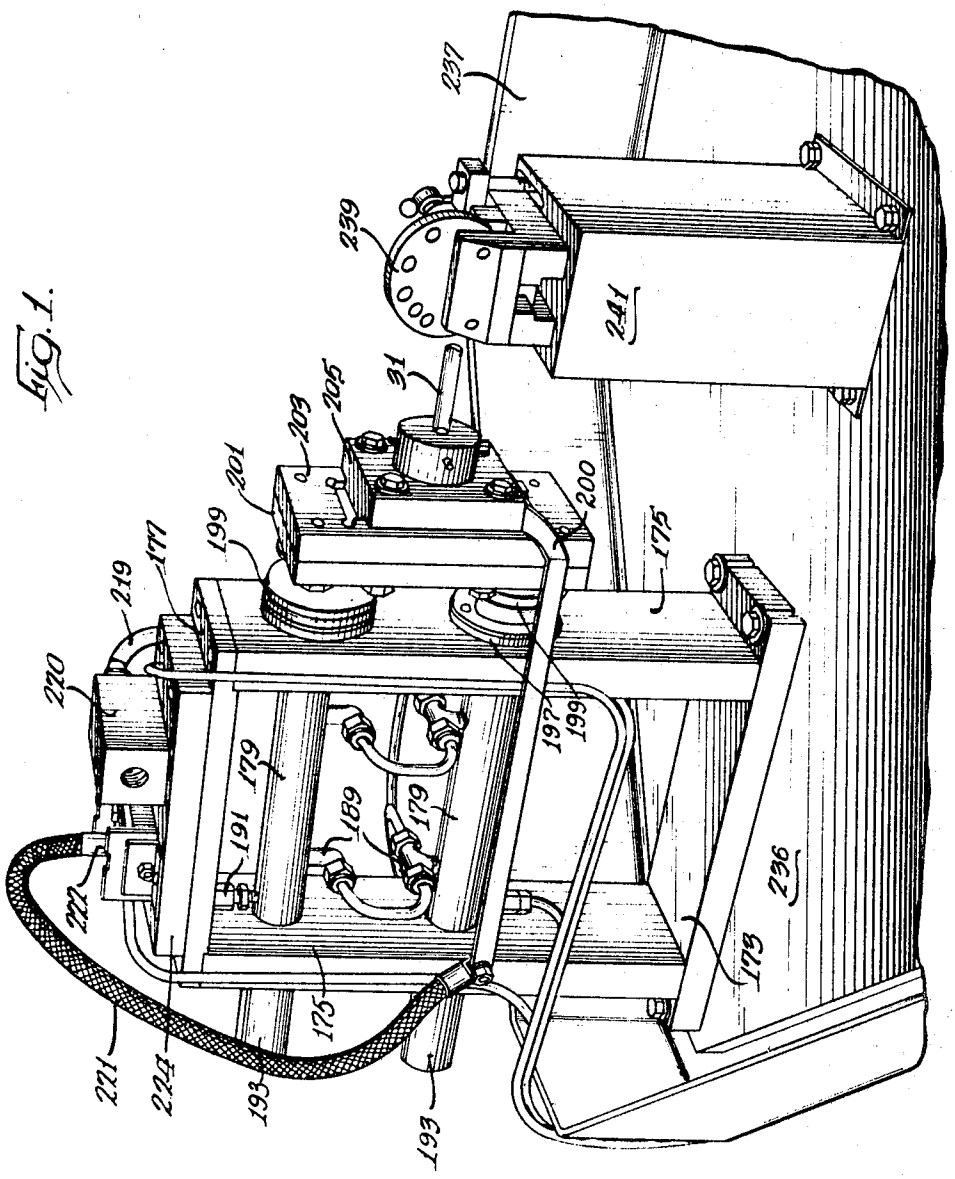
May 13, 1969 L. A. WILLIAMS 3,444,070

ELECTROLYTIC SHAPING APPARATUS

Original Filed Nov. 10, 1958 Sheet 1 of 3

Fig. 1.



