically as a unit.

There is illustrated a rifle barrel 41 which is supported in a vertical position and has surrounding the same a jacket 42 which contains constant-temperature-control heating elements 43 and 44 therein. Rifle barrel 41 extends below the jacket 42 as indicated by reference number 45. This end of the barrel is surrounded by a metallic cap 46 that is in intimate contact with the barrel, so as to create a good electrical connection therewith. Centrally located at the bottom of the cap 46 there is a hole 48 large enough to allow free sliding movement therethrough of an insulating material tube 47, which extends through the cap 46 and upward inside the barrel 41 to become integrally joined with a shroud 50 of insulating material that is in intimate contact with the inside surface of the rifle barrel 41, as will be more fully described below.

At the top of the jacket 42 the barrel 41 extends somewhat beyond the top surface of the jacket and has attached to the projecting tip of the barrel 41, a ferrule 51 which is metallic and is securely attached to the top of the barrel for making good electrical contact therewith. The inside diameter of a central hole or passage 52 in the ferrule 51, is of the same diameter as the bore of the barrel 41 so that the passage 52 acts as an extension of the inside surface of the barrel. Mounted on top of the ferrule 51 there is a cup-like flanged holder 53 for catching excessive electrolyte. This holder 53 is attached to the top of the ferrule 51 and acts to gather any excessive electrolyte which leaks past an upper shroud 54 located within the bore of the gun barrel 41, above shroud 50. The upper shroud 54 has integrally attached thereto a tube 55 similar to the lower tube 47. Tube 55 passes through, and is supported at, the upper member 26 of inner frame 23 in any feasible manner such as by means of collars 56 illustrated. There is another tube 57 that is attached to the lower portion of the holder 53 and acts to allow the excess electrolyte which has gathered in the cup within holder 53 to flow back to the reservoir.

A path for circulating electrolyte is had from a tank or reservoir 61 containing the electrolyte. Electrolyte is tapped off from the bottom of the tank by means of an outlet tube 62 that leads to a pump 63. The electrolyte is a fluid 66 which flows out from the tank 61 via the tube 62 and is circulated by means of the pump 63 so that it flows through a flexible tube 67 to an elbow 68 which has attached thereto a swivel joint 69 for allowing relative rotation between the tube 47 and the elbow 68. It will be noted that tube 67 is shown broken off to indicate that this tube has sufficient length in the flexible portion, to accommodate vertical movement of the elbow 68 and lower member 27 of the frame 23, for the required distance.

The electrolyte continues to flow from the flexible tube 67 via elbow 68 and swivel joint 69 to the tube 47 and up inside the barrel 41 to an exposed area 72 of the inside surface or bore of the barrel, that lies just above the shroud 50. Then after contact is had between the electrolyte and the exposed area on the inside of barrel 41, the flow continues through the hollow internal opening of upper shroud 54 and through the connected tube 55 to a flexible tube 73 through which it returns to tank 61. At the same time the excess electrolyte which is drained off from the cup holder 53 flows through the tube 57 to another flexible tube 74 through which it also returns to the tank 61.

The electrolyte in tank 61 may be maintained at a desired temperature by means of an electric heating element 77 supplied by a pair of wires 78.

The main electroplating electrical circuit includes a cable 81 that is connected to the ferrule 51 and also to the lower cap 46. The source of electroplating current will be supplied to the cable 81 in any convenient manner such as by a D. C. generator (not shown) or the like, which will be electrically connected to a cathode lead 82 that has the caption "cathode" thereon. The anode plating circuit includes a main anode lead comprising a flexible cable 83 that passes through the walls of tube 47 in any feasible manner and then is carried up inside tube 47 by means of a wire or conductor 84 illustrated by a dotted line in Fig. 1. This wire 84 carries the electroplating current up to the anode which lies surrounded by the shroud 50 and which will be described in greater detail in connection with Fig. 2.

Referring to Fig. 2 it will be observed that the rifle barrel 41 is shown near the upper or muzzle end thereof with the ferrule 51 in place over the end of the bar-

rel. It will be observed that the upper shroud **54** is spaced a distance **88** from the top edge of the lower shroud **50**. This distance **88** may be adjusted to any desired size, but when the apparatus is in operation it remains constant.

