April 24, 1951 M. A. TREUHAFT ET AL 2,549,946

ELECTROPOLISHING

Filed Feb. 3, 1948 2 Sheets-Sheet 1

Fig. 1.

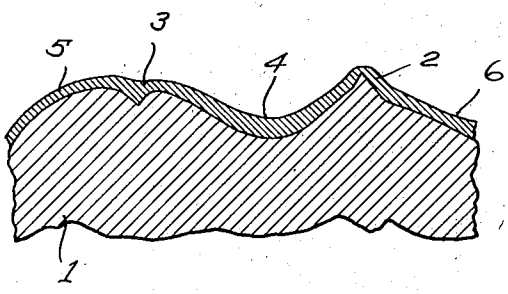


Fig. 2.

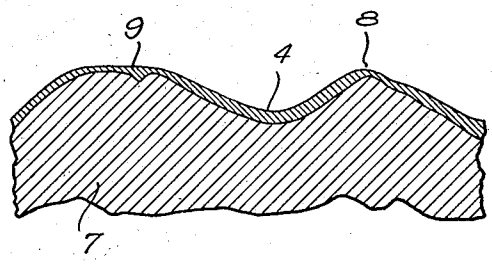


Fig. 3.

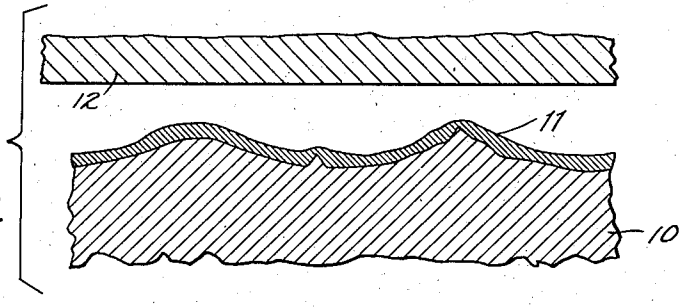


Fig. 4.

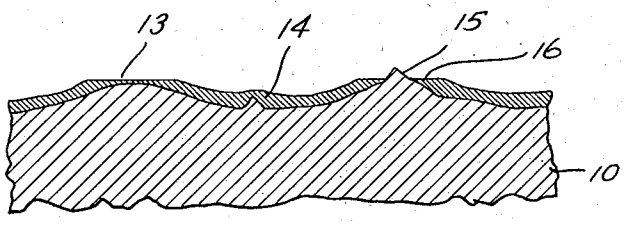
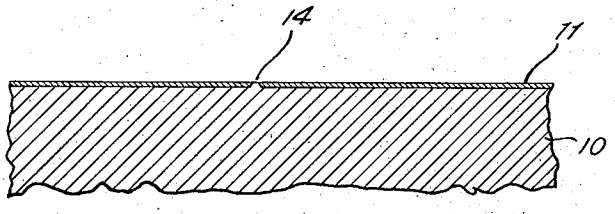


Fig. 5.



