

Dec. 5, 1950

C. W. HANGOSKY  
METHOD AND APPARATUS FOR ELECTROLYTICALLY  
TREATING METAL SURFACES

2,532,907

Filed Sept. 18, 1946

3 Sheets-Sheet 1

Fig-1

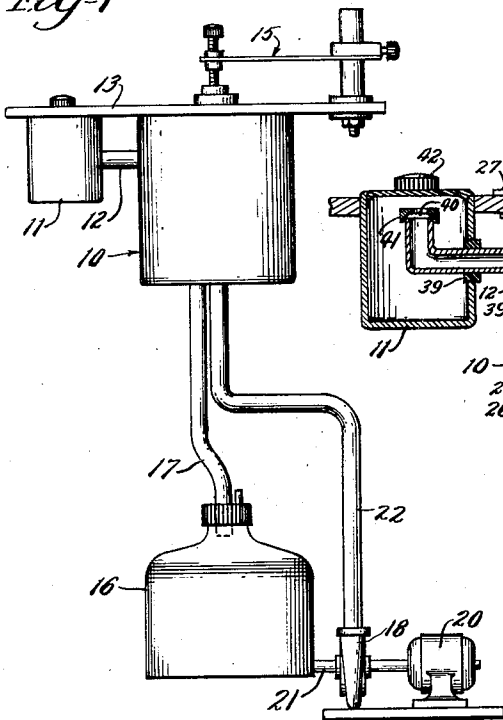


Fig-2

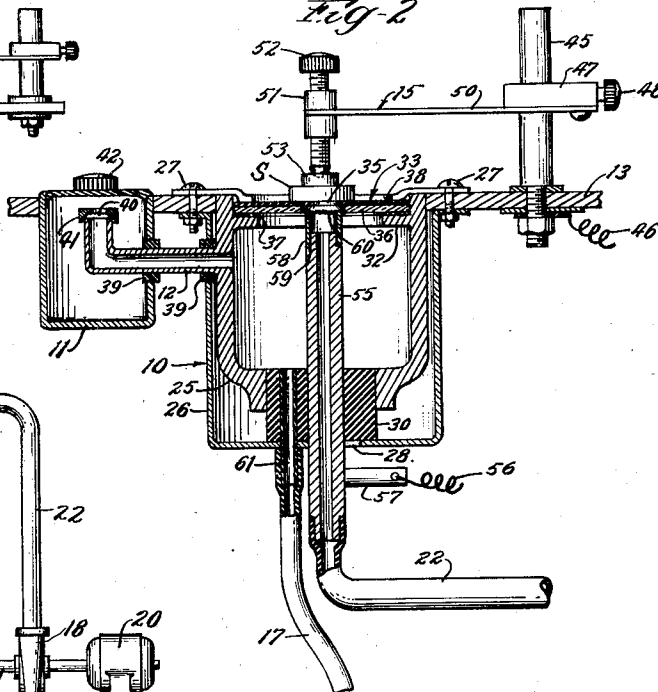
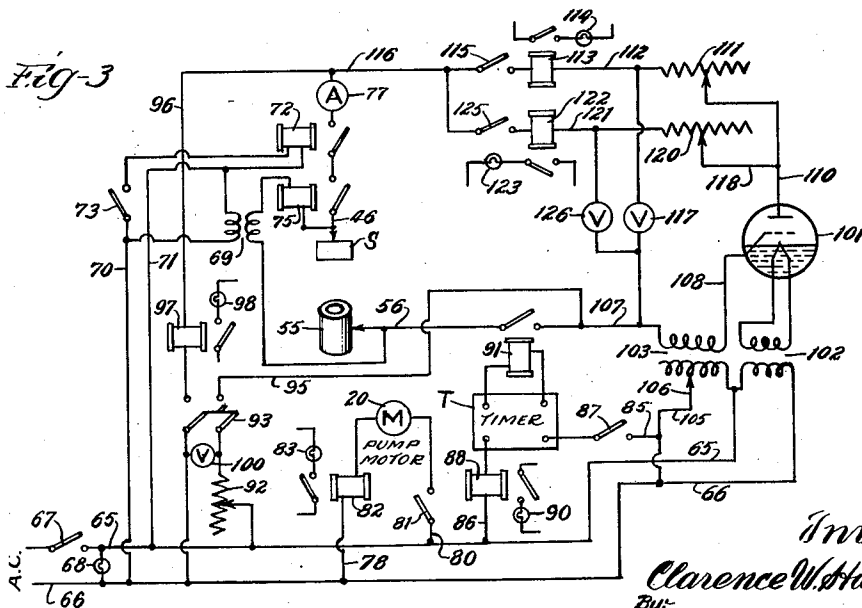


Fig-3



Inventor  
Clarence W. Hangosky  
By: Mann and Brown  
Attys.

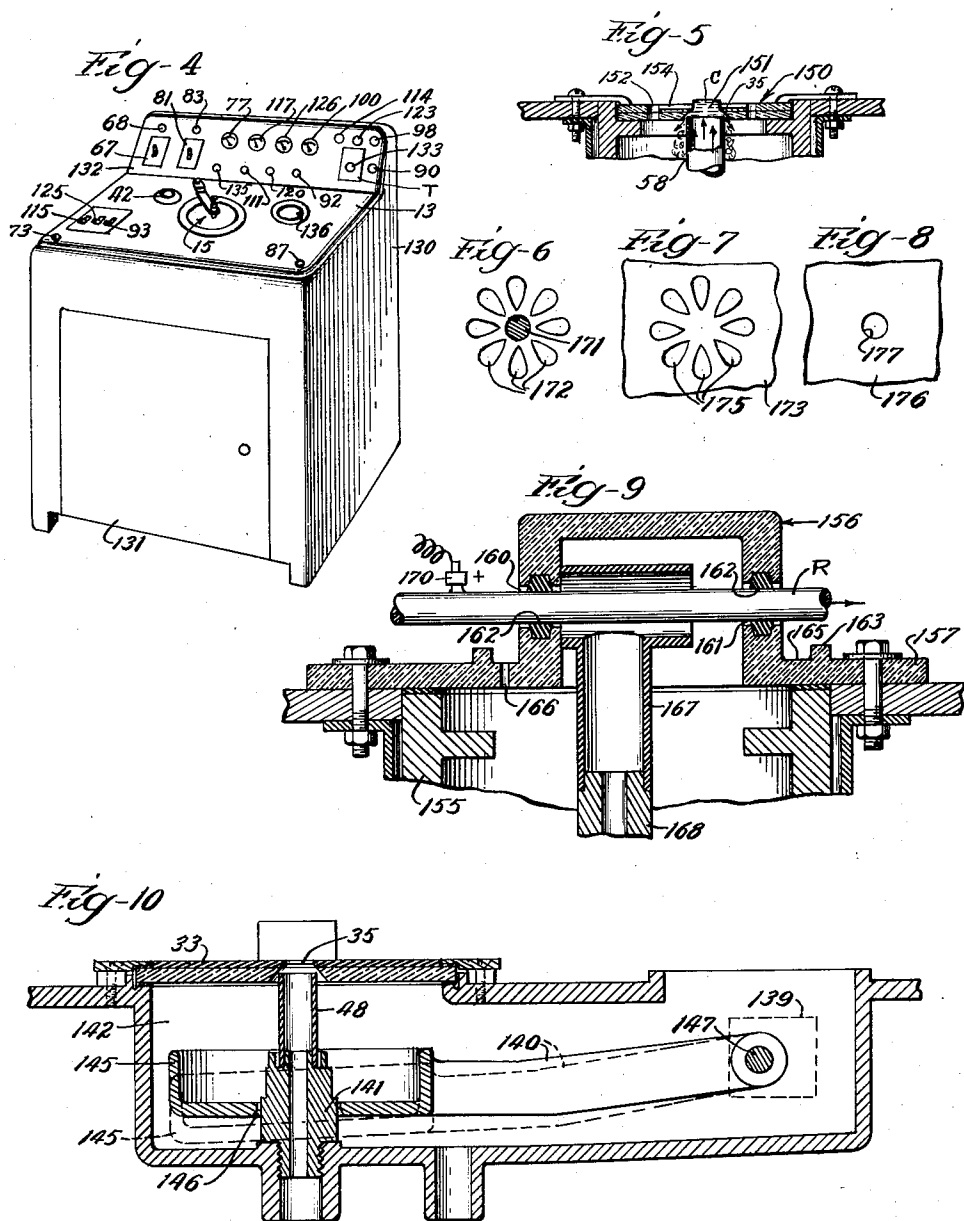
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3 Sheets-Sheet 2



Inventor  
Clarence W. Hangosky  
By: Mann and Brown  
Attys.