A convenient means of making this adjustment is illustrated in Fig. 8, in which a bearing member **93** for the lower end of the tube **47** has a threaded bolt section **93***a* which cooperates with a tapped hole **94** in the member **27** of the frame **36**. The bearing member also has a hub provided with holes to engage a spanner wrench or its otherwise adapted to be screwed in and out for the purpose of adjusting the distance **88** between the ends of the upper and lower shrouds. The tube **47** is provided with a collar **47***a* which fits into the bearing member so that it moves up or down as the bearing nut is adjusted.

The lower shroud **50** fits snuggly within the bore of barrel **41** and has grooves **89** which match the lands of the gun barrel **41**. In this manner the shourd **50** acts to keep electrolyte from making contact with the surface of the bore of barrel **41**. Consequently, the plating action only takes place to any appreciable extent on the exposed area that includes the space as determined by distance **88** in addition to the added areas made up of the exposed surface of the barrel **41** on the grooves thereof. This additional area is indicated by the distance **90** that is the amount of longitudinal extension distance of a plurality of projections, or castellations **91**, of the shroud **50**, which cover each of the lands on the inside surface of the gun barrel **41**. The purpose of these extending castellations **91** is to add additional distance for the path of travel of the electroplating current, from the anode to the gun barrel **41**. It will be observed that the anode is made up of a hollow metallic cylinder **95** that is constructed of any desired anode material, and that is snugly fitted within the shroud **50** concentrically therewith.

The cylinder **95** is shorter than the shroud and leaves a space indicated by distance **92** in Fig. 2, which forces the electrical current to flow through an indirect or diagonal path which is of importance for plating small bore rifles or the like.

Electrical connection for the plating current circuit is carried from the anode sleeve **95** to the wire **84** in any convenient manner, so long as it leaves a free passage for the electrolyte **66** to flow from the tube **47** into the hollow space within the anode cylinder **95**. For example, the wire **84** may be welded to the edge of the anode cylinder **95** as illustrated in Fig. 2.

It is pointed out that the tube **47** is connected by a fluid tight joint to the shroud **50**. This structure may take any convenient from such as by having shroud **50** integrally moulded as one piece with the tube **47**.

The upper shroud **54** is constructed of a size that fits slideably within the minimum diameter of the bore of gun barrel **41**, i. e. it is in contact only with the surface of the lands within the barrel. For this reason electrolyte tends to seep up around the upper shroud **54** to a considerable extent; but this is of no consequence since all such electrolyte is gathered in the cup of the holder **53** and then flows back to the tank **61**, in the manner clearly indicated above. It is pointed out that in Fig. 2 the ferrule **51** is broken off below the holder **53**, for convenience and clarity of the showing. It is to be noted also that the shroud **50** will be rotated about its longitudinal axis as the shrouds and anodes are moved vertically up and down within the barrel. This is true because of the fitted structure of the lower shroud **50** whereby it has its matching grooves **89** that fit over the lands of the inner surface of gun barrel **41**.

Operation

The operation of the Fig. 1 embodiment of the invention will be described using both of the Figures 1 and 2 of the drawings.

A plating operation may be commenced at either end of the gun barrel **41**. In order to do this, inner frame **23** will be slideably positioned up or down as necessary to bring the exposed area **72** within the barrel **41** at one end thereof. This may be rapidly accomplished by opening the two halfs of split nut element **32** by means of turning the handle **33**. Then, when the frame **23** has been slid to the desired position so that exposed area **72** (which includes the area covered by space of the distance **88** plus additional areas of the gun barrel grooves included in the distance **90**) is located at one end of the gun barrel **41**; the handle **33** may be turned back to return the split nut element **32** into engagement with the threads of shaft **15**, and the plating operation is ready to be commenced. Next the pump **63** will be energized to cause circulation of the electrolyte **66** up through the tube **47** and into contact with the exposed surface of the anode cylinder **95**, and then continuing on up into contact with the exposed area **72** of the barrel **41**. The electrolyte **66** also continues via the hollow space within upper shroud **54** to the tube **55** and on via the tube **73**, back to the tank **61** to complete a circuit. Next, the plating current will be supplied via the anode wire **83** and the cathode connector or lead **82**. Thus electric current will flow in order to cause electroplating at the exposed area **72** of the barrel **41** which is acting as the cathode.