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ELECTROLYTIC SHAPING APPARATUS

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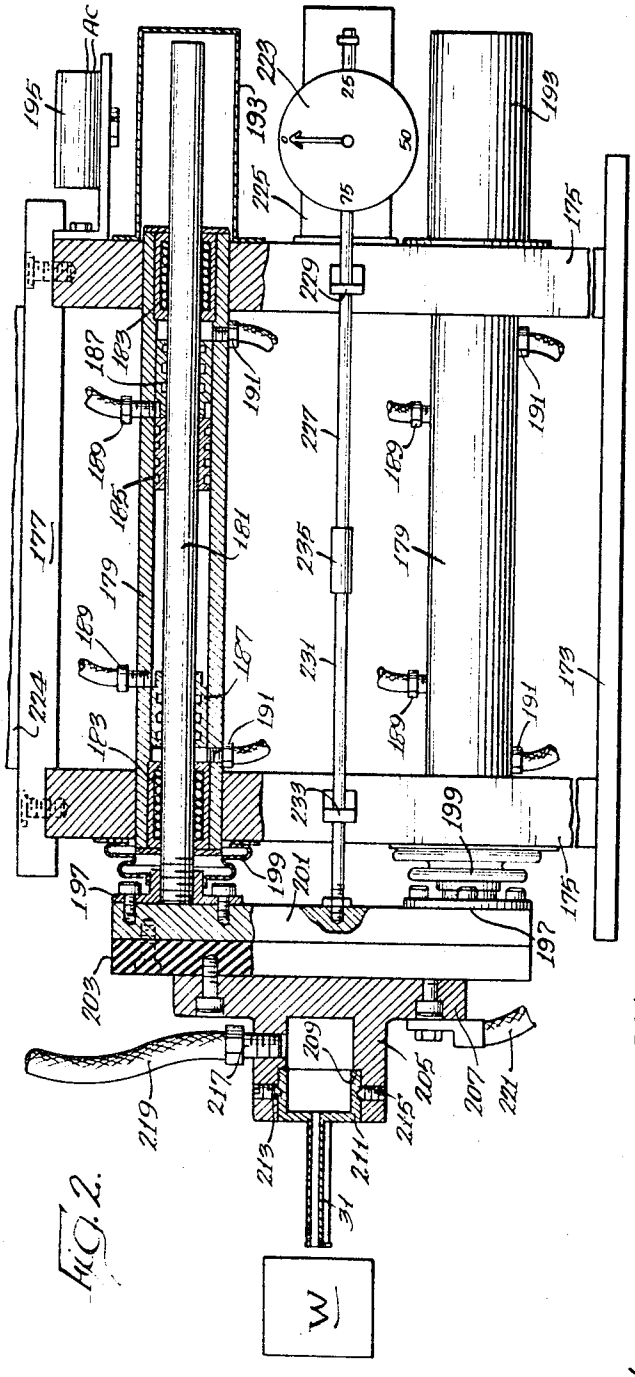


FIG. 2.

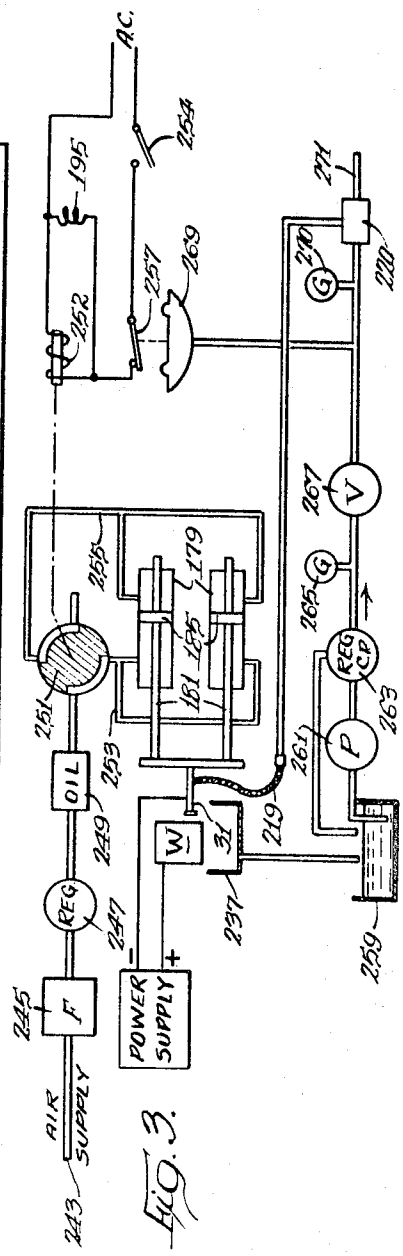


FIG. 3.

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Original Filed Nov. 10, 1958 Sheet 3 of 3

Fig. 4.