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3 Sheets-Sheet 3

Fig-11

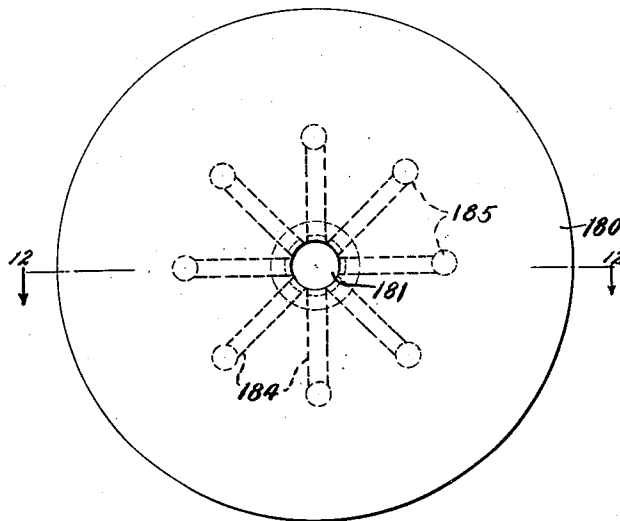


Fig-12

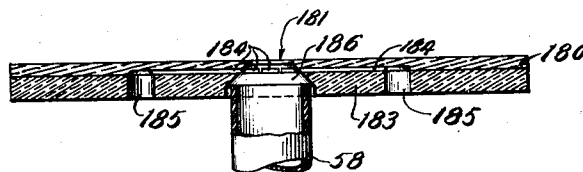
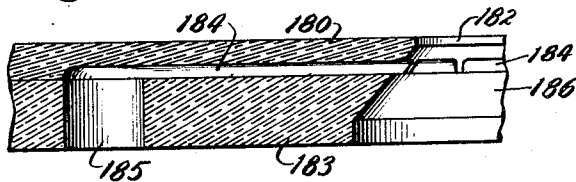


Fig-13



Inventor  
Clarence W. Hangosky.  
By *Mann and Brown*  
Attys.

## UNITED STATES PATENT OFFICE

2,532,907

## METHOD AND APPARATUS FOR ELECTROLYTICALLY TREATING METAL SURFACES

Clarence W. Hangosky, East Lansing, Mich.

Application September 18, 1946, Serial No. 697,765

26 Claims. (Cl. 204—143)

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My invention relates to the electrolytic processing of metal surfaces with special reference to preparation for microscopic examination and is directed to a method, apparatus and electrolytic solution for such surface treatment, and is a continuation-in-part of my copending application Serial No. 548,841 filed August 10, 1944 (now abandoned).

Ordinarily the preparation of a specimen for metallurgical examination under a microscope involves the grinding of the surface with increasingly finer grades of abrasive until the desired polish is obtained. The specimen is then etched by immersion in a suitable reagent to produce the desired etched surface for examination under the microscope. The process requires a great deal of time and care and, even with skilled operators, consistent results are not always obtainable. Electrolytic methods of polishing and etching metallurgical samples have been the subject of considerable investigation since the process potentially offers a rapid and reproducible means of obtaining a high quality polished and etched metallurgical specimen in a very short period of time employing relatively unskilled labor.

However, difficulties have been encountered in the application of the process. For example, the solutions employed in electrolytic polishing and etching are quite often corrosive, inflammable, and, in some instances, explosive, as for example, certain of the perchloric acid electrolytes. The apparatus heretofore employed has usually required the services of a highly skilled operator and has been relatively expensive and bulky. The potential reproducibility of the process has not been realized due to shortcomings in the apparatus. Employing the prior art apparatuses, the surfaces of the specimen will be found to be wavy and, in many instances, burned or pitted.

An object, therefore, of this invention, is to provide a process and apparatus that will consistently and rapidly reproduce on metallurgical specimens, or other metal surfaces, excellent etched and/or polished surfaces even when the apparatus is operated by relatively unskilled workmen.

Perchloric acid solutions, while hazardous, are highly desirable electrolytes for many purposes and it is an additional object of my invention to provide a metal etching and/or polishing device in which substantially any electrolyte, specifically including perchloric acid solutions, may be safely employed.

Since perchloric acid electrolytes are among the most difficult to handle, the following de-

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scription will be largely confined to such material, knowing that such disclosure will furnish adequate guidance for others in the employment of similar or other solutions.

Many of the electrolytic solutions customarily employed have a low conductivity which results in the generation of considerable heat by the passage of electric current sometimes to the point of possible or even actual ignition or combustion of the solution. In addition, the excessive heat, if not dissipated promptly, adversely affects the surface under treatment. Another object of my invention is therefore to provide means for rapidly dissipating from the electrolyte and the metal object being treated both the heat and gas bubbles formed during the process.

Further objects include the provision of an apparatus of the type described which can safely handle hazardous solutions, is relatively inexpensive and compact, which is suitable for substantially all metals, and which can be adapted for the polishing and/or etching of other metal shapes.

Briefly, I attain these and other objectives by providing an apparatus in which a relatively flat crested, gently flowing fountain of a suitable electrolyte from a closely adjacent orifice is directed against a predetermined portion of the surface of a suitably supported metallurgical specimen in such manner that an even flow of electrolyte is produced. This condition having been established, the metal specimen is made the anode, or if alternating current is employed, an electrode of a circuit which includes the fountain of electrolyte. The heat and bubbles generated by the electrolytic action as well as other matter which may be included in the solution are evenly distributed and rapidly eliminated from the surface of the sample by the flow of electrolyte. When the current density employed during the flow of electrolyte is relatively high, the surface of the metal is polished while lower current densities will produce an etched surface. The time required to either etch or polish a specimen is negligible compared to that required when mechanical processes are employed and the results obtained by my method and apparatus are of consistently high quality, the waviness, pitting, and burning which usually characterizes electrolytic polishing or etching being substantially absent. My compact and inexpensive apparatus permits the safe use of hazardous solutions such as those incorporating perchloric acid ( $\text{HClO}_4$ ) since the constant flow of electrolyte cools the solution and the metal parts and, furthermore,

the system is enclosed in such manner as to limit the force and effect of a possible fire or explosion, it being understood that further safety features are incorporated to prevent the possible occurrence of either.

