

May 11, 1965

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3,183,176

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Filed July 28, 1960

3 Sheets-Sheet 1

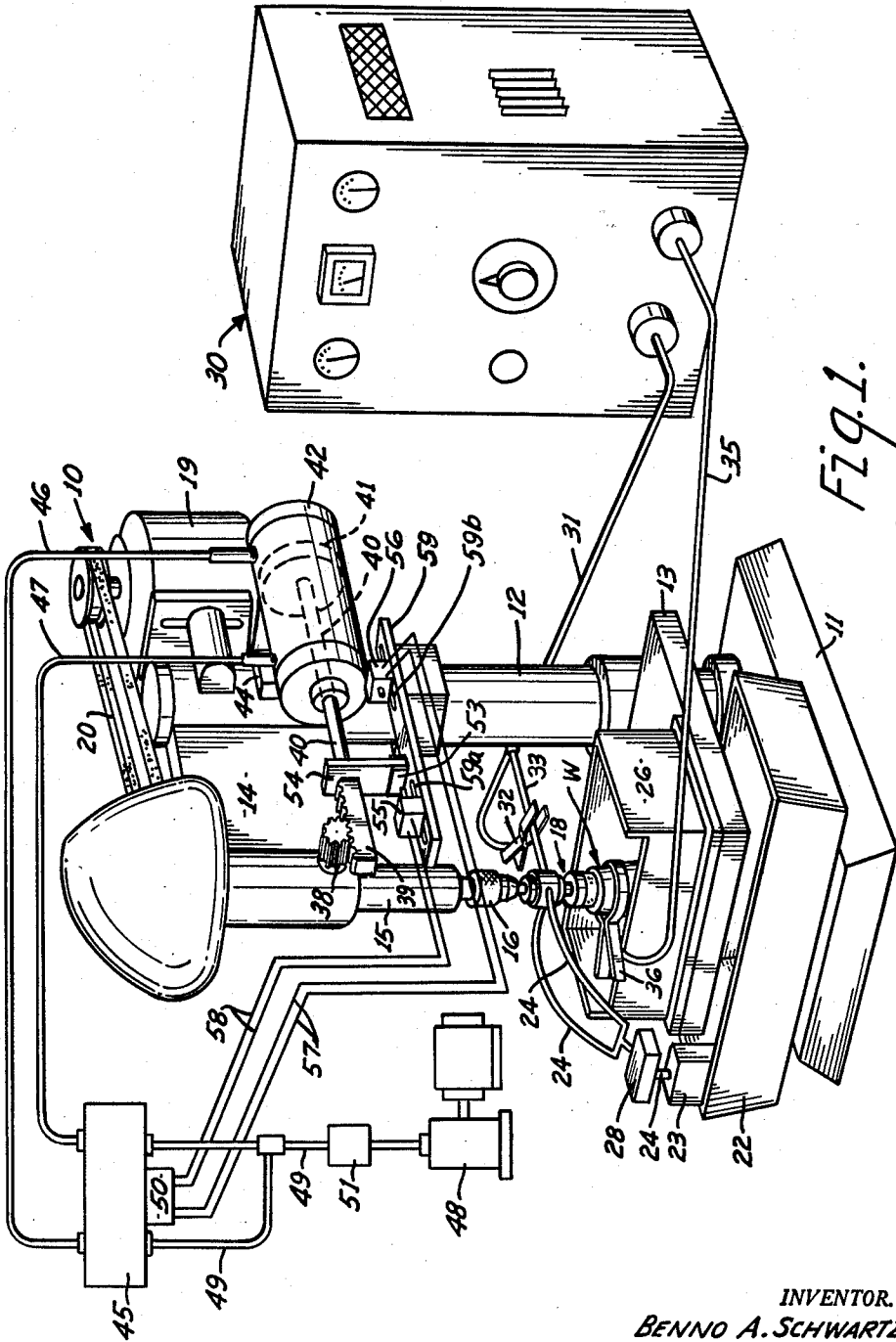


FIG. 1.