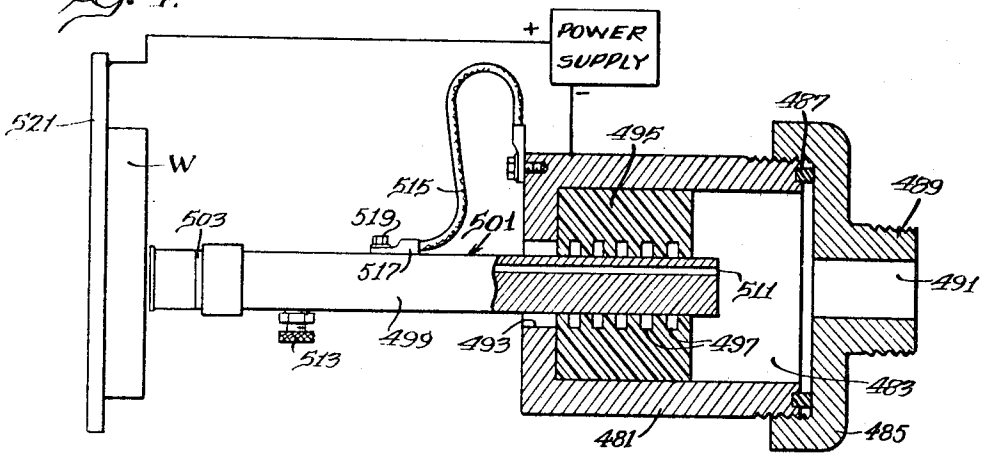
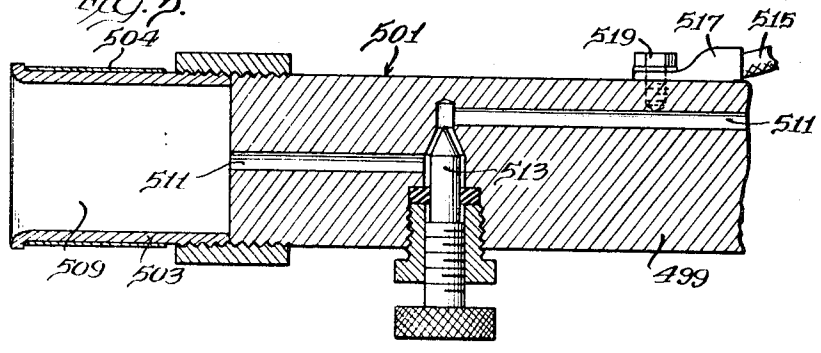


Fig. 5.



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United States Patent Office 3,444,070
Patented May 13, 1969

3,444,070

ELECTROLYTIC SHAPING APPARATUS

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Application Dec. 8, 1961, Ser. No. 158,042, which is a division of application Ser. No. 772,960, Nov. 10, 1958, now Patent No. 3,058,895, dated Oct. 16, 1962. Divided and this application July 25, 1966, Ser. No. 567,690
Int. Cl. B23p 1/14
U.S. Cl. 204—224 11 Claims

This application is a division of my application Ser. No. 158,042, filed Dec. 8, 1961, now U.S. Patent 3,276,987, entitled "Electrolytic Shaping Apparatus," which in turn is a division of my application Ser. No. 772,960, filed Nov. 10, 1958, entitled "Electrolytic Shaping," now issued into Patent No. 3,058,895, dated Oct. 16, 1962.

It has long been known that metal and metalloid materials may be removed by electrolytic attack in a configuration where the metal or metalloid workpiece is the anode in an electrolytic cell. This principle has been used industrially to some degree for the removal of defective plating and the like, and is sometimes referred to as "stripping." It has also been used to some extent for electrolytic polishing in which application, however, the principal purpose is to produce a smooth finish with a minimum removal of the work material. Here the purpose is to remove substantial amounts of metal rapidly and with accuracy.

In the present instance, the term "metalloid" is used somewhat specially in referring to those electrically conductive materials which act like metals when connected as an anode in an electrolytic cell, and are capable of being electrochemically eroded. The term as used here and in the claims includes metals and such similarly acting materials as tungsten carbide, for instance, and distinguished from such conductive nonmetalloids as carbon.

George F. Keeleric has proposed in his Patent No. 2,826,540, issued Mar. 11, 1958, for "Method and Apparatus for Electrolytic Cutting, Shaping and Grinding" the use of electrolysis in conjunction with a metal bonded, abrasive bearing, moving electrode, and the method and apparatus of this Keeleric patent have found extensive industrial use.

The present invention departs from the teachings of Keeleric in utilizing relatively fixed or slow moving electrodes without abrasive, and is intended for work of a quite different character, as will appear in the detailed description of the invention which follows.

In general, in the present invention an electrode quite frequently a hollow electrode, is advanced into the work material by mechanical means while electrolyte is pumped through the work gap between the electrode and the work, and at times the hollow portion of the electrode, under substantial pressure. In some circumstances the side walls of the electrode are protected by an insulating material so as to minimize removal of work material except where desired. Various forms of electrodes are used for different kinds of work, and likewise different techniques of advancing the electrode toward and into the work material are used, depending upon the nature of the operation to be performed. An important aspect of the invention lies in providing electrodes in which a flow of electrolyte betwen the electrode and the work is maintained at high velocity and across a short path between the point of entry and the area of exit regardless of the overall size of the electrode. An electric current is supplied so that current passes from the electrode, which is negative, through the electrolyte to the workpiece, which is positive. For purposes of shaping the electrodes, direct

current may be passed in the opposite sense to make the electrode positive. In some instances, alternating current may be used.