The length of time to which the exposed area **72** is subjected to plating current may be directly controlled by the speed of rotation of threaded shaft **15** which is under control of the source of power for driving the belt **20**, that turns the pulley **18**, which is fastened to the shaft **15**. It is pointed out that the plating operation will be carried out by causing frame **23** to be thus vertically moved or slid to the desired extent, so as to cause shrouds **54** and **50** along with the anode cylinder **95** and the connecting tubes **55** (connected to upper shroud **54**) and **47** (connected to lower shroud **50**) to move together simultaneously up or down within the barrel **41**. In this manner the exposed area **72** on the inside surface of the barrel **41** progressively shifts vertically along the bore of the gun barrel **41**. Thus the internal surface of the gun barrel may be plated with careful control of the amount of plating action that is given to the inside surface, by means of progressively exposing this surface to the plating action created by the flow of electric current from the anode sleeve **95** through the electrolyte **66** and to the gun barrel **41**, which acts as the cathode in the plating circuit.

It will be clear that the plating action may be carefully controlled in any desired manner by regulating the speed of movement of the shrouds and anode up and down the barrel **41** so that the extent of plating at any given time for a particular portion of the bore of the barrel **41** may be regulated to any desired degree of fineness. It is contemplated that it may be advantageous in plating the internal surface of gun barrels to carry out various steps of plating such as alternate high-current heavy plating action for short periods of time, and reverse current deplating steps (in alternation therewith) to create a strong bond between the plating surface material and the metal of the gun barrel **41**. Also, the speed of traversing the inside surface of the barrel **41** may be varied as desired, during any given pass up or down the barrel. In this regard it is pointed out that there may be set up an automatic electrical control for reversing the directions of movement of the inner frame **23** as it reaches the end points of its travel. Such a control could readily be had by mounting switches or switch actuating elements (not shown) on the frame **23** at appropirate locations for causing a reversal of the drive that is driving belt **20** for turning the shaft **15**.

Referring particularly to Fig. 2 and in connection with the operation, it is pointed out that the action of lower shroud **50** is such as to create a predetermined length of

path for the flow of plating current as it traverses the electrolyte in flowing from the upper edges of the anode cylinder **95** to the nearest portions of the exposed surface of barrel **41**. In this regard it is further pointed out that the length of the path for the current flow will be greater for the grooves of the barrel **41**, than for the lands thereof. This is true since the exposed surface of the grooves is closer to the anode cylinder **95** than the exposed surface of the lands. This condition is effected by reason of the castellations **91** at the upper edge of the shroud **50**, which cover the lands of the gun barrel 41 beyond the edge of shroud **50** which is between and joins the castellations **91**.

The purpose for this configuration of the shroud **50** is to compensate for the uneven current density which ordinarily would occur on the inside surface of a rifled gun barrel, by reason of the sharp edges of the lands of which the rifling of the barrel is composed. These sharp edges tend to cause the electroplating current to concentrate therealong, and thus there is a tendency for overplating at these sharp edges, while the inverse situation applies to the corners where the sides of the lands meet the grooves of the gun barrel. Consequently, by reason of the castellations **91**, the path of travel of the plating current is made greater at the sharp edges of the lands and thus the current density is reduced in compensation of the normal increase. Thus, the current density for the plating action may be caused to become nearly the same all the way around the entire inner peripheral surface of the barrel **41** that is being plated. In this manner the plating accomplished is entirely even and exactly controlled, and no under-plating occurs.

It will be noted that one advantage of the structure employed in thus plating the interior surface of small bore tubes, is the fact that as plating occurs at the exposed area of the tube being plated, the bubbles which are created by the electroplating current and chemical action caused thereby, may rise vertically and be carried rapidly away from the surface being plated along with the circulating stream of electrolyte. Furthermore, the bubbles thus being formed and rising are limited to the relatively short exposed area of the tube being plated, and thus no undue concentration of bubbles is had which would otherwise be true if the entire length of the tube were being plated at one time.