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ELECTROPOLISHING

Filed Feb. 3, 1948 2 Sheets-Sheet 2

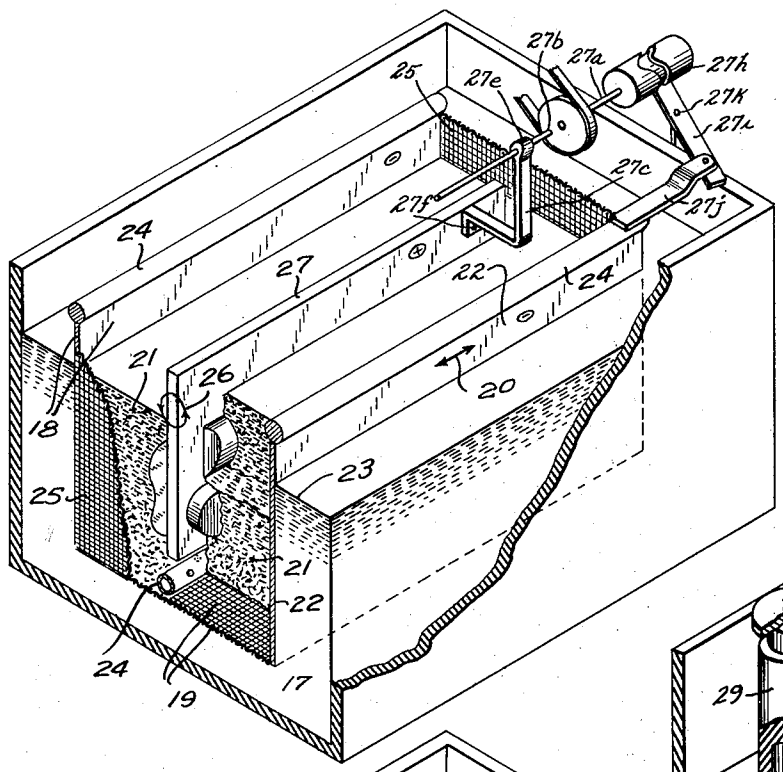
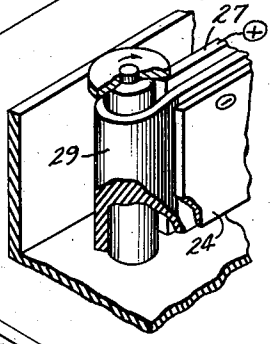


Fig. 6.

Fig. 8.



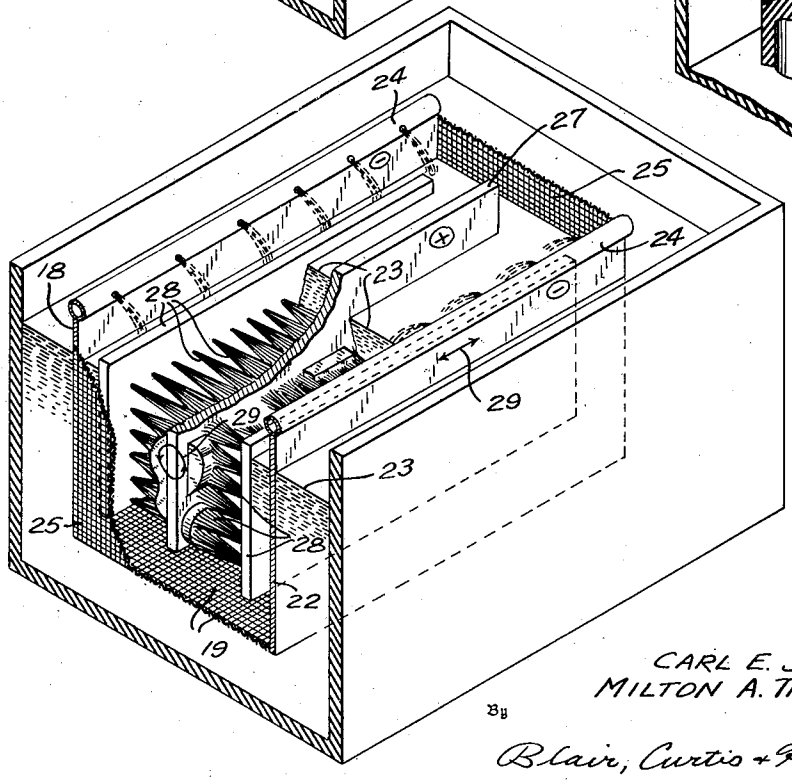


Fig. 7.

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Patented Apr. 24, 1951

2,549,946

UNITED STATES PATENT OFFICE

2,549,946

ELECTROPOLISHING

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Application February 3, 1948, Serial No. 5,978

1 Claim. (Cl. 204—140.5)

1

This invention relates to a method of and device for polishing metals and materials therefor. More particularly, it relates to an electrolytic method, apparatus and materials for treating such metals whereby the surfaces are polished without the necessity of resorting to mechanical abrasion or polishing processes.

It is, therefore, an object of this invention to provide improved means for accomplishing electrolytic polishing.

The methods heretofore used for electrolytic polishing, have had some serious difficulties. We have found that when the part to be polished electrolytically is made the anode in such a chemical bath, bubbles collect on the surface of the anode and may cling to this surface very tenaciously. These bubbles sometimes remain in more or less fixed positions during the electrolytic polishing process and because they affect the current they cause irregularities corresponding to their positions to appear on the surface of the metal.