Among the objects of the invention are the following:

To provide novel apparatus for rapid removal of work material by electrolytic means;

To provide automatic means for advancing electrodes toward and into the work material; and

To provide novel mechanism for accomplishing variable feed rates for advancing electrodes toward and into work material for electrolytic removal thereof.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawings, wherein

FIG. 1 is a perspective view of an electrolytic shaping apparatus which inherently advances the electrode into the work at the proper rate;

FIG. 2 is a side view, partly in section, of the apparatus of FIG. 1;

FIG. 3 is a diagrammatic representation of the electrical, pneumatic, and electrolyte supply system for the apparatus of FIGS. 1 and 2;

FIG. 4 is a fragmentary vertical sectional view through apparatus of the present invention, which uses the hydraulic pressure of the electrolyte for advancing the electrode into the work at the proper rate; and

FIG. 5 is a fragmentary sectional view, on an enlarged scale, showing the lower portion of the apparatus of FIG. 4.

FIGS. 1 to 3 show the electrolytic shaping apparatus of this invention which includes a fluid operated drive for moving an electrode **31** toward and into a workpiece. The electrode **31** shown is of the tubular type having a conductive working face as more fully described in Patent No. 3,058,895.

A frame is provided consisting of a base **173**, two uprights **175** and a top member **177**. These are made of stainless steel and are bolted or welded together. Two stainless steel cylinders **179** are forced into bored openings in uprights **175** so that they are in parallel alignment.

Each cylinder has a hardened push rod **181** adapted to reciprocate in linear ball ways **183** pressed into counterbored ends of the cylinders **179**.

Each push rod **181** has a piston **185** which is pressed into position upon the rod. The piston has a series of annular grooves to serve as a labyrinth seal against excessive leakage, but no cup leathers are used as it is desired to avoid rubbing friction. Piston **185** has a radial clearance of the order of .001 inch to .002 inch relative to the bore of the cylinder.

At each end of both cylinders, there is a labyrinth seal element **187** in the form of a bushing press fitted into the bore and having internal annular grooves to reduce leakage. These also clear the push rod by a few thousandths of an inch.

Each piston and cylinder assembly is put together by first pressnig one seal into position, then inserting the push rod with its piston already in place, then pressing the other seal in place, and finally, pressing the linear ball ways **183** into position, sliding them along the push rods to do this.

Seals **187** are turned down at their inboard ends, and the space thus provided beyond the piston and in communication with the cylinder is connected to the outside through threaded tube fittings **189**.

The inner ends of seals **187** therefore serve the dual purpose of acting as stop abutments against pistons **185** to limit the travel of push rods **181** and also provide annular channels to permit entry and exhaust of air even when the push rods are at the limit of their stroke.

Vent holes **191** are provided at both ends of both cylinders to exhaust any blow-by of air which leaks past

seals **187**. The vent holes are threaded to receive tubes which are led to a position remote from the work area. This prevents electrolyte splatter and mist from entering the air cylinders where it might gum up the working parts.

Canisters **193** enclose the back ends of the push rods to seal them against dirt and electrolyte splatter.

An electric vibrator **195** (FIG. 2), which vibrates in response to 60 cycle current, is attached to one of the uprights **175**. This element is of the kind commonly used in sorting and feeding machines. Its purpose here is to impart a slight vibratory motion to the assembly to minimize any tendency of the moving parts to stick. Additional vibration in a plane transvers to the path of electrode motion may be used to vibrate an electrode tip to avoid pattern effects from a composite electrode, e.g., the bundle of tubes type.

At the working end of the push rods, flanges **197** are pressed or threaded onto the rods (before assembly), and synthetic rubber telescopic boots **199** are sealed to the flanges and the fact of the adjacent upright **175** by clamp rings (not shown). To the flanges **197** there is bolted an intermediate stainless steel plate **201**, and to it, in turn, is bolted an insulating mounting plate **203** of Teflon, nylon, or similar material, which is waterproof and should be impervious to the electrolyte solution being used. The bolt holes should be countersunk and plugged to prevent access of electrolyte to the bolts.

