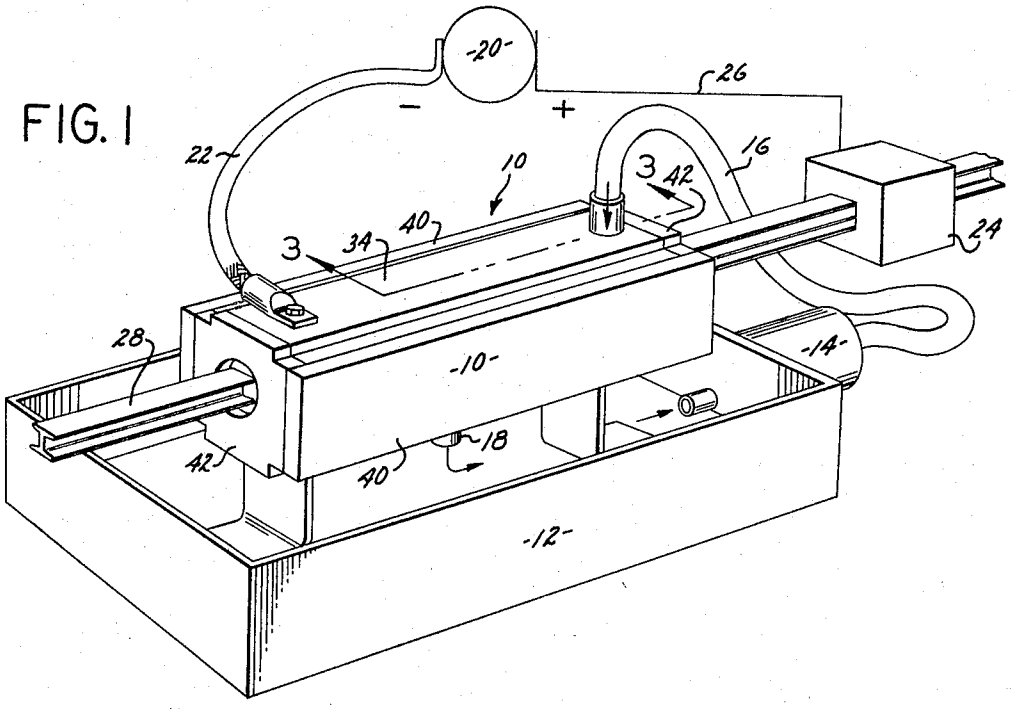
June 6, 1967 G. F. KEELERIC 3,324,022

APPARATUS FOR SHAPING METALS BY ELECTROLYTIC MEANS

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FIG. 1



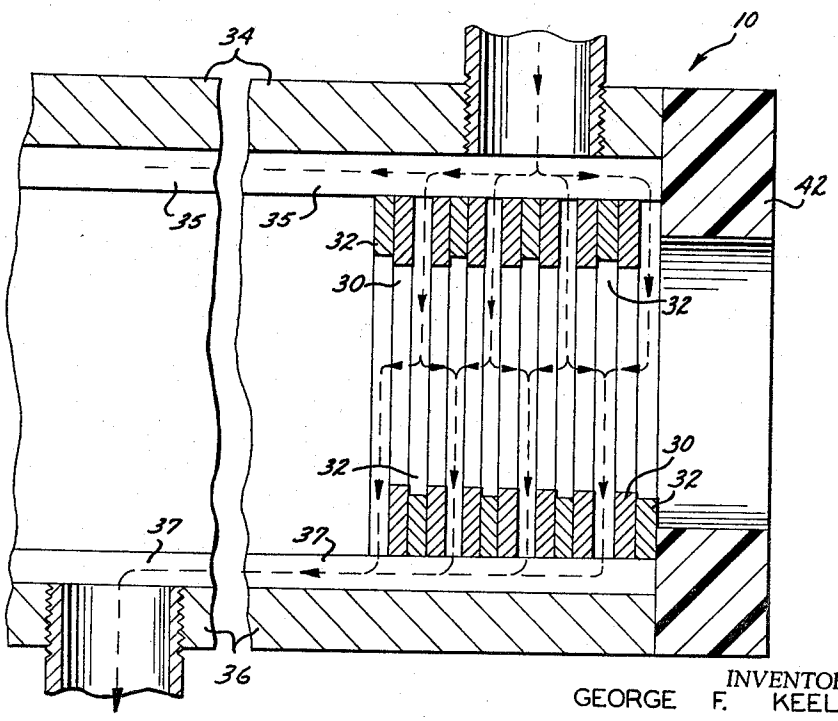