It is an important object of this invention to provide a means for eliminating the bubbles which form on the anode during the electrolytic polishing process.

We have also found, in methods of electrolytic polishing known to the art, that the polish tends to be microscopic rather than macroscopic. Macroscopic irregularities are irregularities in the original surface such that each irregularity is visible individually to the naked eye. The electrolytic baths, known to the art, do not eliminate these macroscopic irregularities. Rather the present art of electrolytic polishing polishes these macroscopic irregularities as it polishes the desired contours of the surface. The end result is that the macroscopic irregularities are made lustrous. In some cases this lustre tends to make the macroscopic irregularities stand out more clearly, making the surface appear rougher than it was at the start of the process. This explains the fact that the present practice of electrolytic polishing, while it may be applied to certain surfaces for making samples for microscopic examination, may be even detrimental to these same surfaces for decorative purposes.

Also, we have found that methods previously devised for electrolytically polishing metals do not eliminate visible scratches on the surface of the metal. The scratches behave like the macroscopic irregularities mentioned above. The edges of the scratches are rounded slightly and the scratches are given a lustre, but the scratches themselves are not removed.

2

It is a further object of this invention to provide means for smoothing down and eliminating macroscopic irregularities and scratches by electrolytic polishing.

The means by which we propose to accomplish these objects is to apply mechanical wiping to the surface of the anode, while subjecting the objects to an electric current in the presence of a viscous electrolyte. The viscosity of this electrolyte is sufficiently high so that the corrosion products are not dissipated too rapidly, and they form a film on the anode surface. We propose to interpose between the anode and cathode a flexible substance which will conform to the contours of the anode and which is wiped across the anode surface, and is continuously or intermittently cleaned of any deposits which it acquires from the anode surface. We propose to do this without altering the shape of the cathode; that is, the cathode is not required to conform to the shape of the anode.

It will be clear that mechanically wiping the surface of the anode will remove the bubbles which tend to cling to it. Since the material used to wipe the anode will in general obstruct the flow of the electrolytic current, it is necessary intermittently to remove it from or move it along the anode surface. This allows the current to flow again and the bubbles again form on the anode. The surface must be wiped with such frequency that the bubbles are not allowed to remain on the anode long enough to cause irregularities on the surface.

The wiping of the anode surface with a flexible material during the electrolytic polishing process is also the means by which we propose to eliminate macroscopic irregularities and scratches from the surface of the metal being polished. In order to better understand how this is accomplished, it is necessary to examine theoretically what happens at the anode surface when wiping is applied.

In methods heretofore devised for electrolytic polishing, the part to be polished is made the anode in an electrolytic bath. By means of electrolysis, the anode is eaten away and the anode corrosion products collect in a film which forms over the surface of the anode. The theory here states that the physical properties of this anode film are such that it tends to form more thickly in the small crevices or valleys on the surface of the anode and less thickly on the small peaks or high points. Since this film impedes the flow of current, less current will flow in the valleys than on the peaks of the anode surface. This

means that the peaks will be eaten away faster than the valleys and the surface will tend to become smooth. This accounts for the electrolytic polishing actions as known to the prior art.

Since the viscosity drops and the rate of diffusion rises with increase of temperature, it is well to operate at room temperature or below or with only moderate warming. When the viscosity drops too low film formation may become impossible.

When a wiping action is applied to the anode, the film which has been formed is wiped from those points where the wiping surface comes into contact with the anode surface. The wiping surface cannot, in general, reach down into the small crevices in the surface of the anode; therefore, only the high points on the surface are wiped. This action strips the film completely from the high points and allows them to be eaten away much faster than the low points, thus introducing an additional smoothing or polishing action. This new polishing action, which has been introduced by the wiping action, is a much more rapid smoothing action than that normally present in the ordinary bath polish where no wiping is present. The reason for this is that in the non-wiped bath polish, the film is merely thinner on the high points than in the crevices, while in the wiped type of polish, the film is completely removed from the high points. This gives a much greater relative rate of attack on the high points than in the valleys, and consequently a much stronger polishing action results.