To the insulating plate **203** may be mounted any desired electrode holder for holding the electrode **31**. Here, this consists of a stainless steel body **205** having an integral flange **207** adapted to be bolted, as shown, to the insulating plate **203**. The body is counterbored, leaving a shoulder **209**. The electrode **31** proper is mounted to a cylindrical base **211** having an external V-groove **213**. Opposite this groove in the body **205** are provided threaded holes to receive set screws **215**. These are pointed, and the screw holes are so located that the points of the screws engage the inner face of the V-groove **213** so that when the screws are tightened there is a wedging action between the screw tips and the inner face of the V-groove which drives the electrode base **211** firmly against the shoulder **209**. This makes an adequately sealed joint, as some small leakage of electrolyte is of little consequence.

A screw threaded tube connection **217** is opened through the body **205** into the counterbored section, thus communicating with the liquid passage in the electrode **31**. A flexible tube **219** leads to a junction connection **220** for the electrolyte supply line. The top surface of top member **177** is one convenient location for such a junction connection. Similarly, a flexible electrical cable **221** is led from flange **207**, to which it is bolted, to a suitable junction for connection to the main power supply cable from the power source, shown diagrammatically in FIG. 3. Alternatively, a heavy copper strip **200**, shown in FIG. 1, could be bolted at one end to the flange **205** and arranged to extend outwardly and thence rearwardly for connection to the end of the cable **221**. It is convenient to do this by carrying the cable **221** to a metal junction member **222** mounted on an insulating block **224** atop top member **177** and in front of the liquid junction previously referred to.

Both the tube **219** and the electric cable **221** must be quite flexible so as not to interfere with the motion of the electrode, and enough extra length must be provided so that there is not much change in force exerted by or against these members during motion of the electrode.

A dial indicator **223** (FIG. 2) is mounted on a suitable bracket **225** with its stem **227** extending forward through guide **229** on the side of rear upright **175**. The stem is engaged by a push rod **231** fastened by screw threading into intermediate plate **201** near its adjacent edge so that the push rod passing through a guide **233** on the forward upright **175** engages the stem **227** to which it is attached by a friction fit rubber collar **235**, thereby permitting elimination of the retracting spring in the indicator assembly, which otherwise interferes with proper balance of the forces involved in the system.

FIG. 1 shows the above assembly mounted for work. The assembly of FIG. 2 is mounted by its base member **173** to a stainless steel plate **236**, which in turn is set within a stainless steel pan **237**. Both are mounted on a stand (not shown). A transparent plastic enclosure (not shown) covers the work area, its back wall being notched for boots **199** and for push rod **231** and provided with openings for the tube **219** and the cable **221**. The enclosure rests on short legs to lift it above the bottom of pan **237** but it still extends well below the pan's upper edge. Thus, ventilation is afforded to the work area, but splash is retained within the pan. A powered exhaust blower (not shown) may be connected to the enclosure by a suitable duct, and thus all fumes may be drawn away from the operator.

The work **239** is mounted on a suitable pedestal **241** in front of the electrode **31** and is positioned so that the cavity to be formed will be in the desired position in the work. In a typical situation, a rotary indexing table may be mounted to hold a disc of super-alloy material so that its edge is toward the electrode in close proximity to it when the electrode is retracted. Then the electrode is advanced to "cut" a cavity constituting the interspace between two turbine blades. The electrode is then retracted, the disc is indexed to the next interspace position, and the operation is repeated. By progressing around the disc in this way a full set of turbine blades is provided, all integral with the remaining central portion of the original disc.

Turning to FIG. 3, there is shown a schematic diagram of the hydraulic (electrolyte), air, and electrical hookup of the apparatus of FIGS. 1 and 2. An air supply line **243** leads through a filter **245**, a pressure regulator **247**, an oil bath **249**, and thence to a valve **251** actuated by a solenoid **252** controlled by push button controls (not shown) which actuates switch **254** in a convenient location. From the solenoid valve, tubes **253** and **255** lead to the two air connections **189** on each cylinder **179**, which are connected together in the same sense at each end. The solenoid valve is of the type (and is so connected) that, when deenergized, the valve takes the position to send air under pressure through line **253** to the cylinders in a direction to cause retraction of the electrode **31**. Thus, in the event of accidental power failure, the electrode moves away from the work instead of the opposite. As a safety device, the solenoid valve control circuit is interlocked with an adjustable pressure switch **257** in the electrolyte supply line so that if the electrolyte falls below a predetermined level the solenoid electrical supply is cut off, causing retraction of the electrode. The electrical control circuit for the solenoid valve as shown includes the on-off switch **254**.