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3 Sheets-Sheet 2

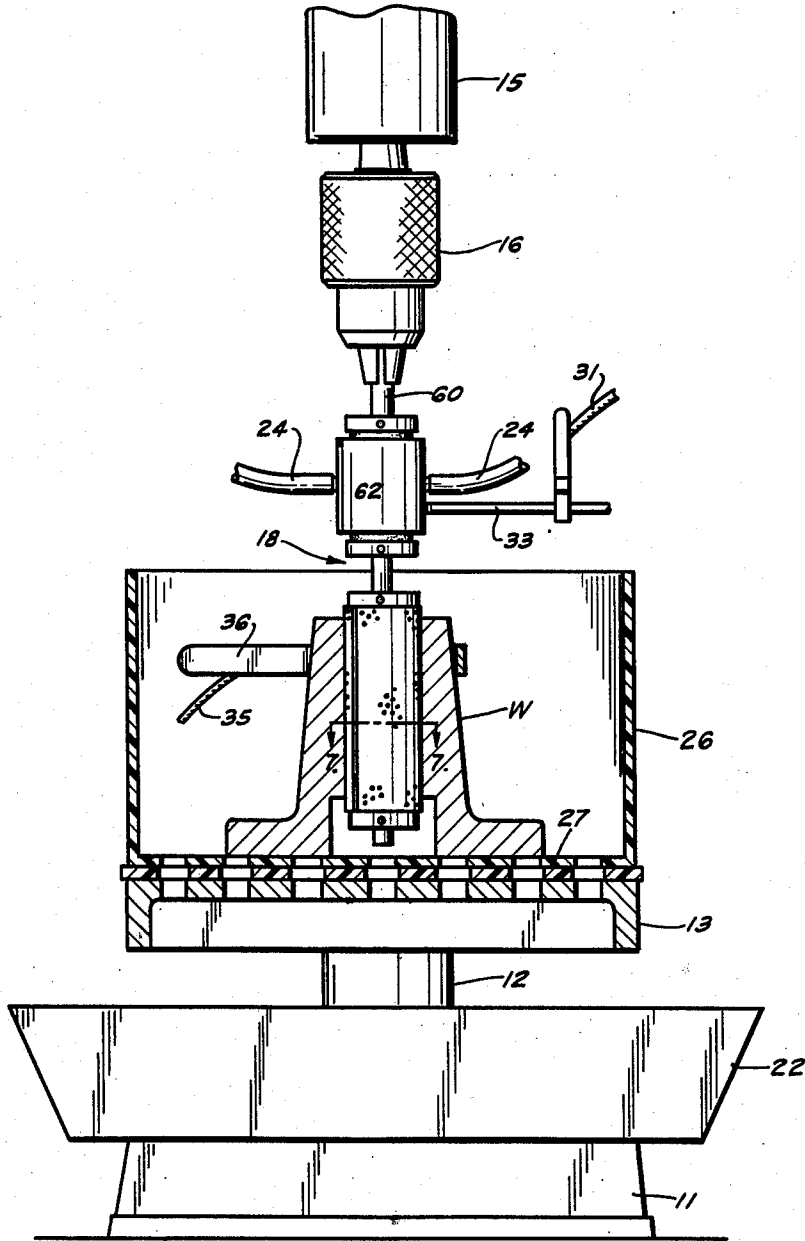


Fig. 2.

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APPARATUS FOR ELECTROLYTICALLY TREATING THE INTERIOR OF A BORE

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5 Claims. (Cl. 204-212)

This invention relates to a method and apparatus, and products thereof, for electrocleaning and electroplating, and more particularly to a method and apparatus for automatically carrying out electrolytic cleaning and electroplating operations of the type in which the surface to be plated is subjected to a rubbing or brushing action as the electrolytic action takes place, and to the products of the method and apparatus.

Electrolytic cleaning and plating operations in which an electrode having a porous surface that is saturated with electrolyte is rubbed over the surface to be cleaned or plated, are well known and are widely and successfully used. Difficulties have arisen with such methods in which hand tools are employed, however, because of non-uniformity of results, the cost of the labor that is involved and the impracticability of plating within cylindrical openings or passageways.

A general object of the present invention, therefore, is the provision of a method and apparatus whereby electrolytic cleaning and electroplating operations can be carried out by machine efficiently and at low cost. Another object is the provision of a method and apparatus particularly adapted to electrocleaning and electroplating the interior surface of cylinders, bores, drilled openings and the like. Another object is the provision of an apparatus for subjecting the interior surfaces of bores and the like to simultaneous electrolytic and scrubbing actions. A further object is the provision of such an apparatus which can be manufactured at reasonable cost, which is reliable and efficient in operation and which produces uniform results on the interior surface of the bore. A further object is the provision of a method for electrolytic treatment of internal bores and the like which will assure simultaneous and uniform rubbing of the surface to be treated while the electrolytic operation is carried out.