FIG. 3

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APPARATUS FOR SHAPING METALS BY ELECTROLYTIC MEANS

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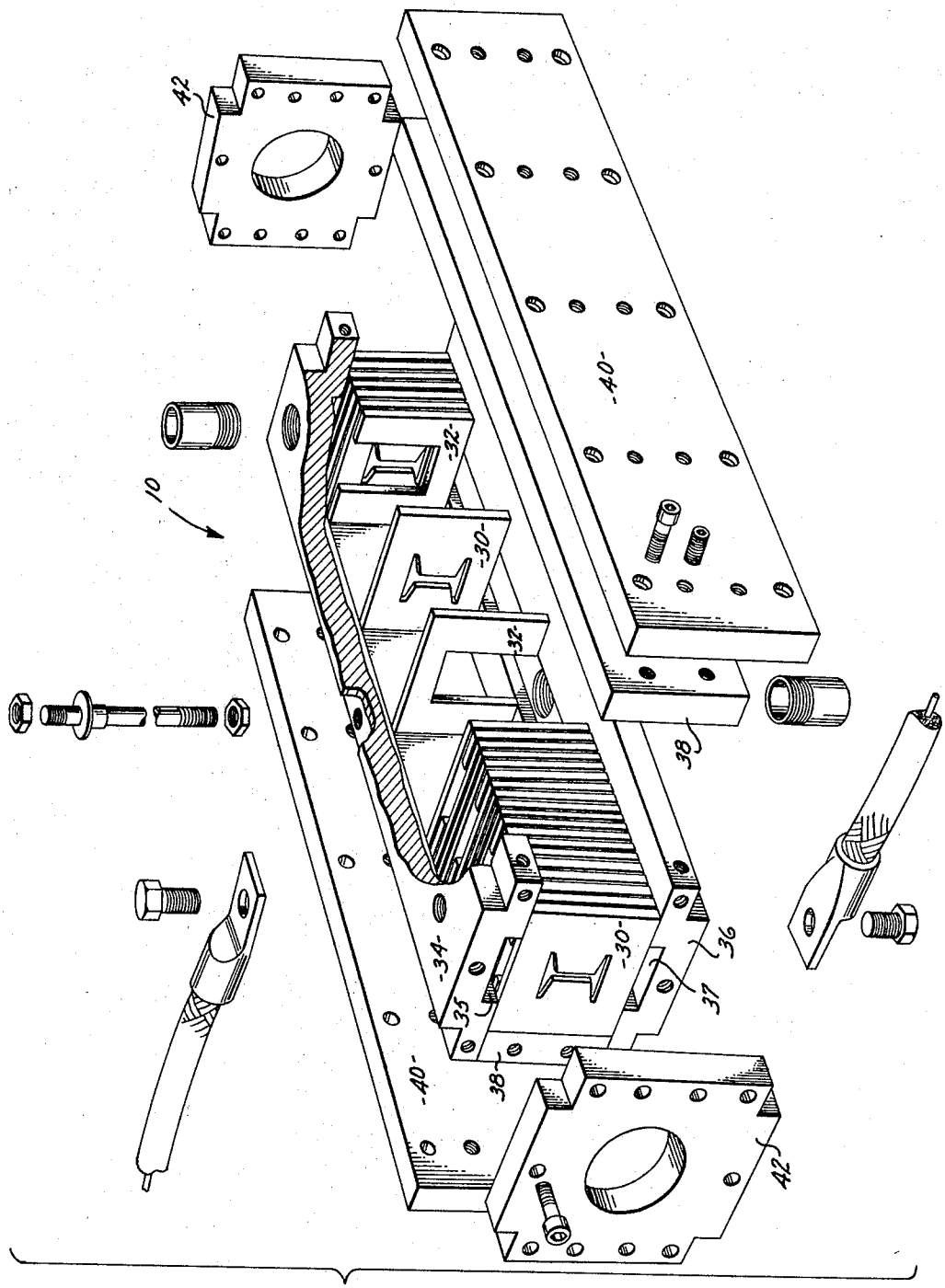


