

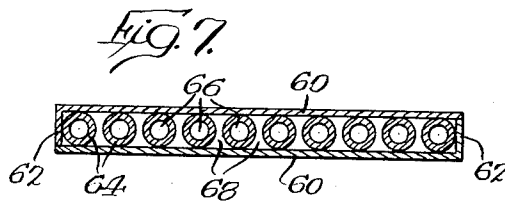
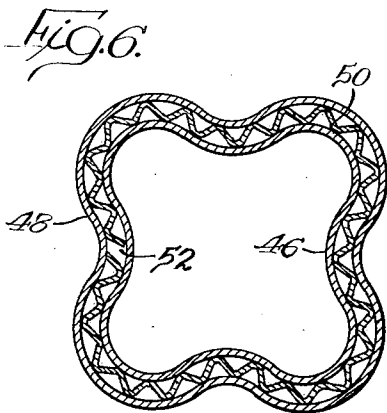
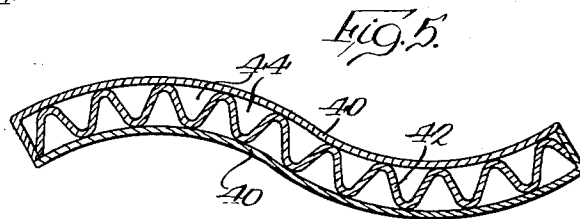
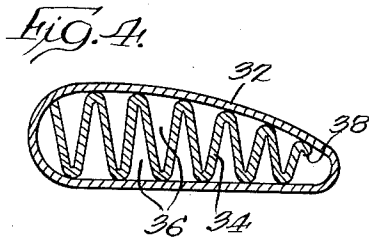
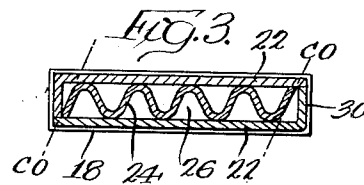
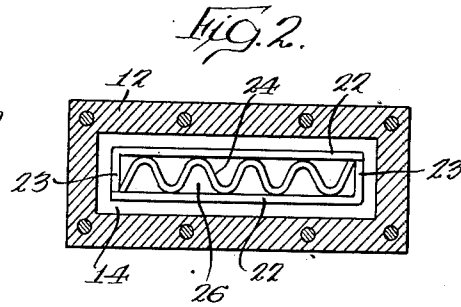
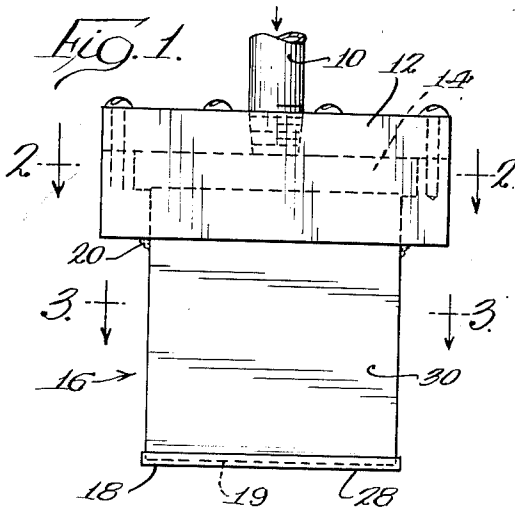
Jan. 30, 1962

L. A. WILLIAMS

3,019,178

ELECTRODE FOR ELECTROLYTIC SHAPING

Filed Oct. 29, 1959



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3,019,178

ELECTRODE FOR ELECTROLYTIC SHAPING
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Filed Oct. 29, 1959, Ser. No. 849,595
14 Claims. (Cl. 204—284)

This invention relates to the art of electrolytic removal of work material and more particularly to electrodes used in such applications.

My copending patent application Serial No. 772,960, filed November 10, 1958, for "Electrolytic Shaping," describes a process with variations for the removal of work material by electrolytic action and also describes equipment for practicing the process including several electrodes of preferred type. This invention relates primarily to an improved electrode to be used as a cathode in such applications for specific purposes as will appear presently. It may in a sense be considered as an extension or special application of the basic principles disclosed in my copending application Serial No. 800,276, filed March 18, 1959, for "Electrode for Electrolytic Hole Sinking" (now abandoned). Whereas, however, the latter patent application is directed principally to problems associated with large electrodes, this invention is concerned primarily with electrodes which are quite small in their transverse dimension although they may be quite long.