Another object is the provision of a method of electroplating whereby dense, high quality deposits can be obtained at high rates of deposition. Another object is the provision of a method and apparatus whereby a levelling or smoothing effect is obtained during the plating operation with electrolytes that are not capable of producing this effect with conventional procedures. Another object is the provision of a method of producing high quality electro-deposited coatings of chromium and alloys thereof. Another object is the provision of adherent, dense and unusually smooth electro-deposited metallic coatings. Further objects and advantages of the invention will become apparent from the following description of a preferred form thereof, reference being made to the accompanying drawings in which:

FIGURE 1 is a somewhat diagrammatic, isometric view illustrating an apparatus embodying a preferred form of my invention;

FIGURE 2 is a front elevational view, partly in section and on an enlarged scale, of a portion of the apparatus shown in FIGURE 1;

FIGURE 3 is an elevational view, with parts broken away, of the electrode tool utilized in the apparatus, showing it removed from the apparatus;

FIGURE 4 is a bottom view of the tool, taken as indicated by line 4-4 of FIGURE 1;

FIGURES 5 and 6 are horizontal sections taken along lines 5-5 and 6-6 of FIGURE 3 respectively; and

FIGURE 7 is a horizontal sectional view taken as indicated by line 7-7 of FIGURE 3, but showing the tool in the position it takes when it is inserted in a bore to be treated.

Briefly, according to a preferred form of the invention electrolytic treatment of metal surfaces is carried out by making the part to be treated one electrode of the electrolytic system while the other electrode is constituted by an electrically conductive tool having a porous dielectric surface that is brought into contact with the surface to be treated and supplied with electrolyte while the tool and the surface are moved rapidly relative to each other, preferably in a plurality of directions. In the case of bores or other surfaces of revolution, the movements preferably consist in rotation about the axis of the surface and simultaneous reciprocation in a direction parallel to the axis of the surface. By this means all parts of the surface to be treated receive substantially equal treatment, and thus the surface can be uniformly cleaned and/or electroplated. The rapid rubbing action makes possible production of uniform, high-quality deposits at high rates of deposition in electroplating operations and has an unexpected result in that the plating operation can be carried out so that the deposited coatings are given a bright, burnished or satiny appearance by the plating operation itself and without requiring buffing or polishing. The circulation of the electrolyte insures that fresh electrolyte is always present at the surface. The result is that the operation can be carried out rapidly and economically and produces results of uniformly high quality. The method employed makes possible the rapid production of electro-deposited coatings that are highly adherent to the underlying surface and that are exceptionally hard, dense and smooth.

The apparatus for carrying out the method consists of a hollow, electrically conductive tool having a porous surface for engaging the work and through which the electrolyte is caused to flow, and means for moving the porous surface rapidly with respect to the surface being treated. This means, in the preferred form of the invention disclosed herein, takes the form of a tool mounted in a conventional drill press modified slightly to enable it automatically to carry out the desired functions. The drill press provides a simple, economical and reliable machine for imparting the required motions to the tool. Preferably, the desired rubbing force is obtained by the action of centrifugal force on parts of the tool. Thus, the tool can be made of extremely simple construction as will appear below. All that is necessary, then, to enable the operation to be carried out is an appropriate source of electric power, which may be of conventional construction, and a simple pump and fluid system for circulating the electrolyte through the tool.

Referring to FIGURE 1, the drill press which forms the basis for the apparatus is indicated in general at 10. The press is of conventional construction and typically may comprise a base 11, a pedestal 12 which supports a bed plate 13 and a bracket 14. The bracket carries a spindle 15 which supports a conventional chuck 16. As appears below, the tool or electrode indicated in general at 18, is supported by the chuck. The spindle is rotated at the desired speed by means of a motor 19 which drives the spindle through a belt 20 in a conventional manner.

As will appear in greater detail below, electrolyte is pumped from a sump or storage tank 22 by a small motor-driven pump 23 through conduits 24 to the tool 18. The electrolyte flows outwardly through the porous, dielectric surface of the tool into contact with the inner surface of the bore in the work W and then falls by gravity into the sump 22.

In order to prevent the electrolyte from splattering and to protect the press from corrosion, the work is preferably surrounded by a shield 26 which may be composed of a transparent plastic. A perforated plastic shield 27 (see FIGURE 2) is also interposed between the work and the bed 13 of the drill press. The bed of the press also has openings through it and thus the electrolyte can run out of the work through the plastic shield 27 and the bed into the sump 22. Preferably, the electrolyte is passed through a filter 28 before it is returned to the work.

The electric power supply to the plating electrode and the work is preferably conventional and preferably consists of a conventional D.C. supply 30 that is connected to the tool by conductor 31, clamp 32 and conductor 33, and to the work by conductor 35 and clamp 36. The power supply 30 contains the usual controls and meters, so that the voltage and current density can be controlled to produce the desired results. When the apparatus is used for plating, the tool 18 is made the anode and the work the cathode; when the apparatus is used for electrolytic cleaning, the polarity is ordinarily reversed, the work being made the anode.