FIG. 2

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APPARATUS FOR SHAPING METALS BY ELECTROLYTIC MEANS

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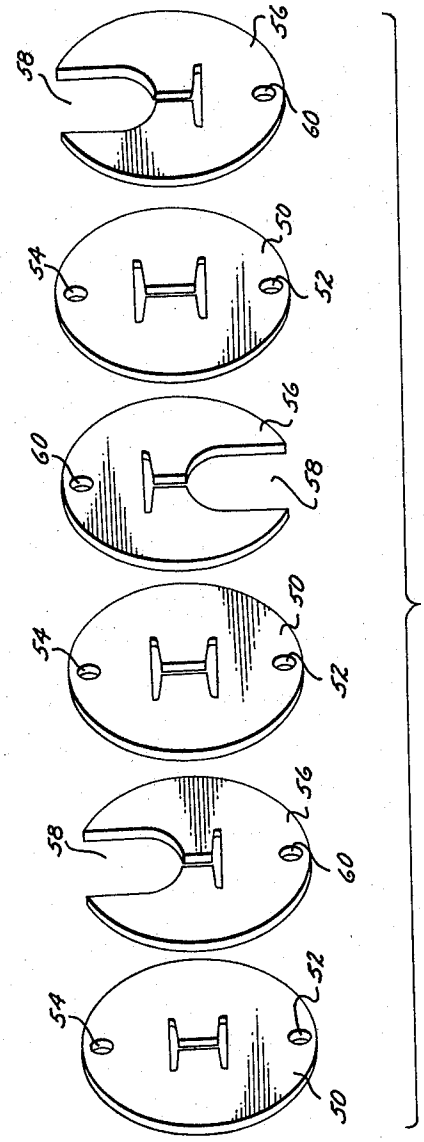


FIG. 4

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APPARATUS FOR SHAPING METALS BY ELECTROLYTIC MEANS

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6 Claims. (Cl. 204—224)

This invention relates in general to the methods and apparatus for electrolytically forming materials, and more specifically, to a new and novel die for electrolytically shaping and finishing to size.

The transfer of metal by electrolysis probably had its inception in the work of Michael Faraday (1791–1867) who found that the transfer of metal in an electrolytic cell is directly proportional to the amount of current flowing between the cathode and the anode. In fact, the ampere is defined by reference to the amount of current which when flowing for one second will deposit 0.001118 gram of silver.

Electroplating is one of the commercial results of Faraday's discovery, electromachining is another, and more recent one.

The application of this basic understanding to practical machining methods was considerably advanced by the inventions of Keeleric 2,826,540 and 3,004,910. A discussion of the practical aspects of electrolytic machining will be found in The Tool Engineer Magazine for December 1959 in an article entitled, "How to Apply Electrolytic Machining," by Lynn A. Williams.

The electrolytic transfer of a metal from an anode into a solution requires an anode and a cathode, an electrolyte occupying the space between, and a flow of current between them. The maximum amount of metal which can be transferred from the anode into the electrolyte depends on the current and the electro-chemical equivalent of the anodic material. In many cases, however, this maximum of transfer cannot be reached except at such small current densities that metal removal for practical purposes could not be accomplished. If the solution in contact with the anode becomes saturated with some compound, the anode becomes passivated and the current between the anode and the cathode becomes infinitely small, thus halting the dissolution of the anode.

In the Keeleric Patent No. 2,826,540, electrically insulating particles are provided in an electrically conducting rotating cathode, serving two purposes: preventing short-circuiting of the anode and cathode, and secondly, flushing fresh electrolyte continuously into the anode-cathode gap. Thus, depletion of the electrolyte is minimized as the replenishment of ions to the anode-cathode surface is no longer dependent on diffusion as it is in an ordinary electrolytic cell.

The Keeleric patent describes and illustrates a rotating cathode, but machining is also possible by maintaining a fixed relationship between the cathode and anode by other means than insulating spacers. Williams Patent No. 3,002,907 describes and illustrates such means. The present invention relates to such a machining operation.

More specifically, this invention is concerned with the removal of surface material from a roughly finished bar to produce a precise sizing and finishing operation.

Another object is to provide a finished machined bar extrusion, the material of which belongs to the so-called exotic metals group. These metals are difficult or impossible to work by conventional cutting tools without cold working. For example, brazed stainless steel honeycomb sandwich constructions sometimes incorporate solid members, such as profiled extrusions. The difference in transformation between the hardworked solid members, the

untransformed honeycomb material, and the coverskins causes a differential growth which may, in severe cases, result in warping and buckling of the honeycomb panel. Electromachined extrusions are not coldworked and therefore metallurgically do not differ from the other components of the sandwiched construction.