Electrodes of this character may be used for slotting and related applications, and the slots so formed may be long or short, annular, or of irregular configuration, and if desired, of varying width. The characteristic feature they have in common is that the dimension across the electrode is quite small, of the order of one-eighth of an inch or so, although the principle to be described may be applied successfully to larger or smaller electrodes.

One of the objects of this invention is to supply a novel, thin, hollow, electrolyzing electrode which provides for the free passage therethrough of the electrolyte solution and which is capable of sustaining high internal electrolyte pressure.

Another object is to provide a novel type of thin electrolyzing electrode having the above set forth advantages, which is well adapted to be formed to irregular contour and which in some embodiments may be shaped within certain limitations to a desired contour subsequent to its manufacture.

An additional object is to provide a novel, thin electrode of this character which largely overcomes the difficulties ordinarily associated with electrodes of this type.

Other objects and advantages will become apparent from the following description of a preferred embodiment of my invention which is illustrated in the accompanying drawings.

In the drawings, in which similar characters of reference refer to similar elements throughout the several views:

FIG. 1 is a side elevation of an electrode embodying features of the present invention;

FIG. 2 is a transverse sectional view which may be considered as taken in the direction of the arrows along the line 2—2 of FIG. 1;

FIG. 3 is a transverse sectional view which may be considered as taken in the direction of the arrows along the line 3—3 of FIG. 1;

FIG. 4 is a transverse sectional view, similar to FIG. 3, but illustrating a thin electrode of variable width;

FIG. 5 is a transverse sectional view of an irregularly shaped electrode;

FIG. 6 is a transverse sectional view of a trepanning type electrode adapted to cut a continuous slot of irregular outline; and

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FIG. 7 is a transverse sectional view of an electrode serving much the same purpose as the electrode of FIG. 3 but constructed in an alternative manner.

As is explained in the above referred to applications, a conductive workpiece can be shaped by the removal of material therefrom by electrolytic action. This is accomplished by bringing an electrode or tool of proper contour into close proximity to the workpiece with the tool and workpiece connected in an electrolyzing circuit such that the electrode is cathodic relative to the work. An electrolyte is supplied to the interface between the tool and the work and as material is removed from the work by electrolytic action, the electrode is advanced. Under some conditions, the work gap may be varied in size so as to produce holes with tapered portions, since the side cutting action is greater with large work gaps, but usually the work gap is kept constant and as small as is convenient in order to reduce side cutting action to a consistent minimum, thereby producing straight, smooth holes or cavities.

It is explained in my previously referred to applications that I have found it to be highly advantageous to use high electrolyzing current densities, low voltages, high electrolyte pressure and flow rates throughout the workgap and to supply the electrolyte to the work gap by way of passages formed within the electrode. It is also an advantage when smooth bottomed cavities are to be formed to provide an electrode wherein the electrolyte supply passages and effective electrode portions therebetween are small and closely interspersed at the electrode working face.

These preferred working conditions are difficult to accomplish in very thin electrodes of a type in which, for instance, the widest portion of the electrode may be no more than one-eighth inch and might be considerably less. This is particularly true if such an electrode is to be provided at reasonable cost.

The electrode of FIGS. 1, 2 and 3 is typical of a simple type embodying features of this invention and for the purpose of illustration may be considered as being about .060" wide and something over 1' long at the working face. It consists of an electrode holder and electrolyte supply pipe 10 which is threaded at one end into a box-like housing 12 having a chamber 14 formed therein. The pipe 10 is connected at its opposite end, not shown, to a suitable support structure adapted to position the electrode and advance it into the workpiece as material is removed therefrom. Usually also it is convenient to connect the negative side of the electrolyzing power supply to the electrode proper by way of the pipe 10. If more particulars are desired with respect to the organization of the electrolyzing equipment generally, reference is made to the previously mentioned copending applications where they will be found in considerable detail.

The housing 12 has a slot—rectangular in the present instance—which fits shank or body portion 16 of the electrode which ends at its working edge in a slight enlargement forming a peripheral terminal lip 18. Electrolyte under pressure is thus supplied from the pipe 10 to the chamber 14, and thence to the body 16. In order to insure good electrical contact and to prevent electrolyte leakage, the electrode is brazed or soldered to the housing 12 as at 20.