In order to impart the preferred reciprocatory motion to the electrode tool 18, the spindle advancing and retracting mechanism of the drill press 10 is employed. In a conventional press such as shown herein this mechanism embodies a rack and pinion or like mechanism which is actuated by a manually operated handle. The modification of the drill press to suit the purposes of the present invention requires that the conventional handle be removed and a pinion 38 substituted therefor. Pinion 38 is engaged by a rack 39 which is connected to a piston rod 40 attached to piston 41 operating in cylinder 42. The cylinder 42 may be supported from pedestal 12 by any convenient bracket 44.

The piston 41 is caused to reciprocate within the cylinder 42 and thus to reciprocate the rack 39 and move the spindle up and down by alternately connecting the opposite ends of the cylinder to a source of fluid, such as air, under pressure and to a discharge port. This may be carried out by means of a conventional solenoid-operated four-way or reversing valve 45 which is connected to the opposite ends of the cylinder by means of conduits 46 and 47, and to a compressor 48 or other source of fluid under pressure by conduits 49. The valve may be of conventional construction and per se forms no part of the present invention. The valve is controlled by a solenoid 50. The speed of reciprocation of the cylinder may be controlled by a flow control or pressure regulating valve 51 interposed in the line leading to the compressor.

In order to reverse the operation of the piston, a dog 53 is mounted on a bracket 54 carried by the piston rod 40. The dog is adapted to engage the actuating plungers of limit switches 55 and 56. The limit switches are arranged to control the operation of solenoid valve 45 through conventional electrical circuits 57 and 58. When the dog 53 engages the switch 55, the connections through the valve 45 are reversed so that fluid under pressure, which theretofore had been supplied through conduit 46, is then supplied through conduit 47 while conduit 46 is connected to atmosphere. When the piston reaches the other end of the stroke, dog 53 engages switch 56 and again reverses the connections so that conduit 46 is connected to the pump and conduit 47 to atmosphere starting the motion of the piston 41 over again in its original direction.

In order to control the length of the stroke, the limit switches 55 and 56 are adjustably mounted in any convenient manner, for example, on a mounting plate 59, the switches being clamped to the plate in the desired positions of adjustment by clamping screws (not shown) extending through the slots 59a and 59b in the mounting plates.

The apparatus described above functions to rotate and reciprocate in the tool 18. The power supply 30 supplies the required electrical energy to the tool and the work, and the pump 23 and associated parts supply the electrolyte to the tool.

As shown particularly in FIGURES 3 to 7, the tool 18 is constructed upon a tube 60 which is closed at both ends by plugs 61. The tube is clamped in the chuck 16 of the drill press and thus supports the entire tool. In order to supply electrolyte to the interior of the tool, a stationary collar 62 is mounted on the tube 60, the collar having a counterbore recess 63 therein and openings 64 to which the conduits 24 leading from the pump 23 are connected. The tube 60 is provided with perforations 65 in the zone within the counter bored portion 63 so that fluid entering the openings 64 can flow into the interior of the tube 60. The conductor 33, which is rigid, also is threaded into the collar 62. This serves to hold the collar 62 against rotation and allow it to supply electric power thereto.

In order to position the collar 62 on the tube 60, rings 66 and 67 are positioned above and below the collar 62 on the tube. These make press fits on the tube which are sufficient to prevent substantial leakage of electrolyte along the tube since the pressure of the electrolyte is relatively low; the rings are held in place by means of set screws. Leakage between the rings 66 and 67, which rotate with the tube 60, and the stationary collars 62 is prevented by rubber packing members 68 and 69.

The work engaging portions of the tool are supported beneath the stationary collar 62 by means of rings 71 and 72 that are secured to the tube 60 by appropriate set screws. These rings pivotally support arcuate work engaging vanes 73; the vanes are provided with pivot pins 75 at their opposite ends which engage within recesses 76 in the rings 71 and 72 as shown particularly in FIGURE 3.

Since the tool 18 acts as an electrode, the tube 60, collar 62, rings 66 and 67, rings 71 and 72, and vanes 73 are all made of conductive material. Preferably, all parts of the electrode tool are composed of materials that are inert to the electrolyte. Stainless steel is satisfactory for the conductive parts for many services and is used in the preferred form of tool illustrated herein. For other services platinum-activated titanium may be required, in other instances carbon or graphite may be found to be satisfactory.