It is pointed out that the apparatus according to this invention and as so far described, would lend itself readily to plating the internal surface of relatively long tubes whether straight or curved, since the anode is relatively short, and the tube for carrying electrolyte into contact with the anode may be flexible.

Additional embodiments

Figures 3, 4 and 5 illustrate another embodiment of the invention, in which the object that is being electro-plated is a rectangular tube, such as an electronic wave guide. In this instance, it is contemplated that a relatively long section of a wave guide tube may be plated on the interior surface thereof while being maintained in a horizontal position during the plating operation. In order to carry out a successful plating operation in this manner, the electrolyte must be circulated through the interior of the wave guide at high velocity, so as to carry away the gas bubbles as formed so that an even contact with the surface of the wave guide may be had which avoids any accumulation of the gas bubbles. None of the apparatus or elements employed for circulating electrolyte through the wave guide are illustrated, since all such elements would be similar to those shown in Fig. 2.

A portion **98**, of a rectangular cross section wave guide is illustrated. Located on the inside thereof in a close fitting manner, there are two inert material supports or bearings **99** and **100**, which act to hold shafts **103** and **104**, respectively, in a central or axial position within the wave guide **98**. These supports **99** and **100** may be made of carbon although other suitable materials might be employed. There are a plurality of passages or holes **105** and **106** through the bearing supports **99** and **100**, respectively. These holes are to allow a free circulation of the electroplating solution, i. e. the electrolyte. The central supporting, or bearing portion, of the bearings **99** and **100** are made of a size which allows the shafts **103** and **104** (supported thereby) to freely slide longitudinally therethrough.

The shaft **104** is made of an insulating material, or it may be a conducting material that is coated with an insulating layer over the entire exposed surface thereof in order not to react with the electrolyte during the plating operation. The shaft **103** is a conducting material rod, or wire, that is coated on the exposed exterior surface thereof with an insulating layer. At the right hand extremity of shaft **103** (as viewed in Fig. 3) there is an anode **109** that is rectangular in its cross sectional shape, corresponding to the rectangular cross section of the inside surface of the wave guide **98**. The anode **109** is composed of a given metal that is being employed in plating the interior surface of the wave guide **98**. At the tip, or left hand extremity of the other shaft **104** (as viewed in Fig. 3) there is securely fastened (for movement with the shaft) a cathode shroud or shield **110**. This cathode shield or shroud **110** is constructed of an insulating material or other so as to be inert with respect to the electrolytic action of the plating operation. It (shield **110**) takes the form of a rectangular plate or shield that is perforated with a plurality of holes **111** to allow the free passage of electrolyte to circulate therethrough. The size of this cathode shroud **110** is somewhat smaller than the interior cross section configuration of the wave guide **98**, so that the shroud **110** has clearance on all sides from the interior surface of the wave guide **98**.

Additional structure at the anode end of the plating apparatus includes an anode shroud **115** which is constructed of an insulating material, or something that is inert in so far as the electrolytic action is concerned. This anode shroud **115** takes the form of a rectangular tube which surrounds the anode **109**. It has scalloped, or rounded edges **116** at the anode end of the shroud **115** in order to control the length of current paths from the anode **109** to the exposed plating area of the inside surface of the wave guide **98**. In this manner the tendency for uneven plating current densities which would be set up by reason of the inside corners of the wave guide **98**, may be overcome by compensating for such tendency, so that the plating current densities will be substantially equal even into the square corners.

The anode shroud **115** is attached to the shaft **103** by any convenient structure which will allow passage of the electrolyte therethrough. The illustrated structure employed includes an inner sleeve portion **117** which is tightly fitted around the shaft **103**. The shroud **115** is supported from this sleeve **117** by a pair of supporting panels **118** and **119** at either end of the sleeve **117**. The panels **118** and **119** are integrally molded or otherwise attached to the anode shroud **115**. As indicated, there are a plurality of holes or passages **122** through both of the panels **118** and **119** both above and below the shaft **103**, in order to allow the free passage of electrolyte inside the shroud **115** and in contact with the anode **109**.