By modifying my apparatus I can provide means for passing metal objects such as rods, tubes, bars, strips or wires through a continuously flowing jet of electrolyte thereby obtaining a highly satisfactory polish or, alternatively, by providing a stencil of insulating material I may etch or polish sections of the surface of a metal specimen to produce a decorative design. For a more detailed description, reference is made to the accompanying specification and drawings in which:

Figure 1 is a side elevation of certain parts of my apparatus;

Figure 2 is an enlarged sectional view of a portion of Figure 1;

Figure 3 is a wiring diagram of an electrical arrangement that may be employed;

Figure 4 is a perspective view of a compact self-contained apparatus for practicing the invention;

Figure 5 is a fragmentary section showing how a portion of Figure 2 may be modified;

Figure 6 shows by way of example a design that may be produced on a metal surface by my invention;

Figures 7 and 8 are face views of stencil means required for producing the design illustrated in Figure 6;

Figure 9 is a sectional view indicating how the structure in Figure 2 may be modified for electrolytically polishing elongated objects;

Figure 10 is a sectional view indicating how a portion of the apparatus in Figure 2 may be modified;

Figure 11 is a top view of a further modification of a portion of the apparatus illustrated in Figure 2;

Figure 12 is a section of Figure 11 taken along the line 12-12; and

Figure 13 is an enlarged section illustrating more clearly the features shown in Figure 12.

The apparatus shown in the drawings is suggested for the preferred practice of the invention. The parts of the apparatus shown in Figure 1 include a processing chamber generally designated 10, an expansion chamber 11 connected with the processing chamber by a duct 12, both chambers being supported by an upper horizontal wall 13, means generally designated 15 for releasably clamping a metal sample in position for processing, an electrolyte reservoir 16 located below the processing chamber and connected thereto by a drainage tube 17, and a centrifugal pump 18 driven by a motor 20, the pump having its intake side connected with the reservoir 16 by a rubber tube 21 and having its output side connected with the processing chamber 10 by a rubber tube 22.

The processing chamber 10, as best shown in Figure 2, includes an inner receptacle 25 and also includes an outer casing 26, the purpose of which is to support the inner receptacle and to serve as a safeguard against accidents or breakage. The inner receptacle 25 may be made of some suitable metal as indicated in the drawing, for example, lead or a stainless alloy, or alternatively may be formed of glass or porcelain. The outer casing 26, which may be of stainless sheet metal, is flanged for attachment by screws 27 to the underside of the wall 13 and has a large central bottom opening 28. The inner receptacle 25 is closed at the bot-

tom by a large plug 30 of synthetic rubber, or other suitable material which will not be affected by the electrolyte, which covers the opening 28 in the bottom of the casing 26 and serves to support the inner receptacle 25. At the upper end of the receptacle 25 an inner flange 32 supports a wall, or stage, generally designed 33, having a central aperture 35. This upper wall not only closes the upper end of the processing chamber but also is adapted to support a sample S of metal to be treated, the metal being positioned over the opening over the aperture 35. Obviously such an apertured wall may be a side wall rather than a top wall of the processing chamber, but I have found that the best results will be obtained where the apertured wall constitutes the top wall of the chamber. In the preferred practice of my invention on the area of the aperture 35 and, therefore, the area of the sample which will be processed is approximately 78 sq. mm. The upper wall 33 may comprise a layer of glass 36 resting on a suitable gasket 37 together with an upper layer 38 of synthetic rubber or other suitable material of resilient character for sealing contact with the sample S.

In the particular construction shown, the previously mentioned duct 12 is integral with the inner receptacle 25, extends through suitable rubber bushings 39, and turns upward in the expansion chamber 11. Since it is desirable that inflammable or explosive vapors be confined to the interior of the processing chamber 25 and precluded from the expansion chamber 11, suitable means are employed to cut off the expansion chamber except in emergencies signaled by pressure rise in the processing chamber. To this end, I may employ a barrier that will yield or break in response to pressure rise. Thus in Figure 2 a disc 40 of very thin mica or other frangible material is shown in position to close the end of the duct 12, the disc being held in place by a suitable retaining bushing 41. Whenever a disc 40 is ruptured by an excessive pressure rise, a hand-hole cover 42 is removed from the expansion chamber for access to replace the disc.

Preferably the clamping means 15 is designed for quick retaining and releasing operation and is also designed to serve as a contactor making electrical connection with the sample S, it being contemplated that the sample will serve as an electrode in the electrolytic process. The illustrated clamping means 15 includes a post 45 that is fixed to the horizontal wall 13 and is suitably connected to a circuit wire 46. Slidably mounted on the post 45 is a metal block or collar 47 that may be adjustably retained at various positions by a thumb screw 48. A resilient arm or leaf spring 50 of stainless steel or the like extends outwardly from the block 47 and carries at its outer end a suitable sleeve 51 into which is threaded a manually adjustable screw 52. The bottom of the screw makes a ball-and-socket connection with a suitable contact block 53 for exerting pressure against the sample S. The block 53 may be stainless steel.

The tube 22 extending upwardly to the processing chamber 10 from the pump 18 is part of a passage means that in the preferred practice of my invention is adapted to project a fountain of electrolyte against the surface of the sample S at the processing aperture 35, and it is contemplated that the interior of this passage means will be provided with a metal surface to serve ordinarily as the cathode in a direct current electrolytic circuit, or an electrode in an alternating

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current circuit. In the preferred practice of my invention I provide the required interior metal surface by using a suitable metal for a portion of the passage means. To this end the rubber tube is connected to the lower end of a cathode tube 55 of lead, stainless steel or other suitable material extending upwardly in sealing engagement with the rubber plug 30. A circuit wire 56 is shown connected to a terminal 57 on the lower portion of the cathode tube 55. The upper end of the cathode tube 55 is provided with a shoulder 59 adapted to receive and support concentrically a tube of insulating material such as glass. As shown more clearly in Figure 5, the internal diameter of the glass tube 58 is somewhat greater than the minimum diameter of the processing aperture 35 and extends upwardly almost into contact with the walls of the aperture, the purpose being to conduct the electrolyte to the surface of the sample without imparting more than the minimum velocity necessary to attain this objective. It is essential for best results that the crest of the fountain formed by the electrolyte emerging from the tube 58 assume as closely as possible a substantially flat configuration as shown at C in Figure 5. By "relatively flat" is meant a crest that is smoothed-surfaced and convex and preferably with the apex of the crest not substantially greater than one-quarter of an inch above the top of the supporting stage. It is believed that the walls of the processing aperture 35 tend to remove from the fountain the slow moving external sections of the liquid fountain returning them to the container 25, and permitting only the central portion of the fountain having a substantially constant velocity in every portion to contact the sample.

To assist in obtaining a relatively flat crest on the fountain a transverse screen 60 of material such as glass may be disposed adjacent the upper end of the insulating tube 58, although the provision of such screen is optional. The screen 60 may be of conventional mesh form, and, if formed of conductive material such as metal, may be electrically connected to the cathode 55.

A suitable glass tube 61 also extends through the plug 30 and is connected to the drainage tube 17 to drain material from the receptacle 25 into the reservoir or storage vessel 16. It should be noted that the cathode member 55 is movably held by the plug 30. If desired, control of the current may be obtained by varying the distance between the sample S and the upper end of the metal cathode 55 particularly if the electrolyte has a high resistance. However, I prefer to provide other means of regulating the current, since regulation by means of electrode spacing requires an adjustment of the height of the insulating tube 58 and greater reproducibility will be obtained if the electrode spacing is held constant for each type of metal.