Hence, it is now apparent that wiping the anode in an electrolytic polishing process introduces a strong smoothing action. Moreover, this polishing action is due to the wiping material wiping the film off the high points of the anode surface. We now propose that this material and the wiping motion be chosen such that it will wipe the film off the macroscopic high points, but will leave the film intact in the macroscopic valleys. The macroscopic high points are now subject to a much faster rate of electrolytic attack than the macroscopic valleys. Thus it will be clear that the new rapid polishing action introduced by wiping polishes the surface macroscopically.

Actually, this new polishing action polishes microscopically too. Initially those microscopic irregularities which are situated in the macroscopic valleys, are protected from the wiping action. However, as the macroscopic peaks are eaten away, the film which has been built up in the valleys is gradually wiped away, so that the film over the microscopic high points which reside in these macroscopic valleys is first thinned and finally wiped away so that such high points are exposed to the electrolytic polishing bath, while the microscopic low points are still somewhat protected from the wiping action. Hence even if the film produced in a polishing bath without wiping were completely uniform over the peaks and valleys and alone could have no polishing action, the wiping of the present invention would be sufficient to produce a polished surface by electrolysis in such bath. We have found in the wiped anode electrolytic process, that since the polishing action due to wiping is so much stronger than the non-wiped polishing action, the latter seems to enter into the process only as a secondary effect.

In order to better illustrate the action of wiping in the electrolytic polishing bath, it is useful to draw an analogy with the corresponding buffing operation. In buffing, a flexible material, usually cloth, is used to wipe across the surface of the work. This cloth conforms to the contours and bears against the high points on the work. The abrasive, which is put on the cloth in the buffing operation, cuts down these high points while leaving the low points intact. Thus the surface becomes smooth.

In the wiped electrolytic polishing process, a very similar thing happens. A resilient material wipes across the work and it bears against the high points on the anode surface. Instead of the abrasive cutting these high points down as in the buffing operation, anode film is stripped from these high points and they are eaten away by the electrolytic current. A high current eats the high points away rapidly and acts like a coarse abrasive whereas a low current eats the high points away more slowly and acts like a fine abrasive. This action in wiped electro polishing process is so similar to buffing as to explain why the wiped electrolytically polished surface has the appearance of a buffed surface.

It is therefore an important object of this invention to provide means for producing an electrolytically polished surface which is similar to a buffed surface.

Other and further objects of this invention will become apparent from the disclosures in the specification and the accompanying drawings.

In order to better understand this invention, reference is made to the drawings.

Figure 1 is a fragmentary sectional view on a magnified scale taken through a surface being subjected to electro-polishing near the start of the polishing operation.

Figure 2 is a corresponding view of the same after polishing has progressed substantially to completion in accordance with methods hitherto known.

Figure 3 is a view corresponding to Figure 1 but showing another surface portion being subjected to electro-polishing in accordance with the present invention.

Figure 4 is a view corresponding to that of Figure 3 showing the same surface after wiping.

Figure 5 is a view corresponding to that of Figures 3 and 4 showing the same surface near the completion of the polishing operation.

Figures 6 and 7 are, respectively, isometric sectional views of types of apparatus suitable for carrying on the electro-polishing operation in accordance with the present invention.

Figure 8 is a detail view of a modified form of construction.

In Figures 1 and 2, the mechanism of the present art of electrolytic polishing is shown. In Figure 1, a greatly magnified cross section of the anode surface is shown at the start of the polishing action. There are irregularities on its surface like the peak 2 and the crevice 3. These irregularities may be considered to be microscopic since they are not individually distinguishable with the naked eye. The more gradually curved valley 4 and the more gradually curved peak 5 may be considered to be macroscopic since they can be distinguished individually by the naked eye. In the electrolytic process, an insulating film 6 of anode corrosion products forms over the surface of the anode. It will be noticed that the thickness of the film is greater in the valleys than on the peaks. However, the relative thickness of the film is the important factor in electrolytic polishing, since on it depends the relative rates of attack on the

peaks and valleys of the surface, and hence the polishing action of the process. The drawing indicates that the relative thickness of the film in the microscopic valley to that on the microscopic peaks is much greater than in the corresponding macroscopic case.