Operation of Fig. 3 embodiment

Basically the plating operation is carried out the same way as that described above in connection with the Fig. 1 embodiment. However, in this instance the work piece being plated, i. e. wave guide **98** is held in a horizontal position, while the electrolyte (indicated by reference number **123** on Fig. 4) is circulated therethrough at a relatively high velocity; as was indicated above. It may be found desirable to cause the solution to be swirled in a spiral or other type of twisting current action as it passes through the interior of the wave guide **98**. If such swirl-

ing is to be employed, it may be caused in any feasible manner e. g. by directing the passages or holes **105** and **106** (as well as holes **111**) in an oblique manner so as to cause the desired swirling action.

It will be noted that the electrolyte is passed through the wave guide **98** in contact with the entire inner surface of the wave guide. This manner of operation does not alter the effect of the anode and cathode shrouds during the plating operation, because current densities of the electroplating current are maintained at such levels by reason of the shrouds that any leakage plating current back through the solution to the areas cut off by the shrouds will cause merely a polarization without any deposit due to plating action.

The plating action is controlled as desired with regard to length of time, direction and amplitude of current flow, while the anode **109** with its shroud **115** is moved longitudinally within the wave guide **98** so as to progressively expose different sections of the inside surface of the wave guide **98** that is to be plated. At the same time the cathode shroud **110** is longitudinally traversed, simultaneously with anode **109** and its shroud **115**, so as to maintain the exposed area of the wave guide **98** at a constant value. In order to be sure that the plating is even around the periphery of the surface, the wave guide **98** will be rotated about its longitudinal axis.

Plating current will be applied from any adequate source of direct current (not shown), and will be connected electrically to shaft **103** for the anode connection of the circuit, while being connected electrically to the wave guide **98** itself, which acts as the cathode in the plating circuit. The length of the section of the wave guide that is being plated during a given plating operation will depend upon the structure of the surrounding apparatus (not shown), but it is contemplated that a relatively long section may be so plated as indicated by the broken line showing near the right end of the Fig. 3 illustration.

Figs. 6 and 7 illustrate yet another embodiment of the invention, wherein the object that is to be plated on the interior surface of an aperture therein, is an impeller hub **125**. The impeller hub **125** is generally like a short cylinder in configuration and has a shaft hole at the center thereof. This hole includes a deep fluted, sharp cornered grooved surface for fitting on a splined shaft in use. Thus there are a plurality of grooves **126** which pass through the hub **125** parallel to the axis thereof.

In order to provide for the plating of this interior grooved surface within the hub **125**, there are provided a pair of metal ferrules **127** and **128** which are mounted to provide a continuation of the grooves **126** and the hole through the hub **125**, above and below the surfaces of the hub.

In order to carry out the plating operation there is a traversing rod or shaft **131** which is an electrically conductive material that is coated with an insulation on the outside exposed surface thereof. This shaft **131** supports an insulating material cathode shield **132** which is generally shaped like an inverted cup and has the closed end thereof formed by a panel **133** which has a hole therethrough at the center for admitting the shaft **131** in a tight fitting manner. The shaft **131** may be also cemented or otherwise securely attached to the panel **133** of cathode shield **132**, so that no relative motion will take place therebetween. There are a plurality of holes or passages **134** through the panel **133** in order to allow free passage of the electrolyte. The outer surface of the shield **132** is constructed with splines **137** which match the grooves **126** in the surface of the hub **125**, and the extensions of these grooves that are located in the ferrules **127** and **128**.

At the extremity, or lower end (as viewed in Fig. 6), of the shaft **131** there is attached a similar cup shaped shield or shroud **140** which surrounds a hollow cylindrical anode **141**. The shaft **131** is securely attached to the anode shroud **140** in any convenient manner, e. g. by having a threaded tip **142** on the end of the shaft **131** which is received by an internally threaded hole at the center of a panel **143** that forms the bottom of the anode shroud **140**. Similarly as with the cathode shroud **132**, there are a plurality of passages or holes **144** through the panel **143** of the anode shroud **140**, and on the outside surface of shroud **140** there are splines **145** which match the grooves **126** in the hub **125** and ferrules **127** and **128**.

In order to make a low resistance electrical path for the flow of plating current from the shaft **131** to the anode cylinder **141**, there is a pair of radial wires or shafts **148**. These wires **148** are insulated on the exterior surface thereof, like the shaft **131**, so that the anode **141** is all that is exposed to the electrolytic action in the course of a plating operation.