In order to provide a porous dielectric surface on the vanes 73 for engagement with the work, the vanes are each covered with a layer of porous dielectric material 78. The material may consist of any appropriate electrolyte-permeable dielectric material that will not be attacked by the electrolyte and that will not contaminate the electrolyte. Felt is satisfactory, but I prefer to employ a perforated plastic material consisting of sheet of nylon about 0.031" in thickness, having about 70 perforations per square inch, the perforations being about $\frac{3}{32}$ " in diameter. This material has better wearing qualities than felt. The material is held in place by arcuate clamping members 79 which are secured to the vanes 73 by means of screws 80. It is to be noted that the vanes, which act as anodes in plating operations, are spaced from the surface to be plated by the thickness of the dielectric material.

In order to provide for the flow of electrolyte into and through the dielectric surfaces that engage the work, the tube 60 is perforated as shown at 82 in the zone between the rings 71 and 72 and the vanes 73 are provided with passages 83 which permit the electrolyte to flow to the inner surfaces of the porous dielectric covers 78. If desired, grooves 84 may be provided in the outer faces of the vanes in order to distribute the electrolyte more uniformly. These grooves ordinarily are not essential, however.

In practice, the diameter of the tool with the vanes 73 in the position shown in FIGURE 7 is only slightly less than the diameter of the bore to be plated. The tool is inserted in the bore with the vanes in the position shown in FIGURE 7; when the tool is rotated in the direction indicated the vanes each swing outwardly a few degrees under the influence of centrifugal force and also under the influence of the pressure of the electrolyte in the space within the vanes. The electrolyte flows through the passages 83 and is distributed by the porous dielectric covers 78 throughout substantially the entire outer area of each vane.

The speed of rotation of the tool is such that the speed at which the dielectric surfaces rub the work is large as compared to the rubbing speed ordinarily employed or possible in brush plating with hand tools. For example, in plating a bore having an internal diameter of an inch and a quarter, I have obtained excellent results by rotating the tool at a speed of 1280 r.p.m. This gives a rubbing speed of a little over 5,000 inches per minute or about 84 inches per second. The rubbing speed of 84 inches per second is much greater than the rubbing speed ordinarily employed in brush plating operations, which usually is about two or three inches per second and rarely exceeds 10 inches per second when brush plating with hand tools.

Although I have not been able to measure the pressure exerted by the vanes on the work, calculations indicate that the pressure of the vanes against the work is of the order of about three to about five pounds per square inch at the speeds ordinarily employed. This pressure increases if the rotational speed of the tool is increased and decreases if the rotational speed is decreased.

According to the present invention, the increased rubbing speed is accompanied by replenishment of electrolyte at the surface to be plated at a much greater rate than is normally employed in brush plating. Conventional brush plating operations are carried out by simply dipping a porous electrode into an electrolyte and then applying it to the work, the electrolyte being replenished every few seconds by redipping the tool in the electrolyte. As distinguished from this, in plating a bore about 1.2 inches in diameter and about 2 inches long according to the present invention, electrolyte is pumped through the tool at the rate of one half gallon to one gallon of electrolyte per minute, i.e., about 9 to 18 gallons of electrolyte per minute per square foot of surface being plated. While the electrolyte is circulated in this manner, the tool is rotated at 1280 r.p.m. as noted above and reciprocated at the rate of sixty one quarter inch strokes per minute, the rotation and reciprocation of the tool, coupled with the preferred staggered arrangement of the perforations in the dielectric integument covering the vanes 73 insures the continuous replenishment of the electrolyte over all of the surface being plated at all times during the plating operation, while the rubbing action physically removes gases and unwanted impurities and other precipitates from the surface to be plated and probably the cathode film is physically disturbed. The impurities and precipitates are carried off with the electrolyte that flows out through the bottom of the bore and into the sump in the example given and are removed by filtering the electrolyte. The gases are either carried away with the electrolyte or permitted to rise into the atmosphere. In any event, it appears that the rubbing at high speed and the rapid rate of circulation of electrolyte insures that the electrolytic action takes place on surfaces that are maintained in clean condition and substantially free from gas and with electrolyte that is in good condition.