The electrolyte supply is fed from a reservoir **259** by a pump **261** capable of supplying the requisite amount of electrolyte (depending on electrode area) at a pressure of from 100 to 200 p.s.i. The electrolyte then passes through one or another form of pressure regulator **263** (which may be essentially a manually controlled bypass valve) to a first gauge **265**, through a needle valve **267**, then to the actuator **269** for the pressure switch **257**, then to a gauge **270**, and thence to the junction block **220** on the top member **177** of the assembly of FIG. 1, and then through tube **219** to the electrode holder, and so into the electrode **31**. It has been found that the system works more smoothly and with complete freedom from hunting when needle valve **267** is connected to the electrode through a length of four to eight feet of neoprene hose which, being slightly expansible, seems to provide a kind of damping or smoothing action. A thermometer **271** is mounted in the junction block **220** to indicate the temperature of the electrolyte. From the electrode, elec-

trolyte falls into the pan **237** and is returned to the reservoir **259**.

The electrolyzing current is fed from the direct current source to the work by a heavy cable, usually by connection of the positive terminal to the work pedestal or holder or to a stainless steel base plate (not shown). The other (negative) supply cable leads to a junction on an insulating block **224** on top member **177** as previously explained.

Vibrator **195** is connected to the power input line to the solenoid valve coil **252** so that the vibrator is energized whenever the solenoid valve is energized so as to be in position to cause the electrode to advance toward the work.

The mode of operation is as follows. After the work is positioned, the electrolyte supply pump is energized, and the control button is pushed to advance the electrode against the work. Air pressure acting on pistons **185** urges the electrode toward the work, while hydrostatic pressure of electrolyte at the electrode tip tends to force it away. By regulating the needle valve **267** in the electrolyte supply line, a restriction is established such that, when the electrode is very close to the work, the pressure rises because of the narrow gap for exit, but when the gap widens the pressure immediately drops. Thus an equilibrium position is reached at which the forces exerted, respectively, by the air on the pistons and the electrolyte on the working tip of the electrode are balanced. This balance may be adjusted, by adjustment of air pressure and of the needle valve, so that the equilibrium is reached at any spacing from .001 inch, or even less, to .012 inch away from the work. This can be checked by observing the dial indicator **223** and pushing the electrode forward manually until it bottoms against the work. All of this adjusting and checking is done without any electrolyzing current. When these conditions have been appropriately established, the current is turned on and immediately the indicator will show the advance of the electrode into the work. As the electrolytic action dissolves away the work material, this tends to open the exit gap between the electrode and the work, thus tending to reduce the hydrostatic back pressure so that the air actuated piston moves the electrode forward into equilibrium. In actual operation this occurs very smoothly, and one sees on the dial indicator only a smooth steady progress. If the work is stopped, by turning off the electrolyzing current at any point, it will be found by advancing the electrode manually until it bottoms, the predetermined spacing distance will be maintained with high accuracy.

It is not necessary that air be used to advance the electrode. Any other fluid medium under pressure will be satisfactory.

A simple form of feed device, shown in FIGS. 4 and 5, may be made for making simple holes where low cost may override considerations of accuracy, versatility, and reliability found in one of the more complex forms of the invention. In this simple form the hydrostatic pressure of the electrolyte itself is used to advance the electrode into the work.

Referring to FIG. 4, a cup shaped cylindrical metal body **481** having a central cylindrical cavity or chamber **483** is fitted with a removable screw threaded cap **485** and a sealing gasket **487**. The upper end of cap **485** terminates in a screw threaded pipe nipple **489** to which an electrolyte supply line from a pressure pump (not shown in this figure, but similar to the arrangement of FIG. 3) is to be connected. A central aperture **491** through nipple **489** is arranged to admit electrolyte to the central chamber **483**.

Body **481** has a cylindrical opening **493** at one end which is slightly larger than the largest electrode carrier shank which is to be used. Within the central chamber **483** of body **481** there is positioned a bushing **495** of Teflon or other similar material. This bushing may conveniently fit finger tight within body **481** and should be substantially liquid tight therein but without being so tight in the chamber as to prevent easy removal when changing sizes of the electrode carrier.

The bushing **495** has a plurality of annular grooves **497** the purpose of which is to prevent excessive bypass leakage around the shank **499** of electrode carrier **501**, which is arranged to slide freely in the bushing. Where the tip of the electrode **503** is round, the shank **499** may be round, and the bore of bushing **495** likewise. But where the tip is of some irregular shape, the shank requires a key to be machined on one side, and the opening in the bushing is provided with a matching key slot to prevent accidental rotation of the electrode. Other anti-rotation expedients may of course be substituted, such as a simple guide for the portion of the tool carrier beyond the cylinder.

The electrode tip must have an area (measured to its extreme perimeter) which is slightly larger than the effective cross sectional area of the shank **499**. The electrode tip is made in the manner previously described, and the electrode above the tip is coated with an insulating material **504**, such as ceramic, and at its upper end it is secured to the lower end of the shank **499**.