In prior electromachining of extrusions, a cathode die is used which generally has the form of a rectangular bar. A longitudinal cavity is provided, running from one end to the other. The cavity is tapered from one end to the other; the exit part being a few thousands of an inch bigger than the desired final form of the extrusion. The entrance to the die is sufficiently larger than the shape of the rough extrusion for facile entry. As well known by those skilled in the art, a flow of an electrolyte is caused to entirely fill the interspace between the die and the extrusion to be machined. An electric current flowing between the cathodic die and the anodic work then removes material from the work, and as the work progresses through the die, it appears from the exit side in the desired form and shape.

The stock removal rate is dependent upon the amount of current which flows between the cathode and the anode, and this current again is limited by the composition of the electrolyte, the areas of the cathode and anode and the rate of ion depletion at the cathode-anode surfaces. If the electrolyte is allowed to stagnate, concentration polarization sets in as the ions of the freshly dissolved metal accumulate in the vicinity of the anode. Thus, there is set up a concentration gradient, and as the current density is further increased, a limiting polarization value is reached when the solution at the surface of the anode becomes saturated with the metal salts. To overcome this phenomenon, the electrolyte is pumped under high pressure in order to obtain a high rate of flow into the cathode-anode interspace. However, as the electrolyte flows from its entrance point in the die to its exit point, it is being gradually depleted. Furthermore, the high pressure of the electrolyte tends to defeat the accurate placement of the work in the die because of the whipping action of the high pressure flow as it enters and flows along the workpiece. As it exits at the end, the electrolyte tends to vibrate the workpiece, sometimes causing a short between the electrodes.

One of the principal objects of this invention, therefore, is to supply fresh electrolyte to all portions of the cathode die and substantially equal pressure and flow rate.

Another object is the provision of an improved and easy process for making a die for cathode machining.

Other objects and a fuller understanding of this invention will become apparent with consideration of the following specification and by a view of the preferred embodiment of the invention as set forth in the following figures:

FIGURE 1 is a substantially schematic prospective view of apparatus suitable for carrying out the objects of the present invention;

FIGURE 2 is an exploded prospective view of the cathode die construction embodying the features of the present invention;

FIGURE 3 is a section view taken substantially along the line 3—3 of FIGURE 1; and

FIGURE 4 is a substantially schematic exploded view illustrating an alternate embodiment of the invention.

There is illustrated a schematic prospective view of apparatus functionally related to carry out the concepts of this invention. FIGURE 1 illustrates a die cathode **10** seated over a tank **12** which is provided to hold a body of electrolyte. Pump **14** is connected to take electrolyte from the tank **12** and supply such electrolyte under high pressure through hose **16** into the die **10**. The electrolyte

exhaust from the die through an outlet **18** falls back into the tank **12**.

An electric supply **20**, which is adapted to provide high current density, is connected by means of cable **22** to the cathode die. A box configuration **24** is employed to indicate a suitable drive device for moving workpieces, and also provides a commutation connection of a cable **26** from supply **20**. A workpiece **28**, illustrated in the form of an I-beam passes through the box **24** and the die **10** to illustrate the relationship.

The drawings illustrate the parts in schematic relationship in the FIGURE 1, and there is no attempt made in the FIGURE 1 to illustrate the relationship of the rough bar before entering the bar **10** and its finished condition as it exists.

Referring then to the FIGURE 2, an actual cathode die construction is illustrated as designed to carry forth the concepts of the present invention. The functional portion of the die **10** is built up of a plurality of die section pieces **30** alternately spaced by a like plurality of spacer pieces **32**. Each of the section pieces **30** is provided with a through opening in the general shape of the workpiece as it should be at the particular phase of electromachining desired for the position of that particular section piece in the die stack. That is, as previously stated, the workpiece is rough in oversize as it enters into the die. Hence, the section pieces at the entrance end are oversized in order to permit the easy entry and the electrolytic action to take place only upon the high spots of the workpiece. As the section pieces **30** progress from the entrance to the exit opening, the configuration of the openings change according to the calculations of the amount of metal that should be remaining at that particular stage of electrolytic machining. The spacer pieces **32** are not part of the machining process and are provided for the important function, according to this invention, of providing a means for supplying a conductive electrolyte into a plurality of locations simultaneously and draining the electrolyte out at a plurality of other locations whereby a given portion of electrolyte passes into the passageway defined by the section pieces **30** and is drained away from the passageway in a limited period of time.