It is also probable that the rapid and alternate wiping of the surface to be plated and replenishment of the electrolyte brought about by the tool contributes materially to the success of the present invention. In the example given, with about 70 openings per square inch in the in-

teguments 78 there are slightly more than eight alternate lands or rubbing areas and perforations for each lineal inch of the surface of the dielectric material 78. Thus, with the tool rotating at a speed of 1280 r.p.m. and the rubbing speed of the dielectric material on the work being a little more than 84 inches per second, we find that as the tool traverses the work the surface of the work is alternately subjected to the rubbing or wiping action of the lands and then replenished with the electrolyte flowing through the perforations at a very high frequency—of the order of 650 or more times per second. As each rubbing element or land of the dielectric material passes over the surface, it at least partially sweeps away and disturbs the thin film of electrolyte, known as the "cathode film," immediately adjacent the surface and then the electrolyte is immediately replenished by electrolyte flowing through the perforations. The mechanical action of the tool seems to insure the removal of unwanted products of the electrolysis while the circulation of the electrolyte insures that fresh electrolyte is always available to replenish the electrolyte that is mechanically swept away. Carrying out these operations at high speed appears to be one of the factors that gives unexpectedly advantageous results in the character of films deposited according to my process. The character of the deposit in terms of density and smoothness can also be varied by varying the speed of rotation of the tool. In general, for a given current density, higher rotational speeds increase the smoothness and density of the deposits, but unexpectedly, by use of high current densities and high rubbing speeds (which results in increased rubbing pressure) it is possible to produce deposits that are porous yet smooth as compared to ordinary porous deposits.

Regardless of the reasons, the results obtained by the use of the present invention are unique and remarkably advantageous; and, so far as I am aware, have not been possible of attainment heretofore. Typical examples are given below.

Example 1.—A cast iron bore having an internal diameter of about 1.2 inches was subjected to the following conventional preliminary operations.

- (1) Degreasing in a solvent degreasing solution.
- (2) Anodic degreasing in a solution of sodium hydroxide.
- (3) Anodic etching for five seconds using a solution of hydrochloric acid with a hand brush plating tool at 13 volts.
- (4) Flash plating with a conventional nickel brush plating solution to provide a nickel coating of approximately .000005" using a conventional brush plating tool for approximately 10 seconds.

Thereafter, the bore was plated according to the present invention using the tool previously described. The tool was rotated at a speed of 1280 r.p.m. and reciprocated for a distance of about 1/4" at the rate of approximately 60 strokes per minute. The plating was carried out by using the following conventional copper cyanide electrolyte.

	Grams
Copper cyanide	124
Sodium cyanide	135
Sodium hydroxide	6.25
Water, to make one liter.	

Using a current of 50 amperes at 14 volts, a bore having an area of about 7 square inches was plated with copper to a thickness of .001 inch in 50 seconds. The average current density was slightly in excess of 1,000 amperes per square foot. The deposit was dense, adherent and smooth and presented a burnished or polished appearance. Even higher rates of deposition with excellent results can be obtained by using proprietary brush plating electrolytes, the composition of which is not known to me, although they are, I believe, electrolytes of the general type set forth above with special additives to make possible increased rates of deposition. For example, I have deposited

copper under the same condition except for increased current densities at rates of from .0010 to .0015 inch in thirty seconds, using a proprietary copper plating solution. This rate is much greater than can be attained by hand brush plating operations with the same electrolyte, just as the rate with the conventional cyanide electrolyte set forth above is much greater than can be attained in ordinary bath plating. Also, the character of the plated deposit is superior from the standpoint of density, adherence and smooth, shiny appearance.

So far as I am aware, any plating solution that is suitable for use in a hand brush plating operation may be used with advantageous and unexpectedly better results according to the present invention.

The method and apparatus of the invention have given especially useful results in the production of very hard chromium iron alloy deposits. An aqueous electrolyte of the following composition was employed:

Ammonium hydroxide [28% —NH ₄ OH]	ml./l.	60
Chromium ammonium sulfate [Cr ₂ (SO ₄) ₃ ·(NH ₄) ₂ SO ₄ ·24H ₂ O]	g./l.	700.0
Ferrous ammonium sulfate [FeSO ₄ ·(NH ₄) ₂ SO ₄ ·6H ₂ O]	g./l.	13.5
Magnesium sulfate [MgSO ₄ ·7H ₂ O]	g./l.	25.0
Ammonium sulfate [(NH ₄) ₂ SO ₄]	g./l.	50.0

This bath is disclosed as Example I in the Snavely et al. Patent No. 2,693,444, except that in Example I in the patent the magnesium sulfate content of the bath is 20 grams per liter and the bath also includes small amount of sodium sulfite, which was not used in the electrolyte employed in my tests.