In Figure 2, the anode 1, of Figure 1, is shown after being electrolytically polished in an ordinary manner. This anode, now designated as 7, has been subject to a certain amount of smoothing. The peak 2 has been considerably reduced and is now represented by 8 and the valley 3, has had it sides rounded off and it is now represented by 9. However, the gradually curved valley 4 and the gradually curved peak 5 have been subject to almost the same rate of attack, since the depth of the film over them is approximately equal. Hence, relative to each other they have remained approximately the same and very little macroscopic polishing has taken place.

The macroscopic polishing action which occurs when the anode surface is wiped in accordance with this invention, will be better understood by reference to the drawing. In Figure 3 is shown the anode 10, with macroscopic and microscopic irregularities. The insulating film 11, covers the macroscopic irregularities more or less uniformly and the wiping surface 12 is in position for wiping the anode surface. In Figure 4, is shown the anode surface after the wiping action is complete. The tops of the macroscopic irregularities 13 and 16 have been stripped of the film and are now subject to rapid attack by the solution whereas the valleys are still coated and there the attack will be very slow. After a period of time the film will rebuild on the peaks of the macroscopic irregularities and wiping will again be necessary. We therefore propose means for alternately wiping the anode and exposing it to the action of the electrolytic current until a smooth surface is obtained. Thus, although the formation of a film which inhibits or slows down the electrolytic solving action by which the metal is converted to salts or other compounds, is important to this invention as it is to all electro-polishing, this invention does not require that the film produce a differential action on the high and low points. Therefore, one may now use, with advantage, an electrolytic solution which so quickly polarizes all exposed surfaces as to substantially inhibit almost all electrolytic solving action except during the instant immediately following the wiping away of such film.

It is apparent from the drawings that the polishing action of the process described above is much greater than available in the ordinary bath electrolytic polishing operation. When the anode is wiped, the film is completely stripped from the high points as in Figure 4, whereas in the other case, where no wiping is available (Figure 1), the film is merely thinner on the high points. This applies to the macroscopic irregularities 13 and 16 and to those macroscopic irregularities on the peaks of the macroscopic irregularities such as 15.

However, the microscopic irregularity 14, which resides in the macroscopic valley between the peaks 13 and 16, is protected from the wiping action by these macroscopic peaks. In Figure 5 is shown the same section of the anode surface as shown in Figure 4, but after wiping and electro-polishing action according to the present invention has almost completely smoothed the surface. The microscopic irregularity 14 is now somewhat reduced but still present. The macroscopic peaks 13 and 16 have been eliminated and the microscopic peak 14 is now subject to wiping and thereafter will be exposed to rapid electro-polishing action. This illustrates that wiping is useful for microscopic polishing as well as macroscopic polishing. It should be understood, however, that the present invention can also be adapted to leave macroscopic contours of desired size while polishing out smaller irregularities.

We have found a large number of materials to be suitable for use in wiping the anode. A partial list of these includes sponge rubber, cloth, various types of brushes, sheepskin, and felt. In general, the type of material required for wiping depends on the contours of the anode surface and the roughness of this surface. Thus, for an anode whose contours are very irregular, a very flexible material will be needed to conform to those contours and properly wipe them. Where the contours are fairly regular but where the surface to be polished is rough, then a material of lesser flexibility is needed so as not to flex into the macroscopic crevices and wipe the film out of them. For irregular contours brushes or masses of loose particles should be used for polishing with the diameter of particle or bristle adjusted to get into the desired contour but to rub over the irregularities which should be polished out.