Construction of the body portion 16 will be understood from inspection of FIGS. 2 and 3. Externally it is made up of a pair of flat plates 22 which are assembled over a corrugated strip 24 in sandwich fashion by copper brazing. If desired, the flat plate 22 may have end closing projections 23 formed therein by bending so as to provide square ends. If square ends are of no importance as in a simple cut-off operation, then the flat plates may be cut off along the planes CO and CO in such a way as to avoid

any free standing projection. The assembly operation may be accomplished in several ways, but I have found it preferable to plate the flat plates 22 with copper and then assemble these plates with the corrugated strip in a fixture which holds the elements in place while they are brought to brazing temperature in a hydrogen furnace.

The flutes in the corrugated strip extend in the same direction as the intended feed direction of the electrode, and therefore subdivide this passage into a plurality of parallel small ducts 26, ten of which are shown in FIGS. 2 and 3. I prefer that the corrugated strip 24 have about the same length as the exterior tubular portion so that the aspect ratio of the ducts 26 will be quite high and the hydraulic cross section quite small. Preferably the transverse dimension of each passage, reckoned from the flat sheet 22 to the deepest opposite corrugation, should range from .004" to .020" and should not exceed .060". The reason for this will be indicated presently.

The free end of the body portion 16 is surrounded by a narrow band which forms the peripheral lip 18 previously mentioned. This band may be brazed in place during the major assembly operation, or, if desired, it may be added later; or it may be formed by sharply folding the flat plates 22 back upon themselves. Externally it has about the same contour as the body portion excepting that it is slightly larger and ordinarily will be finished to more precise dimensions than is necessary for the body portion. Stated differently, if precise dimensions and contour for the electrode working end are advisable, this is easily accomplished by making the lip 18 slightly oversize and then finishing it appropriately, since minor variation in the dimensions of body neck portion 16 are not critical.

Prior to use, the working end 28 of the electrode may be ground or otherwise finished so that the end of the corrugated strip 24, the ends of the plates 22 and the lower edge of the peripheral lip 18 are all in the same plane. Preferably, however, the corrugated strip will have been assembled in the sandwich so that its working end is slightly recessed as indicated by the dotted line 19 in FIG. 1. This tends to even out the flow of electrolyte existing at the working tip and reduces a tendency to cause channeling and roughness on the side walls of the slot in the work.

An electrode of this character may be fabricated from mild steel or stainless steel strip stock having a thickness of .010" or .005", depending principally upon the electrode size. If quite thin stock is used and increased electrical conductivity is desirable, this may be accomplished by plating the electrode after assembly with .002" or .003" of copper or silver.

An electrode constructed as explained will have a high order of passage sectional area for the flow of electrolyte, and yet will supply effective conductive electrode surface throughout the area of the working face such that no portion of the workpiece surface within the work gap will be spaced very far from some portion of the electrode metal surface. This is important since it promotes the formation of a smooth surface at the bottom of the cavity being sunk.

It will be appreciated also that the cross bracing provided by the corrugated strip results in an extremely strong structure well able to withstand internal electrolyte pressures of a high order, upwardly of one hundred pounds per square inch for example. Additionally, the high aspect ratio and the small hydraulic cross section of the small ducts 26 results in considerable resistance to flow at high flow rates, and thus has a flow rate and pressure equalizing effect. This is a valuable characteristic, particularly when an electrode fits the work surface unevenly—as when getting started, for instance, or in breaking through the opposite side of a workpiece in a cut-off operation—since it insures a reasonable electrolyte pressure throughout the work interface, even though a portion of the working end of the electrode is exposed and is leaking.

By maintaining the electrode in a position very close to the work so as to provide a quite small work gap, the rate of removal of work material at a position ahead of the electrode is high as compared with the removal rate along the wall of the cavity above the lip 18 where the distance between the cathode and anode surfaces is greater. Nevertheless I prefer to insulate the body portion 16 above the lip 18 as is indicated at 30. Such insulation may take the form of ceramic enamel or one of the more durable plastics resins. It has the effect of greatly lengthening the electrolyzing current path and hence the electrical resistance between the effective cathode surface which is limited to the end of the electrode and the side wall of the cavity above the lip 18. This almost completely stops unwanted electrolytic erosion of the cavity side wall and results in smooth untapered holes. The lip 18 assures clearance of the insulating material with respect to the walls of the cavity. The same result may be accomplished without the lip by having a band near the working tip of insulation. This band may be about .010" to .040" in width. This is more fully explained in another application now under preparation.