Example II.—In one test, the surface of a bore in cast iron, which had been given the same preliminary treatment set forth in Example I above, including a flash of nickel, was subjected to a plating operation at the rotational speed and rate of reciprocation given above with a circulation of one-half gallon of the above chromium-iron electrolyte per minute. The bath temperature was 149° F. The current was 80 amperes and the average current density was 1650 amperes per square foot. The plating operation was carried out for a period of ten minutes. The thickness of the plate was .0005" indicating a plating rate of .0030" per hour. The deposit was adherent uniform, light and satiny in the area which had been subjected to the brushing action of the tool. In areas of the bore that were not subjected to the action of the tool, the coating was loose and black.

Example III.—In another test, the preliminary treatment, electrolyte, work piece and speed of rotation and reciprocation of the tool were the same as in Example II. The bath temperature was 149° F.; the current density was 50 amperes, giving a current density of 1030 amperes per square foot; the time of plating was 10 minutes. This produced a plated coating of .0002" indicating a plating rate of .0012" per hour. The deposit again was adherent, uniform and shiny in the area that was brushed by the tool and porous, dark and dull in the area that was not brushed. In this example, as in the case of Example II, the plating was very hard.

Example IV.—In this test all the conditions were the same as in the Example III, except that the bath temperature was 144° F., the current was increased to 90 amperes giving an average current density of 1850 amperes per square foot and the plating operation was carried out for five minutes. The thickness of the plating was .0017 inch indicating a plating rate of .020 inch per hour. The deposit was adherent, uniform, light and satiny in appearance throughout the area acted upon by the tool. The hardness tested with a Knoop tester and a 10 gram load gave an average of 1034, which is equivalent to a Rock-

well C hardness of 72.3. The hardness test was made with the indentation parallel to the surface of the plating.

Example V.—In another test, the internal surface of an aluminum tube was first subjected to an anodic cleaning and etching operation with the use of a hand brush plating tool and a hydrochloric acid electrolyte as disclosed in my copending application Serial No. 1,265, filed March 4, 1960, and then given a flash of nickel, by a conventional brush plating operation with a hand tool. The bore was then plated with the apparatus of the present invention operating at a speed of 1280 r.p.m., reciprocating at a rate of sixty one quarter inch strokes per minute and with the above chromium-iron electrolyte circulated at the rate of one-half gallon per minute. The bath temperature was 149° F., the current was 50 amperes, the area plated 5.7 square inches, giving an average current density of 1260 amperes per square foot. The time of plating was 30 minutes which produced a uniform, adherent, light and mirror-like coating, having a thickness of .0011 inch, indicating a plating rate of .0022" per hour. Metallographic examination showed the structure to be dense with only occasional surface to base metal cracks. The average Knoop hardness of the plating with indentation parallel to surface was 955, equivalent to 69.2 on the Rockwell C scale. The hardness given in tests of Examples IV and V is unexpectedly high, the hardness of the coating ordinarily obtained by the method disclosed in the said Snavely et al. patent ordinarily being 600 to 700 Knoop as recited in the patent. The Rockwell C hardnesses of 72.3 and 69.2 compare with usual hardnesses of 45 to 55 on the Rockwell C scale obtained with the same type electrolyte in a conventional plating bath.

Another unexpected result of the plating operation is a smoothness of the finish. As mentioned above, in all of the examples the plated deposits presented remarkably smooth appearances; in some instances the metal as plated looks as though it had been burnished. Profilometer tests were made of the aluminum tube plated in Example V. The surface roughness of the plated sample was 10–13 micro inches R.M.S. A similar aluminum tube subjected to the same etching procedure that was used in producing the sample of the Example V had prior to plating a surface roughness of 35–45 micro inches R.M.S. Thus, the surface roughness was greatly reduced by the plating operation. This result is contrary to expectation. Ordinarily, chromium plating follows closely the underlying surface and the roughness of the plated surface, as determined by profilometer tests, corresponds quite closely to the roughness of the surface prior to plating. The theory underlying the production of the unusually smooth surfaces is not known to me at present. However, it does not appear likely that the surface of the tool, which is non-abrasive and relatively soft and which rubs the work rather lightly, could physically smooth out the metal once it has been deposited. Instead, it seems more probable that the tool, in some manner not presently known to me, but which may result from the probable physical disturbance of the cathode film by the dielectric elements of the tool, causes the electrodeposition to take place in such a way that surface roughness is reduced and the desired smoothness and density is obtained. Another effect that I have observed is that the efficiency of the plating operation is improved as compared with conventional methods; that is, a greater weight of metal is deposited per ampere hour with the present invention than with conventional procedures employing the same electrolyte.