The manner in which the apparatus described to this point operates may be readily understood. A sample to be electrolytically processed is secured by the clamping means 15 in position covering and sealing the aperture 35. The desired clamping pressure may be attained by varying the flexure of the leaf spring 50 either by adjustment of the collar 47 or by adjustment of the screw 52. The operator then closes the circuit of the motor 20 to energize the pump 18 whereupon electrolyte from the reservoir 16 flows upwardly through the tube 22 and the cathode tube 55 and is directed through the insulating tube 58 as a fountain

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to the undersurface of the sample S. Upon contacting the sample S, the liquid moving at a low but uniform velocity and presenting a relatively constant velocity in cross section mushrooms outwardly across the face of the sample contacting it evenly and sweeping away bubbles generated in the electrolyte. The electrolyte dropping away from the fountain to the bottom of the inner receptacle 25 drains into the tube 17 for return to the reservoir 16, the capacity of the return drain arrangement being sufficient to prevent any substantial rise in the liquid level in the processing chamber. When physical circulation of the liquid is established, the electrolytic circuit is closed to obtain a flow of electric current between the sample S and the cathode tube 55 through the liquid fountain. When the electrolytic action has been carried far enough, the operator in sequence opens the electric circuit, de-energizes the motor 20, and then removes the sample S.

It will be noted that the processing chamber, and in fact the complete circuit of the electrolyte, is completely enclosed and is sealed for protection of the operator as well as to limit any possible evaporation of the solution. Any inflammable or explosive vapors incidental to the procedure will be confined to the processing chamber. Should accidental ignition in the processing chamber occur to create a hazardous pressure rise, the safety disk 40 will rupture to permit the gases from the processing chamber to be released into the expansion chamber 11 in such manner as to safeguard the operator. The ignition hazard exists only in the processing chamber and it is important to note that in the described mode of operation, only a small portion of the volume of electrolyte employed is present in the processing chamber at any given time. Such an arrangement makes it possible to employ the relatively large body of electrolyte without correspondingly great risk.

Certain factors may be noted as important in keeping the temperature of the electrolyte down to a safe and practical range. One factor is the use of a relatively large body of electrolyte to absorb the generated heat. Other factors are the cooling effect of the fountain of electrolyte in the processing chamber and the cooling means provided by the electrolyte reservoir 16 and the connecting tubes 17, 21 and 22. The cathode, of course, tends to remain at a relatively low temperature because of the flow of cool electrolyte therethrough. The fountain of electrolyte, by being maintained at a lower temperature, not only cools the metal sample but also rapidly conducts heat therefrom thereby preventing burning of the sample and decomposition of the electrolyte. It may also be noted that control of the shape and velocity of the fountain and its crest contributes largely to the production of planar surfaces, and to the elimination of waviness which is characteristically present in electrolytic samples etched by other known apparatuses.

An important advantage of my invention is that it may be practiced with an exceptionally convenient electrical arrangement such as that indicated by the wiring diagram in Figure 3 and which may be embodied in a compact, self-contained, and inexpensive apparatus such as that shown in Figure 4.

The particular electrical arrangement shown in Figure 3 incorporates a plurality of circuits that may be used selectively for energizing the previously mentioned anode wire 46 and cathode

wire 56 with D. C. current for electrolytic polishing, or for energizing the wires with D. C. current for electrolytic etching, or for energizing the wires with A. C. current for electrolytic etching.

The main leads 65 and 66 in Figure 3, which are adapted for plugging into any suitable A. C. source, are controlled by a main switch 67 and are shunted by a suitable lamp 68 to indicate the closed position of the switch. The main leads 65 and 66 are connected by wires 70 and 71 both to the primary of a transformer 69 and to the coil of a normally open safety relay 72 controlled by a safety switch 73. The secondary of the transformer 69 is in series both with the coil of a second normally open safety relay 75 and with the sample S and cathode 55. The contactors of the two safety relays 72 and 75 are connected in series with the previously mentioned anode wire 46 and with an ammeter 77.

The main leads 65 and 66 are connected also by wires 78 and 80 with the previously mentioned motor 23 for driving the pump 18, the motor being in series with a motor switch 81 and the coil of an indicating relay 82. The purpose of the relay is to control a lamp 83 for signaling pump operation.

In the preferred practice of my invention a timer T is employed to provide precise processing intervals and the timer is connected with the main leads 65 and 66 by wires 85 and 86, the timer being in series with both a timer switch 87 and the coil of a normally open relay 88 controlling an indicator lamp 90. The timer exercises control of the processes through a normally open timer relay 91, one contact of which is connected to the previously mentioned cathode wire 56.

The A. C. processing circuit is traced as follows: main lead 65, a control rheostat 92, one blade of a double-pole-single-throw switch 93, a wire 95, the contactor of the timer relay 91, cathode wire 56, cathode 55, the stream or jet of electrolyte, the metal sample S, anode wire 46, the contactor of relay 75, the contactor of relay 72, ammeter 77, a wire 96, the coil of a normally open indicating relay 97 controlling an indicating lamp 98, and the second blade of switch 93 to the second main lead 66. Preferably a voltmeter 100 is placed in shunt, as shown, to indicate the voltage adjustment of the rheostat 92.

To provide D. C. current in the apparatus, I prefer to use some suitable rectifier means instead of a motor-generator set. For example, I may employ a single mercury rectifier tube 101 of a suitable type. The two main leads 65 and 66 are connected to a transformer 102 for heating the cathode of the mercury tube 101 and are also connected to the primary of a transformer 103, a wire 105 being provided for this purpose. Preferably the primary of the transformer 103 is adjustable relative to the number of turns energized, the wire 105 being connected to a sliding contact 106.

One side of the secondary of the transformer 103 is connected by a wire 107 with the same side of the contactor of the timer relay 91 as the previously mentioned wire 95 and the other side of the secondary is connected by a wire 108 with the cathode of the rectifier tube 101.

The D. C. circuit for electrolytic polishing is traced as follows: the secondary of the transformer 103, wire 108 to the rectifier cathode, wire 110 from the plate of the rectifier, a polish-control rheostat 111, wire 112, the coil of a normally open indicating relay 113 for controlling an indicating lamp 114, a switch 115, a wire 116, am-

meter 77, contactors of relays 72 and 75, anode wire 46, sample S, the electrolytic stream, cathode 55, cathode wire 56, the contactor of timer relay 91, and wire 107 back to the transformer secondary. Preferably a voltmeter 117 shunts the two wires 112 and 107 to indicate the voltage setting of the rheostat 111.

To provide a parallel D. C. etching circuit, a wire 118 connects wire 110 with an etch-control rheostat 120, a wire 121 connects the rheostat with the coil of a normally open indicating relay 122 for controlling an indicating lamp 123, and the relay coil is connected to the previously mentioned wire 116 through a switch 125. The voltmeter 126 across the wires 121 and 107 indicates the voltage setting of the rheostat 120.

The compact apparatus in Figure 4, which may for example be approximately three feet high, has a housing or cabinet 130, the upper wall of which is the previously mentioned wall 13 for supporting the concealed processing chamber 10 and the expansion chamber 11. The cabinet 130 may be provided with a suitable door 131 for access to the interior when desired. At the rear edge of the top wall 13 is an inclined instrument panel 132.

On the instrument panel 132 is a suitable knob 133 for interval adjustment of the timer T, and knob 135 for adjusting the contact 106 of the transformer 103. In addition the panel 132 has the following devices that have been previously mentioned: main power input switch 67, main switch indicating light 68, pump switch 81, pump indicating light 93, ammeter 77, voltmeter 117 for the D. C. polishing circuit, voltmeter 126 for the D. C. etching circuit, voltmeter 100 for the A. C. etching circuit, rheostat 111 for the D. C. polishing circuit, rheostat 120 for the D. C. etching circuit, rheostat 92 for the A. C. etching circuit, indicating lamp 114 for the D. C. polishing circuit, indicating lamp 123 for the D. C. etching circuit, and indicating lamp 98 for the A. C. etching circuit.