The pressure by which the wiping material is held against the anode during wiping affects the selection of materials suitable for the wiping and the practical results obtainable with a given material in a given bath and with a given wiping motion. If the pressure is too light, there is very little if any advantage from the wiping and the anodic piece at the end of the treatment will have substantially the appearance and surface condition which would be obtainable by non-wiped electrolytic polishing. If the pressure is too heavy the film will be wiped out of valleys as well as from the peaks and the finished piece will look as though it had been etched—no polishing action is evident. In the process of the present invention, the pressure is sufficient to assure removal of the film from the high points but insufficient to drive the wiping material down into the valleys with the scouring action necessary for film removal. Obviously the precise pressure required will depend upon the wiping material—a stiffer material can exert a higher pressure on the peaks without flexing over them sufficiently to scour out the valleys—upon the wiping motion—a long and rapid motion in a plane parallel to the average surface of the piece will allow higher pressure than a short undulating or rotary motion toward and away from the piece which tends to sweep the wiping material down the sides of the peaks to the bottoms of the valleys and upon the character of the bath and especially the toughness and formation of the rate of film—with very rapid film formation and with tougher films higher pressure and/or more rapid motion may be necessary to keep the high points exposed, and a higher pressure and slower motion or motion toward and away from the piece can be better tolerated without scouring the film out of the valleys.

Two other factors must be considered in the practical utilization of this invention. The first is the proper chemical solution to use in the electrolytic polishing tank and the second is the motion necessary to wipe the work. The solution, as already stated broadly, need only be one which can electrolytically remove metal from the anode

and provide a film on the anode surface which inhibits or delays further electrolytic solving action.

We have found a solution of orthophosphoric acid and water to be satisfactory for rapid polishing. The proportions used were 70% orthophosphoric acid and 30% water by weight. This solution is suitable for work on copper and its alloys and nickel and its alloys. However, this solution is rather corrosive and it has a tendency to attack certain wiping materials when immersed in the bath. This solution is suitable primarily for coarse polishing because of the rapidity of its action. It is also somewhat difficult to control and since it causes heating it is best when using it, to provide cooling apparatus.

We have found 85% orthophosphoric acid particularly good for polishing copper and copper alloys, but it is good also for other metals. Varying percentages of sulfuric acid can be used satisfactorily in the process. Glacial acetic acid can be used satisfactorily in the process and in general strong acids, individually and in mixtures which are viscous or syrupy in nature. Acids which are too thin to assure the film formation can be combined with other ingredients which add viscosity to the solution.

We have found useful the addition of an inert non-conducting viscous substance which is miscible with the acid and not appreciably decomposed by it, such as glycerine. Taking one volume of the above phosphoric acid solution to one volume of glycerine gave a solution that was much less corrosive. In the solution containing the glycerine, it was possible to use many wiping materials, such as cloth and sheepskin, since the glycerine solution attack on materials of this type was so slow as to be negligible. Also, heating is moderate in this type of solution since the current drain is low, also the polishing time is lengthened so that a difference of a few seconds in withdrawing the work from the solution is not critical. The polish obtained using this solution is much finer than that obtained without the addition of the glycerine. In like manner other addition agents known in the art of electroplating to slow down the electrolytic action can be used and especially those which also reduce the corrosive effect of the acid. The glycerine also serves to increase viscosity.

One of the most satisfactory solutions that we have discovered is made of equal volumes of dextrose and orthophosphoric acid solutions. The orthophosphoric acid is used in its commercial form of 85% acid to 15% water by weight, and the dextrose in the form of a syrup made by melting crystalline dextrose. This solution is economical of current density and it is not critical as to time of polishing or temperature. The proportions of the solution are not critical either. Satisfactory results may be obtained up to doubling or halving either ingredient.

These are only a few of many solutions which may be used and the scope of the broader aspects of this invention is in no way limited to their use.