In general, if the rotational speed of the tool is reduced substantially, the coated deposits do not present as shiny or as burnished an appearance as they do with the higher rotational speed given in the preferred example. However, for some purposes, such surfaces may be desired and may be adequate, and speeds of the order of 400 r.p.m., or about 1200 inches per minute lineal speed is entirely satisfactory for many purposes. Increased current density

may increase the porosity and decrease the density of the deposits. In general, current density and rate of deposition can be increased while maintaining the quality of the deposit if the rubbing speed and rate of circulation of the electrolyte are increased. Again, these factors may be varied in accordance with the character of the deposits required. The use of the method and apparatus of the present invention, however, makes possible the rapid production of high-quality coatings and lends itself particularly to automatic coating lines and long production runs. The apparatus may also be utilized for electrolytic cleaning and etching, and in such uses where conventional electrolytes are employed, similar advantages of uniformity and high speed of surface treatment are attained.

The chromium plating operation, which produces a strong, adherent, highly polished coating that probably is an alloy of about 94% chromium and about 6% iron, is extremely advantageous not only from the standpoint of the quality of the plating, but also because the trivalent chromium bath employed does not give off the noxious fumes associated with conventional chromium baths. It is thus possible to carry out chrome plating operations without the use of hoods and without requiring the precautions that are usually required in order to protect the workers from the health hazard that is present with ordinary chromium plating baths.

The smoothness and density of the plated deposits is also of great importance. By the use of the present invention, bearing metals such as lead-tin alloys or lead-tin-indium alloys can be plated directly in bores or on shafts if desired; aluminum cylinders and other parts as well as parts composed of other metals, can be provided with wear-resistant platings of great hardness, and corrosion resistant deposits of excellent appearance can be produced.

It appears probable that increasing the rubbing speed increases the polishing, levelling or burnishing effect. Also, the higher the rubbing speed, the higher the current density that can be employed with the production of dense adherent plating that presents a polished or burnished appearance. For a given electrolyte, there probably is a minimum speed below which the levelling, burnishing or polishing action does not take place regardless of the current density employed, because this effect does not appear to be obtainable with hand brush plating tools.

The apparatus disclosed herein is intended particularly for the plating of bores. It will be appreciated that machines of other types may be devised which can be utilized to carry out the present method in the plating of external surfaces of revolution, flat surfaces and surfaces of other shapes.

Those skilled in the art will appreciate that various changes and modifications can be made in the invention without departing from the spirit and scope thereof. The essential characteristics are summarized in the claims.

I claim:

1. Apparatus for electrolytically treating the interior of a bore in a workpiece comprising a tool having a central spindle composed of conductive material and adapted to be rotated, a vane composed of conductive material and constituting an electrode mounted on said spindle on a pivot parallel to and spaced from the axis of said spindle, a covering of porous dielectric material overlying said

vane and adapted to engage the interior surface of said bore, means for causing electrolyte to flow through said porous covering into contact with the interior surface of said bore, and means for rotating said electrode tool with respect to a workpiece.

2. Apparatus for electrolytically treating the interior of a bore in a workpiece comprising a tool having a hollow central spindle adapted to be rotated, a pair of vanes pivotally mounted on said spindle and having surfaces parallel to the axis of said spindle, said vanes having passageways therethrough, said vanes and said spindle being composed of conductive material, a covering of porous dielectric material overlying each of said vanes and adapted to engage the interior surface of a bore to be treated, means for supplying electrolyte to the interior of said spindle, said spindle being perforated adjacent said vanes whereby electrolyte can flow through said porous covering and through said vanes and said covering into contact with the surface of the work, and means for rotating said electrode tool with respect to a workpiece.

3. Apparatus according to claim 2 wherein said porous covering comprises a perforated integument composed of flexible insulating material.

4. Apparatus for electrolytically treating the interior of a bore in a workpiece comprising a tool having a hollow central spindle adapted to be rotated, a pair of vanes composed of conductive material and constituting electrodes pivotally mounted on said spindle and having surfaces parallel to the axis of said spindle and being adapted to swing outwardly away from said spindle, said vanes having passageways therethrough, a covering of porous dielectric material overlying each of said vanes and adapted to engage the interior surface of a bore to be treated, means for supplying electrolyte to the interior of said spindle, said spindle being perforated adjacent said vanes whereby electrolyte can flow through said porous covering and through said vanes and said covering into contact with the surface of the work, and means for simultaneously rotating and reciprocating said electrode tool with respect to a workpiece.

5. Apparatus according to claim 4 wherein said vanes are pivoted adjacent the edges thereof whereby the vanes tend to swing outwardly toward said bore under the influence of centrifugal force when said tool is rotated.

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