On the cabinet top 13 in Figure 4 is the clamping means 15 for releasably retaining a metal sample over the aperture 35 of the processing chamber, the hand-hole cover 42 for the expansion chamber, timer switch 87 in the form of a push button, safety switch 73 also in the form of a push button, D. C. polishing switch 115, D. C. etching switch 125, and A. C. etching switch 93. The cabinet top 13 may also be provided with a water fountain 136 for the convenience of the operator, the fountain being used to wash metal sample surfaces before and after electrolytic processing as required.

The manner of using a compact apparatus constructed as indicated by Figures 3 and 4 will be readily apparent. The operator manipulates the clamping means 15 to secure the metal sample over the aperture of the processing chamber as heretofore described, adjusts the polishing rheostat 111 if the reading of the voltmeter 117 indicates adjustment should be made, closes the switch 81 to start the pump, closes the D. C. polishing switch 115, adjusts the timer T by means of the knob 133 for whatever time interval is desired, presses the button safety switch 73 with one hand and presses the timer button switch 87 with the other hand.

It is to be noted that the two switch buttons 73 and 87 are spaced too far apart to be manipulated simultaneously by one hand, the purpose of such spacing being to require both hands of the operator and thereby make it impossible for

the operator to inadvertently touch the clamping means 15 while exposed conducting material of the clamping means is energized by electric current.

A relay 75 controlled by the electrolytic jet prevents closing of the polishing or etching circuits in the absence of a stream of electrolyte from the pump 18 which electrolyte furnishes a current conducting connection between the cathode 55 and the sample S and serves as a safeguard against the creation of an arc in the process chamber 25, which might result in fire or explosion, or damage to the sample as by pitting. The ammeter 77 indicates the amperage of whatever electrolytic circuit is employed.

When the timer light 90 goes out to indicate the end of the predetermined interval of polishing, the operator may immediately etch the sample without removing the sample from the apparatus. I have discovered that many materials may be etched simply by continuing the electrolytic process very briefly with substantially reduced voltage and amperage. It is necessary merely for the operator to open the D. C. polish switch 115, close the D. C. etch switch 125, adjust the rheostat 120 guided by the voltmeter 126, adjust the timer T for the shorter processing period, and then again close the push button switches 73 and 87. When the timer breaks the circuit at the end of the desired etching period, the sample may be released from the clamping means 15 and briefly washed at the water fountain 136.

If desired, the three switches 93, 115 and 125 may be biased by spring action to open position and require manual pressure for closing. In such case, the switch 73 is omitted since the two switches 115 and 125 serve the safety feature of requiring use of one of the operator's hands.

In some instances etching with an A. C. current instead of D. C. current is desirable. In such event, guided by the voltmeter 100, the operator sets the rheostat 92, adjusts the timer, closes the double-pole switch 93, and depresses the two push button switches 73 and 87. If it is desirable to employ chemical etching, the sample will, of course, be removed from the apparatus at the end of the polishing interval.

While various electrolytic solutions may be employed in various practices of my invention, I prefer to use a mixture including perchloric acid and a suitable alcohol. Nearly any kind of alcohol will be found satisfactory. Preferably water is added primarily to increase the conductivity of the mixture, ordinary tap water being preferred over distilled water.

As an example of a preferred electrolytic formula, I may employ the following:

800 cc. of methyl alcohol with 3% ether  
146 cc. of tap water  
54 cc. of perchloric acid (70-72% concentration)

Another electrolytic solution, adapted for use in polishing stainless steel, is sulfuric acid 15%, phosphoric acid 63%, and water 22%.

In employing the described apparatus and the preferred solution for electrolytically processing a metal surface of approximately 78 sq. mm., the cathode tube is adjusted to space the metal of the cathode tube 55 approximately  $1\frac{1}{4}$  inches plus or minus  $\frac{1}{8}$  of an inch from the surface of the sample S and the electrolyte is maintained at a temperature below 90° F. The glass or insulating tube 58 extends upwardly to within approximately  $\frac{1}{2}$  mm. of the wall of the processing aperture 35. A supply of 12 or more quarts of

electrolyte is placed in the reservoir 16 and the electrolyte is pumped through the cathode tube 55 at approximately 1 quart per minute, the rate of flow being controlled to yield a fountain having a relatively flat crest which projects upwardly beyond the upper surface of the outer wall 33 of the processing chamber from  $\frac{1}{8}$  to  $\frac{1}{4}$  of an inch when the sample S is not in place. Preferably the power adjustment permits a range of current up to 10 amperes and independently a range up to 300 volts potential, it being understood that this can be varied either by the apparatus or by a movement of the cathode 55 when required by the circumstances.

It should be understood that the above values are given merely to illustrate preferred and satisfactory practices, and should not be construed as absolute or limiting values.

D. C. current of from 2 to 3 amperes at 175 to 200 volts may be used for the electrolytic polishing of various types of steel. For most of the aluminum alloys, D. C. current of 2.5 to 4 amperes may be employed at the same voltage. For brass or bronze alloys the amperage should be raised to the range of 2.5 to 5 amperes. Pure copper, pure nickel, pure iron and other metals in pure state can be successfully polished by varying the current values within the given ranges. With few exceptions the values mentioned result in polished surfaces. To etch steel, direct current of 0.5 to 0.75 ampere at approximately 38 volts may be used, or instead, alternating current of only a fraction of an ampere may be used at 110 to 220 volts.

The high current values recited above and the high resistance of the electrolytic solution result in the generation of considerable heat which if not adequately dissipated results in burned or pitted metal surfaces. The described method of circulating the electrolyte with special reference to the projection of a fountain of the solution against the sample effectively dissipates the generated heat and keeps the sample surface cool. The mushrooming of the liquid stream against the metal surface carries away gases released in the process and prevents the formation of any appreciable number of retained bubbles on the metal surface.

The electrolytic polishing may require from 8 to 30 seconds and the subsequent etching only a fraction of a second. The entire procedure of polishing and etching a sample may be cut down to as low as 10 seconds. The time required for mounting and dismounting the sample is negligible.

An important advantage of my process is that additional time is saved over prior art procedures since the sample need not be finely ground in preparation for electrolytic polishing. Heretofore it has been a common practice to carry a sample through a number of preparatory operations prior to the polishing step, a typical series of operations including semi-rough grinding, successive hand-sanding on successive abrasive belts, and lapping on one or two lapping wheels, the whole preparatory procedure requiring say twenty minutes. In contrast, a sample may be prepared for my polishing procedure in a single operation with an 80 mesh abrasive belt, or with a rubber wheel.

The described apparatus is so simple in operation and incorporates so many safeguards that a person of no technical skill can learn to operate the apparatus rapidly and efficiently with less than five minutes of instruction. The standards of a "research" polish may be attained by a novice

repeatedly because of the controlled conditions inherent in the operation of the apparatus. The control conditions are important not only for insuring good results but also for insuring uniform results for any number of samples. Since apparatus factors are constant including the processing area, the path of electrolytic current, the volume and rate of flow of the electrolyte, the amperage and voltage of current, and the process intervals, the human equation is entirely eliminated. For a large run of samples of a given character, no adjustments of the rheostats are necessary so that the procedure narrows down to merely the operation of switches with perhaps adjustment of the timer when electrolytic etching follows electrolytic polishing. By keeping a record of the adjustments employed for various runs of samples, given procedures may be readily duplicated and standards of procedure established.