Because the pattern of effective electrode surface at the working end 28 is quite fine and the electrolyte distribution is uniform, the bottoms of cavities produced with this type electrode are quite smooth and only a small complementary pattern remains in the work. If greater smoothness is required, this can be accomplished by making the electrode slightly undersize and then moving it about slowly during use. This has the effect of erasing any pattern that might otherwise be produced by distributing the effective cathode surface evenly over the area at the bottom of the cavity. Ordinarily, however, I prefer to smooth the bottom by stopping the advance of the electrode while maintaining the electrolyzing current.

With this and the other embodiments to be described presently, I prefer to use high electrolyte pressures, one hundred pounds per square inch and above for instance, and high current densities at low voltages; for example, a current density of 1000 amperes per square inch of effective cathode area at a potential of no more than twelve volts. I also prefer high electrolyte temperatures, upwardly of 140° F. and small work gaps, of the order of .010" to less than .001". The electrolyte flow rate should also be high, but the suggested electrolyte pressures will insure this. The objective here is to have a flow rate and pressure within the work gap which is sufficient to prevent, or largely inhibit, the separation of gas or vapor bubbles from the liquid electrolyte until after the electrolyte has been expelled from the work gap. High flow rate also removes the electrolyte from the work gap before it has been appreciably ion depleted and thus rendered inefficient as an electrolyzing medium.

The electrodes of FIGS. 4, 5, 6, and 7 illustrate variations upon the basic structure of FIGS. 1 to 3. In each of these only a transverse section through the body portion is illustrated, and it will be understood that in each instance the body portion is fitted at the top end to a hollow housing, such as at 12, while the working end may be provided with a narrow circumscribing band, similar to that at 18, and insulation 30 upon the side wall.

FIG. 4 illustrates an electrode structure similar to that of FIG. 3, excepting that instead of being rectangular it is shaped to a more complicated contour such that there are several curved surfaces and the transverse dimension varies considerably. It may be considered for purpose of illustration as having a maximum width dimension of .060". The external sheath 32 may be formed from seamless tubing as shown; or a strip of the thin metal may be bent to the desired contour with the ends brazed or resistance welded together. In any event, a corrugated strip 34 is pressed into place within the tube and oven brazed thereto so as to strengthen the tube against distortion from internal pressure and to subdivide the passage through the

tube into a plurality of small, parallel, high aspect ratio ducts 36.

Although the corrugated strip 34 is shown in this figure as being rather precisely formed, this is not as critical in practice as might be thought, since the corrugations will be flattened slightly as necessary so as to reduce the thickness at particular locations when the corrugated strip is pressed into place. If the overall effect of this dimensional adjustment during assembly is to increase the length of the strip across the corrugations, no difficulty will be encountered if the strip is cut slightly short, much in the manner shown at 38. Usually this length allowance will not be needed inasmuch as some adjustment of the thickness of the corrugated strip will result from slight bowing of the short relatively straight portions which extend angularly across the strip from side to side.

The electrode of FIG. 5 is similar to that of FIG. 3, but its aspect ratio is much higher and it is shown as being curved. Depending upon the degree of curvature, and to some extent upon choice, it may be formed as a flat, rectangular, internally subdivided and braced tube, such as that of FIG. 3, which is subsequently bent or rolled to the desired configuration, after which it is assembled to its electrolyte inlet housing. Conversely, the plates 40 which form the tube, may be preshaped before assembly or may in some instances simply be shaped by clamping in an appropriately designed brazing fixture. With any of these manufacturing procedures, no difficulty should be experienced with the corrugated strip, since it is extremely flexible when it is not bent transversely of its corrugations. The electrode illustrated in FIG. 5 may be considered as being about .060" wide by about six inches long and as having a very large number of electrolyte supply ducts 44 intersecting the working face.

The embodiment of FIG. 6 is intended for cutting a continuous slot. Thus, it is essentially a trepanning tool, excepting that ordinary trepanning tools are limited to the machining of circular slots of uniform width, whereas the limitations of circularity and slot width uniformity do not apply to tools of the present type. In most instances, however, where the objective is simply to shape the external or internal contour of a blank or other workpiece, it is convenient to make the slot of uniform width, since this simplifies manufacture of the electrode somewhat, and because ordinarily the desire is to obtain a slot of minimum practical width, it being useless and costly to remove more metal than necessary. The FIG. 6 embodiment is thus shown as adapted to cut a slot of uniform width, but it should be appreciated that no such limitation is inherent.