Many methods are available to provide the motion necessary to satisfactory wiping action. In one embodiment of our invention, the wiping action is provided by motion of the anode in a suspension of sponge rubber particles. This will be better understood by reference to the drawings. In Figure 6 is shown a cross-sectional view of the electrolytic polishing tank. The work to be polished is made the anode, **27**; and as shown in Figures 6 and 7 consists of a plate with irregular projections thereon. A basket is made up of the two metal plates, **18** and **22**, which form the sides of the basket and the pieces of metal screen **19** and **25** which form the bottom and the ends of the basket. The whole basket is made the cathode and it is filled with particles of sponge rubber, **21**. The two metal plates, **18** and **22**, carry most of the cathode current. The metal screen **19** and **25**, serves to confine the sponge rubber without seriously restricting the circulation. The anode is inserted into the basket below the level of the solution **23**. The anode, in this particular embodiment, is given a circulatory translational motion in a plane perpendicular to the two cathodes **18** and **22**. That is, each point on the anode moves in a circle whose plane is perpendicular to **18** and **22** and each line in the anode remains parallel to its original position. This is illustrated by the arrow **26**. The basket is given a motion back and forth as indicated by the arrow **20**. With these two motions every part of the anode surface is subject to wiping by the sponge rubber particles. The two motions are set slightly out of phase so that the anode is wiped by a constantly changing group of sponge rubber particles and no wiping pattern results on the anode. It will be understood, of course, that the wiping action is a relative motion between anode and wiper, consequently the absolute motion may be imparted to either or both to produce the desired relative motion. As one example, a brass article connected as anode and treated as described above with the orthophosphoric acid-dextrose bath described above, at a temperature of 30° C. a current density of one-quarter ampere per square inch (of anode surface) and five volts between the electrodes and a wiping velocity of 15 R. P. M., polishing was complete in 15 minutes.

The wiping in this embodiment has an alternating feature desirable for proper electrolytic polishing. Each sponge rubber particle which bears against and moves across the anode surface, wipes the film away from the high points in its path. The sponge rubber particle is then carried away from this particular part of the anode surface and the current is again free to flow and it again forms the film at this particular point. Thus the size of the particles and the speed of the motion determine how often the film is formed and wiped in a given interval of time.

The undulating motion having a component toward and away from the piece being wiped has advantage also in its tendency to intermittently squeeze the absorbent particles. That part of the wiping material nearest the anode tends to acquire deposits of metal and that nearest the cathode deposits of the film material wiped from the surface. If such materials are allowed to accumulate in the pores or interstices of the wiping material it is likely eventually to impair its usefulness; but by this undulant squeezing action such deposits are dislodged from the wiping material.

Since the sponge rubber mass may restrict the solution and impair its circulation, there is danger of local overheating of the solution within the sponge rubber mass and of the solution becoming exhausted in the vicinity of the electrodes unless some means of circulation is provided. We accomplish this by providing a pumping system and the manifolds **24** running the length of the baskets, to circulate the solution to the locations within the tank **17** where the bath is subjected to the polishing current.

If the injection of liquid through the perfora-

tions or jets of the manifold 24 is gradually increased a condition will be reached in which the particles are in a state of teeter i. e., are supported by the flow, which counteracts their tendency to settle, and the particles in consequence are in constant motion bouncing against each other and the surfaces exposed to them. If this condition is maintained, this spontaneous motion of the particles can be used instead of an externally imposed motion of the body as a whole; and in this case the statistical averages of particle movements cover the surface instead of any planned transitional or rotary movement of the wiper as a whole.

If the particles thus used in teeter are very small they will tend to get down into small crevices and to wipe all surfaces except the very small valleys and the narrow spaces between projections. Thus one may polish a decorated or etched surface without destroying the etching or decoration; with larger particles, the etching or fine detail of decoration would tend to be polished off, and for the same reason irregularities of that order of magnitude can be polished from surfaces where they are not desired. Instead of using motion in teeter, the wiping particles can be entrained in a liquid and flowed over the surface being polished.

Since this action is essentially a rubbing and scrubbing action, a wide variety of materials can be used. In general, abrasives will not be used because they tend to produce scratches which it is the purpose of electropolishing to eliminate, but mild abrasives can be used to assist in film removal if so soft as to avoid scratching the metal; and abrasive action (especially the pressure exerted against the surface being polished) can be regulated so that it acts primarily on the film which is to be removed and scratching of the metal is substantially avoided. Hard particles even if non-abrasive, are not recommended because they tend to have point contact with the surface. Softer materials which give a wiping action are preferred. In the rubbing exerted by such material, the film material wiped off the surface under treatment may exert a mild abrasive action. In general, it has been found best to use irregularly shaped particles of softer resilient materials (such as sponge rubber or ground rubber, chopped acid-resistant fiber scrap, etc.), which exert a squeegee action on the metal surface to clean away the polarizing film.