A passage **509** for electrolyte is provided through the central portion of electrode **503**, its shape and size being suited to the electrode tip shape. If the tip is round, square, or hexagonal, for example, the passage may be round. If the tip is of crescent shape (to form interblade spaces for a turbine wheel, for instance), then the passage may be of some more convenient shape.

This passage through the electrode communicates by way of a passage **511** through the shank **499** of the electrode holder with the chamber **483** and the flow rate or pressure drop through the passage **511** is adjusted by a conveniently located needle valve **513**.

A flexible electrical connection **515** leads from the body to the electrode holder **501** where it is secured by a terminal **517** and terminal screw **519**.

A direct current power source is then connected between the lead **515** and the holder **521** for the work W, the positive connection going to the work or the vise or fixture therefor.

The complete electrode drive assembly is then mounted by any suitable means to bring the electrode **503** in working relationship to the work, and the work is held by a vise or clamp or fixture. The work area is then enclosed, preferably by movable screens or curtains of transparent material, so that it is easy to see and have access to the work area while still being protected from the considerable splatter of electrolyte during operation.

The electrolyte pressure source should, for convenience, provide, adjustably, from 50 to 200 p.s.i. of electrolyte pressure and the work area should be cupped and drained so that electrolyte is returned to the supply tank. This arrangement is adequately shown in FIG. 3 and is believed clear enough as not to require repetition.

In operation, the work is positioned such that the electrode tip is near the work surface with the electrode in the retracted position.

Electrolyte pressure is then turned on, and as the liquid enters the chamber **483** in body **481** it forces the electrode holder shank **499** outwardly toward the work as the shank **499** acts is a piston. But as the tip of electrode **503** almost engages the face of the work, a hydrostatic pressure is built up between the tip and the work face, and this pressure produces a force tending to push the electrode away from the work. Since the area of the tip was deliberately made greater than the effective cross sectional area of the shank **499**, the tip can never touch the work face in such manner as to seal off the flow entirely, for as the tip moves closer and closer to work, the flow of liquid is pinched off so that liquid pressure between the tip and work approaches the pressure in the chamber **483**, acting upon shank **499** as a piston. But before the liquid pressure under the electrode tip

equals the pressure in the chamber **483**, the force acting upwardly against the tip equals the force acting outwardly on shank **499**, and an equilibrium position is reached with the tip in very close proximity to the work but not touching it.

At this point the electrolytic current supply is turned on, and the full coaction of all the elements, pressure pump, electric power source, electrode tip, electrode shank, etc., comes into play. Through electrolytic action material is removed from the work under the electrode tip. This increases the space between the work and the tip, and the hydrostatic pressure at the tip tends to fall, but the instant this work gap pressure falls, the hydraulic force on the shank **499** exceeds the upward force on the tip, and so pressure generated by the pump moves the electrode downwardly to a new equilibrium point. This occurs as a continuous motion, thereby maintaining a desirably small work gap to maximize the electric current which can be passed at a reasonable and modest voltage.

The orifice constituted by the needle valve **513** in the passage **511** through the electrode shank permits fine adjustment of the work gap distance, and this is desirable because in practice, it is not easy to maintain an exact area of the electrode tip, particularly if it is of an irregular shape. By reducing the needle valve opening so as to impede electrolyte flow through the electrode, the tip must move closer to the work in order to develop a back pressure sufficient to exert an upward force on the tip equal to the downward force on the shank. Thus, reducing the needle valve opening results in closer work gap spacing, while opening it has the opposite effect. This eliminates what might be a troublesome problem, namely, the balancing of areas of tip and shank to secure just the work gap desired. All that is needed is that the tip area, whatever its shape, be a little larger than the cross sectional area of the shank, and the needle valve will permit the rest of the adjusting.

Adjustment may also be accomplished by changing the applied electrolyte pressure. At lower pressure a smaller work gap will result, and vice versa. While this might be relied upon alone in a very low cost embodiment of the apparatus, it could introduce some problems, as changes in pressure may affect electrolyte temperature and gassing in the work gap, thereby affecting size, finish, etc. In most cases, therefore, it is better to select a more or less fixed working pressure and to make adjustments in other ways, such as with the needle valve **513**.

This form of the invention permits construction of very low cost apparatus, and may have special value in the extraction of broken taps, for example. A range of sizes of electrodes and matching insulating bushings **495** is provided for ready interchange. One great advantage of this system (as is also true of the other forms of the invention) is the fact that there is very little, if any, wear or erosion of the electrode, whereas in the so-called "tap busters" of the prior art in which there is arcing between the electrode and the work, the electrode is worn away at a substantial rate and is a substantial factor in overall cost.

From the foregoing it will be appreciated that the objectives which were claimed for this invention at the outset of the description are fully attained by the apparatus shown and described.