To provide the electrode of FIG. 6, the inner and outer shells 46 and 48 respectively are preformed in any convenient manner to provide a pair of irregular or regular shaped tubes as required, which nest with a small space between the tubes all the way around. As explained, it is most convenient if this space is of substantially uniform width. The tubes are copper plated as mentioned earlier, to provide brazing material. A strip 50 of the corrugated metal is then pressed into the space between the tubes with its ends touching or almost touching, as indicated at 52. The assembled article is then heated in a brazing oven to form a rigid unitary structure and is subsequently inserted into a housing at one end and sealed therein, the housing having a slot of appropriate shape to receive the end of the brazed tube. If desired, the fabricated tube prior to brazing can be assembled to the housing member so that a single brazing operation will unite all of these elements.

The article formed as indicated above then may have a narrow lip element, such as at 18, attached to both the inner and outer periphery at the working end as previously discussed. Similarly also, the inner and outer side walls above the lip may be insulated to limit erosive side action.

The electrode is used in the same manner as those described previously, and as with the others, it is extremely

resistant to distortion, considering its size and the amount of metal therein. Furthermore it provides effective electrode surfaces which are well distributed electrically and a multiplicity of small high aspect ratio electrolyte supply passages.

The FIG. 7 electrode may be considered as for essentially the same purpose as the electrode of FIG. 3, and it is used in the same manner. The principle upon which it is constructed applies, however, to any of the illustrated electrode types. Here a pair of side plates 60, with or without end extensions 62, enclose a plurality of closely spaced, parallel, small diameter tubes 64. For this purpose I have found hypodermic needle stock to be admirably suited. Similar tubes originally intended for other purposes may, of course, be used. As with the previous examples, the flat plates 60 are copper plated and the assembly is hydrogen brazed to unite the tubes and side plates into a high strength, unitary structure which is secured at one end to an electrolyte supply housing. In this instance the passages 66 through the tubes as well as the passages 68 between them serve as small, high aspect, ratio ducts for conducting electrolyte from the housing to the electrode-to-workpiece interface.

From the above description of a preferred embodiment of my invention which has been illustrated as incorporated in several typical alternative structures, it will be clear that modifications may be made without departing from the scope of the invention and that this invention is to be measured by the scope of the following claims.

Having described my invention, what I claim as new and useful and desire to secure by Letters Patent is:

1. In an electrolyzing electrode the combination comprising, means providing a thin walled tubular structure, a corrugated member within said tubular structure with the corrugations thereof extending from side to side of said structure and secured to the internal walls thereof so as to cross brace said tubular structure against bulging under the application of internal hydraulic pressure, said corrugated member also serving to subdivide the passage through said tubular structure into a plurality of separate ducts of small transverse dimension and high aspect ratio, one end of said structure being finished to expose an end of said tubular structure and an edge of said corrugated member and providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, and means connected to the other end of said structure to support said structure and to supply electrolyte under pressure to the ducts extending therethrough.

2. In an electrolyzing electrode the combination comprising, means providing a thin walled tubular structure, a corrugated member within said tubular structure with the corrugations thereof extending from side to side of said structure and secured to the internal walls thereof so as to cross brace said tubular structure against bulging under the application of internal hydraulic pressure, said corrugated member also serving to subdivide the passage through said tubular structure into a plurality of separate ducts of small transverse dimension and high aspect ratio, means providing a narrow transversely outwardly extending lip circumscribing one end of said structure, said one end of said structure being finished to expose an end of said tubular structure, the end face of said lip, and an edge of said corrugated member and providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, and means connected to the other end of said structure to support said structure and to supply electrolyte under pressure to the ducts extending therethrough.

3. In an electrolyzing electrode the combination comprising, means providing a thin walled tubular structure, a corrugated member within said tubular structure with the corrugations thereof extending from side to side of said structure and secured to the internal walls thereof so as to cross brace said tubular structure against bulging

under the application of internal hydraulic pressure, said corrugated member also serving to subdivide the passage through said tubular structure into a plurality of separate ducts of small transverse dimension and high aspect ratio, means providing a narrow transversely outwardly extending lip circumscribing one end of said structure, said one end of said structure being finished to expose an end of said tubular structure, the end face of said lip, and an edge of said corrugated member, said one end providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, means providing an insulating coating for the exterior wall of said structure, said coating being limited to the region above said lip, and means connected to the other end of said structure to support said structure and to supply electrolyte under pressure to the ducts extending therethrough.