In general, the current flow through the electrolyte at a given potential will vary with the proportion of perchloric acid and will vary also with the proportion of the water content. Thus the current at a given potential dropped to 0.3 ampere when the electrolyte comprised 99% alcohol and 1% perchloric acid with no water present. At the same potential 3.0 amperes of current passed through an electrolyte comprising 40% alcohol, 20% perchloric acid and 40% water. At low alcohol content, however, considerable gas is released and pitting of the samples is likely to occur, both for aluminum and steel samples. A relatively high proportion of alcohol increases the resistivity of the electrolyte but minimizes gas formation and reduces the possibility of pitting. Electrolytic solutions of high alcohol content work well not only on steel and aluminum but also on bronze.

While employing an electrolytic solution with the perchloric acid as high as 20% by volume of the solution produces excellent results, such a solution is so highly corrosive that for the sake of the operator a perchloric acid concentration of approximately 5% is ordinarily preferred. Raising the perchloric acid content above 5% causes the metal to be removed faster and in special instances may produce desirable results that cannot be obtained at lower acid concentrations. For extremely accurate work, however, mixtures of low acid content and high alcohol content are indicated.

While the described wiring diagram incorporates a single timer for three different circuits, namely, a D. C. circuit for polishing, a D. C. circuit for etching and an A. C. circuit for etching, obviously separate timers for the different circuits may be employed. Since a polishing operation extends over several seconds while an etching operation requires only a fraction of a second, such separate timers may be specialized for the particular time ranges involved. The use of separate timers for the different circuits will eliminate the necessity for timer adjustment every time a change is made from one circuit to another.

The purpose of Figure 10 is to indicate how the described apparatus may be modified by using a mechanical arrangement for operating the relay 76. In the arrangement shown in Figure 10, it is contemplated that a lever 140 responsive to the flow of the electrolyte will open and close a switch indicated in dotted lines at 139, controlling the safety relay 75, the switch being substituted

for the low voltage circuit through the sample S and cathode 55.

In the particular arrangement shown in Figure 10, a relatively short cathode tube 141 in a processing chamber 142 carries the previously mentioned glass extension 48 directed towards the processing aperture 35 in the wall 33 as previously described.

Surrounding the cathode tube 141 is a movable receptacle 145, the receptacle being cup-shaped with a bottom aperture 146 surrounding the cathode tube. The receptacle 145 is carried by the previously mentioned lever 140 and the lever in turn is carried by a shaft 147. The shaft 147 extends through the chamber wall and is operatively connected to the switch 139.

The lever 140 is suitably biased towards an upper position either by gravity or spring loading but the bias is overcome by loading the receptacle 145 with electrolyte. In the absence of electrolyte flow, the cup is in the upper position shown in full lines in Figure 10. When the electrolyte begins the flow at a rate sufficient to contact the sample, it drops from the sample into the receptacle 145 at a rate greater than electrolyte can drain from the receptacle through the annular clearance between the cathode tube 141 and the receptacle aperture 146. Consequently the liquid level in the receptacle 145 rises and the lever 140 is weighed down to close the switch 139. Upon the cessation of electrolyte flow against the sample, the receptacle 145 drains quickly to permit the lever 140 to rise and thereby open the switch 139.

Either the low voltage control circuit of Figure 3 or the alternative switch arrangement of Figure 10 serves the important function of minimizing fire hazard. The preferred electrolyte is so highly inflammable that any arcing will start violent combustion.

Figure 5 indicates how the structure in Figure 2 may be modified by substituting a wall, or stage generally designated 150, for the previously described wall or stage 33. The substituted wall 150 may be in the form of a glass plate having a central aperture 151 to expose a sample S to electrolytic action. The glass plate is additionally apertured to provide one or more drainage ports 152 positioned away from the sample S, preferably four such ports being provided.

It is contemplated that a small portion of the fluid from the stream of electrolyte impinging on the sample at the aperture 151 will flow radially outward over the outer surface of the glass plate to return to the interior of the processing chamber 25 through the drainage ports 152. The outer surface of the glass plate may be roughened to permit fluid to flow radially outward between the bottom surface of the sample and the upper surface of the glass plate, or channels 154 extending radially outwardly from the processing aperture may be formed in the upper surface of the glass plate for similar purpose. Under some conditions such radial flow to the outer drainage ports is desirable to prevent a gas pocket from forming in the aperture 151. As in other forms, the minimum diameter of the aperture 151 should be less than the internal diameter of the tube 58.

It will be noted that Figure 5 illustrates an approximation of the desired shape of the crest C of the foundation of electrolyte shown with the sample S removed. A slight convexity, such as that illustrated, has not been found objectionable, but every effort must be made to approach

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a plane crest. This is best attained through the use of low velocities and the use of aperture walls to remove the outer sections of the fountain. Failure to control the shape of the crest, or use of relatively high velocities, will result in inconsistent and usually unsatisfactory results.

Figure 9 indicates how the structure shown in Figure 2 may be modified to serve as means for electrolytically polishing or otherwise electrolytically treating elongated objects, such as wires, rods, strips, bars or tubes. The particular arrangement shown is designed for electrolytically polishing a metal rod R.

Figure 9 shows an inner receptacle 155 corresponding to the inner receptacle 25 of Figure 2. The inner receptacle 155 defining the processing chamber has a removable cover generally designated 156 in the form of an inverted cup having a radial flange 157 for bolting to the inner receptacle 155. Such a cover member may be fabricated from glass. The cover 156 has two coaxial apertures 160 and 161 to slidably receive the rod R so that a shifting portion of the rod may be enclosed for electrolytic processing. Preferably the two apertures 160 and 161 are provided with rubber bushings 162 to minimize the escape of electrolyte from the interior of the processing chamber. Preferably the radial flange 157 is formed with an annular rib 163 to provide an annular drainage groove 165 for collecting any electrolyte that may escape through the apertures 160 and 161, the collected electrolyte draining back into the processing chamber through one or more drainage ports 166.

Mounted inside the cover 156 of the processing chamber is a T-shaped passage member 167 of lead, stainless steel or other suitable material, the end of the passage member surrounding the aperture 160. The body or stem of the T-shaped passage member 167 is shown telescoped over the reduced upper end of a metal cathode 168 corresponding to the previously described metal cathode 55 in Figure 2. For connecting the rod R into a circuit as anode, a suitable brush 170 is provided for contact with the rod at a suitable location. The rest of the apparatus, suggested by Figure 9, is constructed as shown in Figure 2.

The manner in which a length of rod R is electrolytically processed by means of the apparatus shown in Figure 9 may be readily understood from the above description. The rod is shifted progressively through the two apertures 160 and 161 in the direction indicated by the arrow while a stream of electrolyte is pumped upward into the T-shaped passage member 167 and while electric current is flowing between the metal wall of the passage member 167 and the enclosed rod R, the current flowing through the stream of electrolyte.

Figures 6, 7 and 8 indicate how my method and apparatus may be employed to apply designs to metal surfaces, which designs may be ornamental or may be in the form of letters or numbers. The design shown in Figure 6, for example, is a formal or conventional design for a flower having a dark center 171 and light petals 172.

The first step in applying the design shown in Figure 6 is to replace the wall 33 of Figure 2 with a wall 173 (Figure 7) that differs from wall 33 only in having a plurality of radially positioned apertures 175 instead of the single central aperture 35. The radial apertures 175 conform to the areas of the petals 172 of the desired design. The metal surface to be decorated is placed

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against the outside surface of the wall 173 and the areas of the metal surface at the radial apertures 175 are electrolytically polished in the manner heretofore described.