Also from theabove description of my invention, it will be appreciated that many changes may be made in the apparatus without departing from the scope or spirit of the invention, and that the scope of the invention is to be determined from the scope of the accompanying claims.

I claim:

1. In an electrolytic apparatus for removing material from an electrically conductive and electrochemically erodible workpiece by means of an electrode having one or more electrolyte passages therethrough and a conductive working face, the workpiece and said electrode being relatively movable toward each other to define a work gap between the workpiece and said electrode working face, means connected to said electrode for pumping electrolyte through said electrode and to and through the work gap at a superatmospheric pressure so that the electrolyte is adapted to push said electrode and the workpiece apart with a variable hydraulic force which increases as the electrode-to-workpiece spacing decreases, means for applying a substantially constant force between said electrode and the workpiece in a direction to urge said electrode and the workpiece together closely to space said electrode working face from the workpiece, the last said means being adapted to apply a force appreciably less than said variable hydraulic force under conditions where said electrode would touch the workpiece, whereby the electrode-to-workpiece spacing will be maintained substantially constant in dynamically stable equilibrium, and circuit means connected to said electrode and the workpiece for passing an electrolyzing current between the workpiece and said electrode working face.

2. Apparatus as claimed in claim **1**, wherein said constant force applying means comprises a fluid operated expansible chamber means.

3. Apparatus as claimed in claim **1**, wherein said constant force applying means comprises a fluid powered cylinder and piston means connected to said electrode to drive the latter toward the workpiece.

4. Apparatus as claimed in claim **3**, including means connected to said cylinder and piston means for regulating the advance of said electrode toward the workpiece.

5. Apparatus as claimed in claim **1**, wherein said constant force applying means comprises a pneumatic powered cylinder and piston means connected to said electrode to drive the latter toward the workpiece, and control means for regulating the air pressure to said cylinder and piston means at a level to provide a driving force balancing the hydrostatic force of the electrolyte in the work gap when a predetermined spacing distance between the workpiece and said electrode working face is reached.

6. Apparatus as claimed in claim **3**, including means responsive to a failure of the electrolyte pressure or of the electrolyzing current to reverse said fluid operated cylinder and piston means to withdraw said electrode from the workpiece.

7. Apparatus as claimed in claim **1**, wherein said constant force applying means comprises hydraulic expansible chamber means connected to receive electrolyte at substantially the same pressure as said electrode for supplying a substantially constant force to said electrode in a direction to urge aid electrode toward the workpiece.

8. Apparatus as claimed in claim **7**, including means for regulating the flow rate of electrolyte to said electrode.

9. Apparatus as claimed in claim **7**, wherein said electrode is mounted on an electrode holder which slidably projects into said chamber means and the inner end of which forms a piston therein, the effective area of said electrode working face at the work gap being greater than that of said piston, and a passage through said holder to transmit electrolyte to said electrode.

10. Apparatus as claimed in claim **9**, including means for regulating the flow of electrolyte to said electrode, said flow regulating means comprising an adjustable needle valve in said passage.

11. In electrolytic apparatus for removing material from an electrically conductive and an electrically erodible workpiece by means of an electrode having one or more electrolyte passages therethrough and a conductive working face, the workpiece and the electrode being relatively movable toward each other to define a work gap between the workpiece and the electrode working face, and circuit means connected to the electrode working face and to the workpiece for passing an electrolyzing current between the workpiece and the electrode working face in a sense that the latter is cathodic and

when there is electrolyte in the space between the workpiece and the electrode working face, the improvement comprising, means connected to the electrode for pumping electrolyte through the electrode and to and through the workgap between the electrode working face and the workpiece at a super-atmospheric pressure so that the electrolyte is adapted to push the electrode working face and the workpiece apart with a variable hydraulic force which increases as the electrode to workpiece spacing decreases, and hydraulic means for applying force between the electrode working face and the electrode workpiece in a direction to urge the electrode working face and the workpiece together closely to space the electrode working face from the workpiece, said last named means being adapted to apply a force appreciably less than said variable hydraulic force under conditions where the electrode working face would touch the workpiece whereby the electrode through workpiece spacing will be maintained substantially constant in dynamically stable equilibrium.

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U.S. Cl. X.R.

204—143, 225

Dedication

3,444,070.—*Lynn A. Williams*, Winnetka, Ill. ELECTROLYTIC SHAPING APPARATUS. Patent dated May 13, 1969. Dedication filed Dec. 23, 1971, by the assignee, *Anocut Engineering Company*.

Hereby dedicates to the Public the portion of the term of the patent subsequent to Dec. 24, 1971.

[*Official Gazette April 25, 1972.*]