4. An electrolyzing electrode comprising means providing a thin walled tubular structure which is narrow from side-to-side, means providing a housing attached to one end of said structure and adapted to supply electrolyte under pressure to the passage through said tubular structure, said tubular structure including generally opposed walls, an internal bracing element extending across the narrow dimension of said structure, and said bracing element being mechanically secured to the inner surfaces of both said walls to support and brace said structure and to resist outward bulging of said walls upon the application of internal pressure to said structure, said bracing member also serving to divide the passage through said structure into a plurality of substantially parallel smaller passages connected at one end to said housing and adapted to supply electrolyte to the other end, said other end constituting the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped.

5. An electrolyzing electrode comprising means providing a thin walled tubular structure which is narrow from side-to-side, means providing a housing attached to one end of said structure and adapted to supply electrolyte under pressure to the passage through said tubular structure, a narrow lip forming element secured to and circumscribing the other end of said structure, said tubular structure including generally opposed walls, an internal bracing element extending across the narrow dimension of said structure, and said bracing element being mechanically secured to the inner surfaces of said walls at both sides to support and brace said structure and to resist outward bulging of said walls upon the application of internal pressure to said structure, said bracing member also serving to divide the passage through said structure into a plurality of substantially parallel smaller passages connected at one end to said housing and adapted to supply electrolyte to said other end, said other end constituting the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped.

6. An electrolyzing electrode comprising means providing a thin walled tubular structure which is narrow from side-to-side, means providing a housing attached to one end of said structure and adapted to supply electrolyte under pressure to the passage through said tubular structure, said tubular structure including generally opposed walls, an internal bracing element extending across the narrow dimension of said structure, said bracing element being mechanically secured to the inner surfaces of said walls at both sides to support and brace such structure and to resist outward bulging of said walls upon the application of internal pressure to said structure, said bracing member also serving to divide the passage through said structure into a plurality of substantially parallel smaller passages connected at one end to said housing and adapted to supply electrolyte to the other end, said other end constituting the working end of said electrode adapted to be brought into close spacing relationship with

a conductive workpiece to be shaped, and means providing insulation for the major portion of the exterior surface of said structure, the portion of said exterior surface immediately adjacent said working end being uninsulated.

7. An electrolyzing electrode comprising means providing a thin walled tubular structure which is narrow from side-to-side, means providing a housing attached to one end of said structure and adapted to supply electrolyte under pressure to the passage through said tubular structure, said structure including generally opposed walls, a narrow lip forming element secured to and circumscribing the other end of said structure, means providing insulation for the exterior side wall of said structure above said lip, an internal bracing element extending across the narrow dimension of said structure, and said bracing element being mechanically secured to the inner surfaces of said walls at both sides to support and brace said structure and to resist outward bulging of said structure upon the application of internal pressure to said structure, said bracing member also serving to divide the passage through said structure into a plurality of substantially parallel smaller passages connected at one end to said housing and adapted to supply electrolyte to said other end, said other end constituting the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped.

8. In an electrolyzing electrode the combination comprising, means providing a pair of nested, thin walled tubular structures providing a space therebetween, a corrugated member within said space with the corrugations thereof extending across said space and secured to the adjacent walls of said structures so as to secure together said tubular structures along a plurality of closely spaced, longitudinally extending, parallel lines, said corrugated member also serving to subdivide the passage formed between said tubular structures into a plurality of separate ducts of small, transverse dimension and high aspect ratio, one end of the assembly thus formed being finished to expose the ends of said tubular structures and an edge of said corrugated member, said one end providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, and means connected to the other end of said assembly to support said assembly and to supply electrolyte under pressure to the ducts extending therethrough.

9. In an electrolyzing electrode the combination comprising, means providing a pair of nested, thin walled, tubular structures providing a space therebetween, a corrugated member within said space with the corrugations thereof extending across said space and secured to the adjacent walls of said structures so as to secure together said tubular structures along a plurality of closely spaced, longitudinally extending, parallel lines, said corrugated member also serving to subdivide the passage formed between said tubular structures into a plurality of separate ducts of small transverse dimension and high aspect ratio, a narrow lip forming element secured to and circumscribing one end of the exterior of said tubular structures, a second narrow lip forming element secured to and inscribing the interior of said one end of said tubular structures, said one end of the assembly thus formed being finished to expose the ends of said tubular structures, an edge of said corrugated member, and the end faces of said lips, said one end providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, and means connected to the end of said assembly opposite said lips to support said assembly and to supply electrolyte under pressure to the ducts extending therethrough.