Where a flat polished surface is desired it is preferable to use a flat, stiffly flexible and resilient material such as felt or cloth or a stiff rubber sponge or the like, with a plane surface or a cylindrical roll moved back and forth across the metal being polished. Likewise with surfaces of revolution, the anode may be rotated on the axis of such surface and the wiping pad have a form corresponding to the generatrix of said surface. This provides a method for electrolytic "machining." Also, certain objects may be electrolytically polished quite satisfactorily on a moving belt principle, the anode or object to be polished and the cathode placed on opposite sides of an endless belt of cloth, felt, etc. Ordinarily, it is not necessary to have a rubbing pad which conforms to the desired shape of the particular article.

Many differently shaped items may be electrolytically polished in such equipment. It is not necessary to alter the shape of the cathode surfaces to accommodate each new shape of work piece, and if the resilient or suspension type wiper is used it accommodates itself to each new shape automatically.

The relative movement may be brought about by any well known or suitable mechanism as, for example, by a drive shaft 27*a* carrying one or more eccentrics 27*b* which, in the present instance, operates through the medium of a resilient metal strap 27*c* pivoted at 27*e* and is connected at 27*f* with the plate 27. From the worm cam 27*h*, a crank 27*i* pivoted at 27*k*, operates a link 27*j* for the basket 25.

In another embodiment of this invention, shown in Figure 7, brushes 28 are used instead of sponge rubber as the wipers. They are given a reciprocating motion as indicated by the arrow 29. The anode is given the same type of motion as in the preceding embodiment. The film is allowed to form at each point between the wiping passage of each bristle or group of bristles. The brushes 28, also accommodate themselves to various shapes of work pieces without any alteration in the cathode surfaces. For major differences in surface shape, however, it is desirable to use brushes of approximately corresponding shapes.

In another embodiment, shown in Fig. 8, an endless belt 29 composed of resiliently flexible material as above indicated serves as the polishing element.

This invention is in nowise limited by these two embodiments, but as will be obvious to those skilled in the art, various changes and modifications may be made within the scope of this invention.

From the foregoing description, it will be apparent that we have discovered a means of electrolytically polishing metals whereby any desired range of irregularities may be removed from a metal surface. We have also discovered a means whereby bubbles are removed from the surface of the work. The means we have employed to do this have resulted in a polishing action that is much stronger than the methods known to the prior art. We accomplish these objects without having to resort to cathodes which conform to the surface of the part being polished.

We claim:

An improved method of electro-buffing metal, which comprises establishing a circulating bath of an electrolyte of a type which electrolytically removes metal from an anode with continuous production of a by-product film on the anode surface, immersing a metal object as anode in said bath with its surface which is to be electro-buffed, under the surface thereof and facing into a free portion of the bath to provide electrolyte circulation space across said surface, connecting and maintaining in the same circuit a cathode, wiping the high areas of the surface being electro-buffed with physically separated wipers, continuously circulating electrolyte between said wipers, said wiping occurring only at a plurality of separated areas at any one instant, continually shifting the wipers relative to the surface being electro-buffed so that all such high areas on such surface are wiped, but the wiping of individual areas thereon is intermittent, the area of the immersed surface which is undergoing electro-buffing being substantially in excess of the portion of that area which is being wiped at any one time, whereby to allow the electrolyte to act on each area between said intermittent wipings, and continuing the wiping and free exposure to circulating bath and the

maintaining of by-product film on the low areas thereof until minute high areas in which surface irregularities had existed are brought to a surface substantially co-directional and contiguous with adjacent surface areas to form a distinct-image-reflecting surface.

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CARL E. SWANSON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
398,045	Hermite et al.	Feb. 19, 1889
2,412,186	Whitehouse et al.	Dec. 3, 1946

FOREIGN PATENTS

Number	Country	Date
921,192	France	Jan. 10, 1947

OTHER REFERENCES

"Transactions of The Electrochemical Society," vol. 82 (1942), pages 227 through 230.

"The Monthly Review," of the American Electroplaters' Society, Aug. 1947, pages 942, 943.

"Bibliography of Scientific and Industrial Reports," vol. 1, No. 9, page 304, Mar. 8, 1946.