After the polishing operation is completed to produce the pattern of light-colored petals 172, the metal surface is removed and a wall 176 (Figure 8) is substituted for the wall 173, the wall 176 having a single central aperture 177 of the same configuration as the dark center 171 of the design. The metal article to be decorated is then placed against the outer surface of the wall 176 with the aperture 177 concentric to the previously applied light petals 172. The metal surface of the object to be decorated is then subjected to a brief etching operation through the aperture 177 in the manner heretofore described. As a result, the metal surface will have the design shown in Figure 6, the areas of the petals 172 being lighter than the untreated metal surface and the center 171 of the design being darker than the untreated metal.

In some practices of my invention for applying designs to metal surfaces, anodic dyes may be employed, the metal surface being treated or processed electrolytically and dyed. By employing successive stencils, as explained above, multi-color designs may be obtained.

Figures 11, 12 and 13 illustrate a modified form of sample-supporting wall for the container 25 and in this modification comprises a generally circular disk 180 of glass having an axially disposed frusto-conical processing aperture 181, the uppermost portion of which may be cylindrical as shown at 182. A second disk 183 of glass, or similar material, is secured to the rear face of the disk 180 by a suitable cement and has formed therein an opening 186 adapted to register with the opening 181. The lower portion of the opening 186 is generally cylindrical while the upper portion is conical forming an extension of the walls of the aperture 181. Either the lower face of the disk 180 or the upper face of the disk 183 has formed therein a plurality of grooves 184 extending radially from the aperture 181 or the opening 186 forming conduits which communicate with a plurality of discharge ports 185 extending through the lower disk 183. Thus it may be seen that the grooves 184 constitute internal conduits properly disposed to rapidly conduct used electrolyte, together with accumulated gas bubbles, from the surface of a sample disposed over the aperture 181. It is understood, of course, that the insulating tube 58 extends upwardly into the opening 186 approximately to the end of the cylindrical section in such manner that a small quantity of electrolyte will be permitted to flow between the lips of the tube 58 and the opening 186. If desired, the disk 180 may be provided with a facing of resilient material such as rubber similar to that previously described. The effect of this structure is to permit a somewhat increased flow of electrolyte since its ability to dispose of bubbles formed in the process is somewhat greater than is the case of other forms of supporting walls hereinbefore illustrated.

The preferred practice of my invention set forth in specific detail herein for the purpose of disclosure will suggest to those skilled in the art various changes and substitutions under my basic concept and I reserve the right to all such departures from my description that properly lie within the scope of my appended claims.

I claim:

1. In an apparatus for electrolytically treat-

ing a surface of metal, a support having an aperture therein denning the portion of the surface of the object to be treated, means for directing a solid column of electrolyte through the aperture against the surface of the object, said means including a conduit having a discharge orifice somewhat wider than the said aperture-defining surface and also including an electrolyte discharge zone for removing an external portion of the said stream prior to its contacting the said surface, a cathode in contact with the electrolyte, means for establishing an electrical circuit including the cathode, the object, and the electrolyte, and means including grooves formed in a surface of the support extending radially from said aperture for conducting electrolyte from the surface being treated, said conduit being substantially vertically positioned in alignment with the aperture over which said object is supported.

2. In an apparatus for electrolytically treating a surface of a metal object, a wall adapted to support the object on one side thereof, said wall having an aperture and a plurality of radially disposed internal channels extending from the aperture to the other side of the wall, means including a conduit having a discharge orifice somewhat wider than the said aperture for projecting electrolyte through the aperture in the form of a smooth surfaced column into contact with the metal object, and a cathode in contact with the electrolyte whereby electrolyte is conducted uniformly and rapidly from the surface of the object, said conduit being substantially vertically positioned in alignment with the aperture over which said object is supported.

3. In an apparatus for electrolytically treating the surface of a metal object, a wall adapted to support the object, said wall having an aperture and a plurality of grooves radiating from said aperture and terminating in drain openings extending through said wall, conduit means for projecting electrolyte through the aperture in the form of a smooth-surfaced column into contact with the metal object, and a cathode in contact with the electrolyte whereby electrolyte is conducted uniformly and rapidly from the surface of the object, said conduit means being substantially vertically positioned in alignment with the aperture over which said object is supported.

4. In apparatus for electrolytically treating a surface of a metal object, a substantially horizontal support of substantial thickness having an aperture therein over which the object is placed, and which aperture defines the surface of the object to be treated, said aperture being enlarged from below, a nozzle extending into the enlarged lower part of the aperture with clearance thereabout, and means for projecting a low velocity non-particulated stream of electrolyte upwardly through the nozzle into contact with the exposed surface of the object, the cross-sectional area of the stream being substantially as great as the area of the surface to be treated said clearance between the nozzle and the aperture permitting excess electrolyte to flow away from the object and be recaptured.

5. In apparatus for electrolytically treating the surface of a metal object, the combination of a stage adapted to support the object and having an aperture therein defining the surface of the object to be treated, a nozzle in substantial alignment with the aperture for delivering a stream of electrolyte to said surface, said

stage having at least one laterally extending passage communicating with said aperture for carrying away electrolyte after contacting the metal surface.

6. In apparatus for electrolytically treating a surface of a metal object, a substantially horizontal support of substantial thickness having an aperture therein over which the object is supported, and which aperture defines the surface of the object to be treated, a nozzle in substantial alignment with said aperture and in close proximity thereto, means for delivering a solid stream of electrolyte upwardly through the nozzle into contact with the exposed surface of the object, the cross-sectional area of the stream being substantially as great as the area of the surface to be treated, and radial passages in the support communicating with the aperture for conducting away electrolyte.

7. In apparatus for electrolytically treating a surface of a metal object, a substantially horizontal support of substantial thickness having an aperture therein over which the object is placed, and which aperture defines the surface of the object to be treated, with said aperture being enlarged from below, a nozzle extending into the enlarged lower portion of the aperture with clearance therebetween, said nozzle having a discharge orifice coaxial with but of greater cross-sectional area than the exposed area of the surface of said object, and means for delivering a low velocity non-particulated stream of electrolyte upwardly through said nozzle into contact with said surface, the enlarged nozzle orifice in conjunction with the clearance between the nozzle and the wall of said aperture causing the outer annular portion of the upwardly moving stream to be sheared from the stream, thereby to have that portion of the stream which contacts said surface characterized by substantially uniform velocity throughout its cross-sectional area and by having a substantially flat crest in free flow.

8. In apparatus for electrolytically treating a surface of a metal object, a horizontal support of substantial thickness having an aperture therein over which the object is placed, and which aperture defines the surface of the object to be treated, with said aperture being enlarged from below, a nozzle extending into the enlarged lower portion of the aperture with clearance therebetween, said nozzle having a discharge orifice coaxial with but of greater cross-sectional area than the exposed area of the surface of said object, and means for delivering a low velocity non-particulated stream of electrolyte upwardly through said nozzle into contact with said surface, the enlarged nozzle orifice in conjunction with the clearance between the nozzle and the wall of said aperture causing the outer annular portion of the upwardly moving stream to be sheared from the stream, thereby to have that portion of the stream which contacts said surface characterized by substantially uniform velocity throughout its cross-sectional area and by having a substantially flat crest in free flow, and lateral passages in the support communicating with the aperture for conducting away electrolyte which does not escape through said clearance.

9. In apparatus for electrolytically treating a surface of a metal object, a substantially horizontal support having an aperture therein over which the object is placed, and which aperture defines the surface of the object

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to be treated, a nozzle in substantial alignment with said aperture and positioned in close proximity to said surface, means for projecting a low velocity non-particulated stream of electrolyte upwardly through the nozzle into contact with the exposed surface of the object, and a fine mesh screen in the nozzle for imparting to the stream substantially uniform cross-sectional velocity, the velocity of the stream and the size of said mesh being such that the projected stream maintains its non-particulated character as it contacts the object being treated.