10. In an electrolyzing electrode the combination comprising, means providing a pair of nested, thin walled, tubular structures providing a space therebetween, a corrugated member within said space with the corrugations thereof extending across said space and secured to the

adjacent walls of said structures so as to secure together said tubular structures along a plurality of closely spaced, longitudinally extending, parallel lines, said corrugated member also serving to subdivide the passage formed between said tubular structures into a plurality of separate ducts of small transverse dimension and high aspect ratio, a narrow lip forming element secured to and circumscribing one end of the exterior of said tubular structures, a second narrow lip forming element secured to and inscribing the interior of said one end of said tubular structures, said one end of the assembly thus formed being finished to expose the ends of said tubular structures, an edge of said corrugated member, and the end faces of said lips, said one end providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, means insulating the interior and exterior side walls of the assembly above said lips, and means connected to the end of said assembly opposite said lips to support said assembly and to supply electrolyte under pressure to the ducts extending therethrough.

11. In an electrolyzing electrode the combination comprising, means providing a pair of nested, thin walled, tubular structures providing a space therebetween, a corrugated member within said space with the corrugations thereof extending across said space and secured to the adjacent walls of said structures so as to secure together said tubular structures along a plurality of closely spaced, longitudinally extending, parallel lines, said corrugated member also serving to subdivide the passage formed between said tubular structures into a plurality of separate ducts of small transverse dimension and high aspect ratio, one end of the assembly thus formed being finished to expose the ends of said tubular structures and an edge of said corrugated member, said one end providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, means insulating the interior and exterior side walls of said assembly above a position closely adjacent said working end, and means connected to the end of said assembly opposite said working end to support said assembly and to employ electrolyte under pressure to the ducts extending therethrough.

12. In an electrolyzing electrode the combination comprising, means providing a pair of thin plates, a corrugated member between said plates secured to the adjacent surfaces thereof so as to form a strong, cross braced structure having a plurality of parallel ducts of

small, transverse dimension and high aspect ratio, one end of said structure being finished to expose the ends of said plates and an edge of said corrugated member and providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, and means connected to the other end of said structure to support said structure and to supply electrolyte under pressure to the ducts extending therethrough.

13. In an electrolyzing electrode the combination comprising, means providing a pair of thin plates, a plurality of small diameter, parallel tubes between said plates, each tube being secured to at least two inner surfaces thereof so as to form a strong structure having a plurality of parallel ducts of small transverse dimension and high aspect ratio, one end of said structure being finished to expose the ends of said plates and the ends of said tubes and providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, and means connected to the other end of said structure to support said structure and to supply electrolyte under pressure to the ducts extending therethrough.

14. In an electrolyzing electrode the combination comprising, means providing a thin walled, tubular structure having opposed walls, a plurality of small, parallel tubes arranged in a single row within said tubular structure each tube being secured to at least two internal surfaces of said walls so as to cross brace said tubular structure against bulging under the application of internal hydraulic pressure, said plurality of small tubes also serving to subdivide the passage through said tubular structure into a plurality of separate ducts of small transverse dimension and high aspect ratio, one end of said structure being finished to expose an end of said tubular structure and the ends of said small tubes and providing the working end of said electrode adapted to be brought into close spacing relationship with a conductive workpiece to be shaped, and means connected to the other end of said structure to support said structure and to supply electrolyte under pressure to the ducts extending therethrough.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,019,178

January 30, 1962

Lynn A. Williams

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 41, for "l'" read -- l' --; column 3, line 15, for "recokoned" read -- reckoned --; line 41, for "existing" read -- exiting --; column 7, line 67, for "such" read -- said --; column 8, line 44, for "ot" read -- to --.

Signed and sealed this 5th day of June 1962.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

Dedication

3,019,178.—*Lynn A. Williams*, Winnetka, Ill. ELECTRODE FOR ELECTROLYTIC SHAPING. Patent dated Jan. 30, 1962. 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 March 14, 1972.*]