Anode shroud **140** has a plurality of castellations **149** that extend upward from the edge of the shroud **140** (as viewed in Fig. 6) and overlie the high surface ribs between grooves **126** of the hole in hub **125**. These provide an increase in the oblique path for the plating current in flowing between the anode cylinder **141** and the surface on the inside of the hole in hub **125**, which surface is being plated.

Operation of Fig. 6 embodiment

As with the previous embodiments of this invention, the basic plating operation remains the same. In this instance, it is contemplated that the plating operation may be carried out by inserting the entire impeller hub **125** and its attached ferrules **127** and **128**, in a plating bath of the electrolyte. Then by retaining the hub **125** in an upright position (as illustrated in Fig. 6) a free circulation of the solution may be had, up through the passages **144** and out of the top passages **134** to complete a circulation path. The plating current will be set up to flow via shaft **131** and connecting wires or shafts **148**, to the anode **141**. Then the current will flow from the anode sleeve **141** through the electrolyte and to the exposed area of the grooved interior surface of impeller hub **125**. The impeller hub being connected to the other side of the plating-current power source so as to act as the cathode.

In order to plate evenly the entire surface of the grooved hole through the impeller hub **125**, anode **141** and its shroud **140** along with the cathode shield **142**, will all be moved simultaneously up or down so as to progressively expose the full depth of the grooved hole through impeller hub **125**. In other words, there will be relative movement with respect to two groups of elements, one being the aforementioned structure attached to shaft **131**, and the other being the impeller hub **125** along with its attached ferrules **127** and **128**.

It will be noted that in the operation of this embodiment the gas bubbles formed during the plating process are free to rise directly upward and pass out through the electrolyte bath via passages **134** in cathode shield **132**. Thus, no harmful accumulation of bubbles takes place at the surface being plated so that a troublesome problem is overcome.

While certain embodiments of the invention showing the best modes contemplated for carrying out the invention have been described in considerable detail in accordance with the applicable statutes, this is not to be taken as in any way limiting the invention but merely as being descriptive thereof.

It is claimed:

1. In a system for electroplating the interior surface of a small cross section area tube of conductive material, the improvement comprising in combination, an anode located inside said tube, means for supporting said tube in an upstanding position, means for circulating an electrolyte through the inside of said tube, tubular insulating means contacting the surface to be plated for limiting the exposed area of said interior surface and extending beyond the anode to determine the length of electric cur-

rent paths from said anode to the exposed area of said interior surface, means for moving said tubular insulating means and said anode relative to said tube to expose the entire inside surface to be plated progressively, and means for connecting a supply of electric current to said anode and to said tube to plate the inside surface of the tube at said exposed area.

2. In a system for electroplating the interior surface of a small cross section area tube of conductive material, the improvement comprising in combination, an anode located inside said tube and shaped to permit the passage of an electrolyte through the tube, means for supporting said tube in an upstanding position, means for circulating an electrolyte through the inside of said tube, an insulating shroud around said anode extending axially beyond the end of the anode and contacting the surface to be plated for limiting the exposed area of said interior surface and for determining the length of electric current paths from said anode to the exposed area, said electrolyte circulating means including conduit means connected to said insulating shroud for carrying the electrolyte into contact with said anode and to said exposed area to be plated, means for supplying electric current to said anode and to said tube for causing the inside surface of the tube to be plated at said exposed area.

3. In a system for electroplating the interior surface of a small cross section area passage through conductive material, the improvement comprising in combination, an anode located inside said passage and shaped to permit the flow of electrolyte through said passage, means for maintaining said passage in an upstanding position, means for circulating the electrolyte through the inside of said passage, a hollow insulating shroud contacting the surface to be plated for limiting the exposed area of said interior surface and extending axially beyond the anode to determine the length of current paths from said anode to the exposed area, means for moving said insulating means and said anode relative to said conductive material to expose the entire inside surface to be plated, and means for supplying electric current to said anode and to said conductive material for causing the surface of the passage to be coated at said exposed area.