10. The method of anodically removing metal from the surface of a metal object which comprises the steps of moving a non-particulated column of electrolyte upwardly through an opening in a horizontal stage toward said object, controlling the flow of the electrolyte in said column so that in the absence of the object, the crest extends above the top surface of the stage and is characterized by having a smooth-surfaced, convex form, contacting the object with said stream, removing electrolyte which has contacted the object by conducting it radially outwardly, and passing electric current through said stream with said object connected as anode.

11. The method of anodically removing metal from the surface of a metal object which comprises the steps of moving a non-particulated column of electrolyte upwardly through an opening in a horizontal stage toward said object, controlling the flow of the electrolyte in said column so that in the absence of the object, the crest extends above the top surface of the stage and is characterized by having a smooth-surfaced, convex form, adjusting the velocity of said column so that in the absence of the object the crest of the stream will not be substantially greater than one-quarter of an inch above the top surface of the stage, contacting the object with said stream, removing electrolyte which has contacted the object by conducting it radially outwardly, and passing electric current through said stream with said object connected as anode.

12. The method as set forth in claim 10 in which the control of the electrolyte flow in the column is effected by removing the outer periphery of the column.

13. The method as set forth in claim 10 in which the control of the electrolyte flow in the column is effected by interposing a screen in the column adjacent to said opening in the stage to thereby render more uniform the velocity of all portions of the stream which contact said object.

14. In apparatus for anodically removing metal from the surface of a metal object, the combination of a substantially horizontal stage having a frusto-conical, vertical opening therethrough with the larger diameter portion of the opening facing downwardly, a conduit projecting upwardly into the lower portion of said frusto-conical opening and terminating short of the top surface of said stage, but having the upper end of the conduit spaced from the walls of said opening to provide a passageway therebetween, and means for forcing a column of electrolyte upwardly through said conduit with sufficient force to cause the crest of the column to extend above the top surface of the stage.

15. The apparatus as set forth in claim 14 in which radial passages communicating with said vertical opening are formed in the stage ad-

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jacent the top surface thereof for conducting away electrolyte.

16. The apparatus as set forth in claim 14 in which the upper portion of the conduit is made of insulating material.

17. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed chamber including an apertured top wall, means for supporting the object to be processed on the exterior of said top wall over said aperture, means including a nozzle within the chamber for projecting a solid stream of electrolyte upwardly through said aperture into contact with the object, a cathode positioned to contact the electrolyte while the electrolyte impinges against the object, and circuit means for connection with said cathode and said object to cause current flow through said projected stream.

18. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed chamber including an apertured top wall, means for supporting the object to be processed on the exterior of said top wall over said aperture, means including a nozzle within the chamber for projecting a solid stream of electrolyte upwardly through said aperture into contact with the object, a cathode positioned to contact said stream before the stream impinges against the object, and circuit means including a low voltage control circuit for applying high voltage between said object and said cathode only when the object and cathode are bridged by electrolyte.

19. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed chamber including an apertured top wall, means for supporting the object to be processed on the exterior of said top wall over said aperture, a tubular passage in said chamber directed upwardly towards said aperture, the interior of said passage being provided with a metal surface, means to cause a solid stream of electrolyte to flow through said passage thereby to form a jet of electrolyte flowing upwardly through said aperture and impinging on said object, and means for connection with said object and said metal surface to form an electric circuit including said jet, said metal surface being connected in said circuit as a cathode.

20. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed chamber including an apertured top wall, means for supporting the object to be processed on the exterior of said top wall over said aperture, a tubular passage in said chamber directed upwardly towards said aperture, the interior of said passage being provided with a metal surface, means to cause a solid stream of electrolyte to flow through said passage thereby to form a jet of electrolyte flowing upwardly through said aperture and impinging on said object, main circuit means for connection with said object and said metal surface to form an electrolyzing circuit including said jet, and a safety circuit including a relay having its contacts in series with the main circuit for energizing said electrolyzing circuit after the object and metal surface are bridged by said jet, said metal surface being connected in said circuit as a cathode.

21. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed chamber including an aper-

tured top wall, means for supporting the object to be processed on the exterior of said top wall over said aperture, a tubular passage in said chamber directed upwardly towards said aperture, the interior of said passage being provided with a metal surface, means to cause a solid stream of electrolyte to flow through said passage thereby to form a jet of electrolyte flowing upwardly through said aperture and impinging on said object, means for connection with said object and said metal surface to form an electrolyzing circuit including said jet, a normally open switch in said circuit to prevent current flow between said object and said metal surface, and means to close said switch in response to jet flow of the electrolyte, said metal surface being connected in said circuit as a cathode.

22. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed chamber having a top wall provided with an aperture therein surrounded by insulating material, conducting means above said top wall for releasably clamping said object over said aperture in a position to close the aperture, means including a nozzle within the chamber for projecting a solid stream of electrolyte upwardly through said aperture into contact with the object, a cathode positioned to contact the electrolyte while the electrolyte impinges against the object, and circuit means for connection with said cathode and said clamping means to cause current flow between the cathode and the object through said projected stream.

23. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed processing chamber including an apertured top wall, means for supporting the object to be processed on the exterior of said top wall over said aperture, means including a nozzle within the processing chamber for projecting a solid stream of electrolyte upwardly through said aperture into contact with the object, a cathode positioned to contact the electrolyte while the electrolyte impinges against the object, circuit means for connection with said cathode and said object to cause current flow through said projected stream, and a second chamber communicating with said processing chamber and separated therefrom by a frangible wall to provide an expansion space to prevent hazardous pressure rise in said processing chamber in the event of combustion therein.

24. In an apparatus for electrolytically polishing or etching the surface of a metal object, a substantially closed chamber including an apertured top wall, means for supporting the object to be processed on the exterior of said top wall over said aperture, means including a nozzle within the chamber for projecting a solid stream of electrolyte upwardly through said aperture into contact with the object, a cathode positioned to contact the electrolyte while the electrolyte impinges against the object, and circuit means for connection with said cathode and said object to cause current flow through

said projected stream, said circuit means including a timer effective to cause energization of said circuit for time periods of predetermined duration.

25. In an apparatus for electrolytically treating metal surfaces, an apertured plate for supporting a metallic object to be treated, means containing a body of electrolyte beneath said plate, means for projecting a column of electrolyte from said body onto the exposed surface of the object overlying the aperture in said plate, a main circuit including said body of electrolyte, said column and said object arranged to pass an electric current between said column and said object across said exposed face of the object, a relay having contacts included in said circuit for controlling the latter, and auxiliary circuit means actuated by the impingement of electrolyte upon said object for controlling said relay to close said main circuit, whereby energization of said main circuit is dependent upon the column of electrolyte being in contact with said object.

26. In an apparatus for electrolytically treating metal surfaces, an apertured support for an object to be treated, means for holding such an object upon said support with a surface of said object exposed through said aperture, a chamber disposed beneath said support, an electrolyte container disposed generally below said chamber, a cathode electrode secured by said chamber and having a passageway for electrolyte, means for projecting electrolyte from said container through said passageway, a shoulder on said electrode, and a conduit telescoped over said shoulder and extending upwardly to a point adjacent the aperture in said support, whereby electrolyte projected through said passageway is directed toward the surface of said object exposed through said aperture.

CLARENCE W. HANGOSKY.

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