4. In a system for electroplating the interior surface of a small cross section area tube of conductive material, the improvement comprising in combination, an anode located inside said tube, means for supporting said tube in an upstanding position, means for circulating an electrolyte through the inside of said tube, an insulating shroud around said anode extending beyond its end and contacting the surface to be plated for limiting the exposed area of said interior surface and for determining the length of electric current paths from the exposed end of said anode to the exposed area of the interior surface, means for moving said insulating shroud and said anode together relatively to said tube to progressively expose the entire surface to be plated, said electrolyte circulating means including conduit means connected to said insulating shroud for carrying the electrolyte into contact with said anode and to said exposed area to be plated, means for supplying electric current to said anode and to said tube for causing the inside surface of the tube to be plated at said exposed area.

5. In a system for electroplating the interior surface of a small cross section area tube of conductive material, the improvement comprising in combination, a hollow cylindrical anode located inside said tube, means for supporting the tube in an upstanding position, means for circulating an electrolyte through the inside of said tube and of said hollow cylindrical anode, an insulating shroud around said anode and contacting the surface to be plated for limiting the exposed area of said interior surface and for determining the length of current paths from said anode to the exposed area, insulating means spaced from said anode insulating shroud for exposing a predetermined longitudinal amount of the interior surface of said tube, means for moving both said insulating means simultaneously with said anode relatively to said tube to progressively expose said predetermined interior surface area to be plated, said electrolyte circulating means including conduit means connected to said insulating shroud for carrying the electrolyte into contact with said anode and to said exposed area to be plated, and means for supplying electric current to said anode and to said tube for causing the inside surface of the tube to be plated at said exposed area.

6. A system for electroplating the interior surface of a small cross section area rifled gun barrel comprising in combination, a hollow cylindrical anode located inside said barrel, means for supporting said barrel in an upstanding position, means for circulating an electrolyte through the inside of said barrel and of said hollow cylindrical anode, an insulating shroud around said anode and contacting the surface to be plated for limiting the exposed area of said interior surface and for determining the length of current paths from said anode to the exposed area, insulating means spaced from said insulating shroud for exposing a predetermined longitudinal amount of the interior surface of said barrel, means for moving both said insulating shroud and said insulating means simultaneously with said anode relatively to said barrel to progressively expose said predetermined interior surface area to be plated, said electrolyte circulating means including conduit means connected to said insulating shroud for carrying the electrolyte into contact with said anode and to said exposed area to be plated, and means for supplying electric current to said anode and to said barrel for causing the inside surface of the barrel to be plated at said exposed area.

7. A system for electroplating the interior surface of a small cross section area rifled gun barrel comprising in combination, a hollow cylindrical anode located inside said barrel, means for supporting said barrel in an upstanding position, means including a flexible conduit for circulating an electrolyte through the inside of said barrel and into contact with said anode and with said barrel, insulating means surrounding said anode and contacting the surface to be plated for limiting the exposed area of said interior surface and for determining the length of current paths from said anode to the exposed area, said anode insulating means including castellations extending over the lands of said rifled barrel, additional insulating means spaced from said anode insulating means for exposing a predetermined longitudinal amount of the interior surface of said barrel, means for moving both said insulating means simultaneously with said anode relatively to said barrel to progressively expose said predetermined interior surface area to be plated, said electrolyte circulating means including connections between said flexible conduit and each of said anode insulating means and said additional insulating means for carrying said electrolyte to and from said exposed longitudinal amount of the interior surface of the barrel without operative contact with the non-exposed interior surface of the barrel, and means for supplying electric current to said anode and to said barrel for causing said electrolyte to plate the inside surface of the barrel at said exposed area.

8. A method of electroplating the interior surface of an aperture in a conductive material object comprising the steps of locating an anode adjacent the center of the cross sectional area of the aperture, directing plating current obliquely toward said object from said anode to increase the minimum current path through the electrolyte, traversing said anode longitudinally within said aperture to cause even plating over the entire inside surface of the aperture.

9. A method of electroplating the interior surface of an aperture in a conductive material object comprising

the steps of locating an anode adjacent the center of the cross sectional area of the aperture, directing plating current obliquely toward said object from said anode, shielding said interior surface at an area displaced longitudinally from said anode, traversing said anode and said interior surface shield together to maintain a given effective area of surface to be plated while progressively plating the entire interior surface to be plated.

10. A method of electroplating the interior surface of an aperture in a conductive material object comprising the steps of locating an anode adjacent the center of the cross sectional area of the aperture, directing plating current obliquely toward said object from said anode, varying the length of path of the plating current at predetermined places spaced circumferentially around said anode in accordance with a desired relative magnitude of plating of said interior surface, shielding said interior surface at an area displaced longitudinally from said anode, traversing said anode and said interior surface shield together to maintain a given effective area of surface to be plated while progressively plating the entire interior surface to be plated.

11. Means for electroplating the interior surface of a small bore rifled gun barrel comprising means for supporting the gun barrel in an upright position, a direct current electrical circuit connection to the gun barrel, whereby it constitutes the cathode of the electroplating circuit, a pair of axially spaced hollow cylindrical insulating shrouds mounted within the gun barrel, an anode closely fitted into one of said shrouds but shaped to permit electrolyte to flow through, a flexible electrical connection to the anode and means for supporting the shrouds and moving them axially of the gun barrel, said shroud which contains the anode being of greater length and extending beyond the anode, whereby the electroplating current is forced to flow diagonally from one end of the anode to the exposed surface of the gun barrel.

12. Means for electroplating the interior surface of a small bore rifled gun barrel comprising means for supporting the gun barrel in an upright position, a direct current electrical circuit connection to the gun barrel at the respective ends, whereby it constitutes the cathode of the electroplating circuit, a pair of spaced hollow cylindrical insulating shrouds mounted within the gun barrel, one of said shrouds being fitted into and adapted to rotate in response to the gun rifling, an anode, so shaped as to permit electrolyte to flow through it, closely fitted into said rotating shroud, a flexible electrical connection to the anode and means for supporting the shrouds and moving them axially of the gun barrel, said shroud which contains the anode being of greater length and extending beyond the anode, whereby the electroplating current is forced to flow diagonally from one end of the anode to the exposed surface of the gun barrel.

13. Means for electroplating the interior surface of a small bore rifled gun barrel comprising means for supporting the gun barrel in an upright position, a direct current electrical circuit connection to the gun barrel, whereby it constitutes the cathode of the electroplating circuit, a pair of spaced hollow cylindrical insulating shrouds mounted within the gun barrel, a hollow cylindrical anode closely fitted into one of said shrouds but extending less than the entire length of the shroud, an electrical connection to the anode whereby the electroplating current flows diagonally outward from the end of the anode through the end of the shroud to the portion of the gun barrel exposed between the two shrouds, means for simultaneously moving the shrouds axially of the gun barrel and means for circulating an electrolyte through the gun barrel.

14. Means for electroplating the interior surface of a small bore rifled gun barrel comprising means for supporting the gun barrel in an upright position, a direct current electrical circuit connection to the gun barrel, whereby it constitutes the cathode of the electroplating circuit, a hollow cylindrical shroud loosely fitted within the gun barrel at its upper end, a lower cylindrical shroud formed to fit the rifling of the gun barrel, spaced below the upper shroud and adapted to rotate as the shroud is moved axially relative to the gun barrel, a hollow cylindrical anode fixed within the lower shroud, but shorter than the shroud so that it does not reach the upper end of the shroud, an insulating tube within the gun barrel fastened to the bottom of the lower shroud, means for circulating electrolyte through said tube and through the shrouds past the exposed surface of the gun barrel between the shrouds and means for simultaneously moving the shrouds axially of the gun barrel to expose the interior to the electrolytic action, the upper end of the lower shroud being provided with castellations which extend over the lands of the gun rifling, whereby the current from the anode has a longer path through the electrolyte to the lands than to the other exposed surfaces of the gun barrel.

References Cited in the file of this patent

UNITED STATES PATENTS

1,793,069	Dunkley	Feb. 17, 1931
1,904,432	Fink	Apr. 18, 1933
1,953,955	Crouch	Apr. 10, 1934
1,822,240	Schade	Sept. 8, 1937
2,106,004	Inglee	Jan. 18, 1938
2,764,540	Farin et al.	Sept. 25, 1956