In order to accomplish such function, the spacer pieces are made in U shape as illustrated in the central area of FIGURE 2. They have two side arms and a connecting cross bar to provide an open top and a closed bottom. The section pieces **30** and the spacer pieces **32** are then assembled with the section pieces aligned to define the passageway and with the spacer pieces disbursed between selected ones of the section pieces. The preferred embodiment as illustrated provides the spacer pieces **32** being placed between each of the section pieces and with alternate ones of the spacer pieces facing in opposite directions. This is illustrated in the FIGURE 2. The spacer piece to the left in the area where some pieces have been removed for illustration is facing downwardly. The one to the right is opening upwardly.

A header **34** is clamped over the top of the stack of section and spacer pieces. The hose **16** connects to the header **34**. A longitudinal extending recess **35** provides a trough through which the electrolyte may flow along the entire top of the stack of section pieces and spacer pieces. Thus, as the electrolyte flows through the recess **35** it will find many entrance openings into the spacer pieces which are opening upwardly. Of course, it will not enter into those which open downwardly. The electrolyte therefore flows down into each of the upwardly opening spacer pieces and then flows in both directions into the neighboring adjacent section pieces and thence through to the next spacer piece which opens downwardly. The downwardly opening spacer piece permits the electrolyte to flow out of the die back into the tank **12**. By this construction each section piece **30** is supplied by an entrance opening on one side and an exit on the other. The electrolyte does not need to flow any farther. The electrolyte

which flows into one spacer member is divided between two section pieces, and the downwardly opening spacer piece acts as a drain for two adjacent section pieces. Hence, the flow is uniform throughout the die stack and there is no buildup of pressure in any area of the workpiece passing through the section pieces.

A header **36** on the bottom of the die is provided with a recess **37** which will collect the electrolyte and guide the electrolyte to the outlet **18**.

Spacers **38** on either side of the stack of section and spacer pieces provides structural strength for the clamping of the headers **34** and **36** and side members **40** enclose the entire assembly. End pieces **42** provide structural unity and means for establishing a positive pressure uniting the section pieces and spacer pieces as a cooperative stack without undue leakage possibilities therebetween.

Because the flow of electrolyte into the die is distributed so evenly and is allowed to exit without buildup of back pressure, there is no considerable tendency to leak from the die as there would be in the prior methods of permitting a high pressure to force to the ends for exit.

The FIGURE 3 illustrates the flow of electrolyte as previously described and suggests in very exaggerated form the fact that the sections **30** provide a progressively smaller and more closely defined opening as the spacing of the section piece proceeds from the entrance opening.

The FIGURE 4 is highly schematic but will serve to illustrate an alternate embodiment providing refinements of construction and distribution useful for many purposes. The drawing illustrates a series of section pieces **50** corresponding generally to the section pieces **30**, with the exception of the provision of opposed through openings **52** and **54**.

Spacer **56** is provided with a U-shaped notch **58**, corresponding to the similar notch shown in FIGURE 2. This spacer has a through opening **60**.

In the simplified version illustrated in FIGURE 4, section pieces **50** are separated by the spacers **56**, and alternate ones of the spacer **56** are positioned to direct the notch thereof in opposite directions. In the illustration the notch **58** of the first spacer in the left of the series is directed upwardly. The next spacer being the fourth element in the drawing from the left is spaced downwardly. Thus, when the members are all forced together in a stack, the openings **54** of the section pieces are all in alignment but the spacers alternately present the notch **58** and the opening **60** in alignment with the openings **54**. Likewise, the openings **52** are aligned and notches **58** and openings **60** are in alternate alignment with the series of openings **52**.

Therefore, one or the other of the through openings of the section pieces may be selected as a feed entrance and the other as an exhaust outlet. Assuming the opening **54** at the top of the first section piece to be the supply line entrance, the electrolyte may be fed under pressure through this line and will fill the notch **58** of the adjacent spacer **56**. The electrolyte will then flow into the central openings of the section pieces on either side thereof. The electrolyte will flow from the face of the die through the first of the section pieces but that electrolyte supplied to the second section piece will pass on through into the notch **58** of the fourth element, which is a spacer having the notch **58** thereof in alignment with the series of through openings **52** and hence is a drain outlet.

The fluid supplied to the entrance opening **54** will also pass through the notch **58** and on through the opening **54** in the third element, which is a section piece. The opening **54** in the third element does not connect in any manner with an outlet and hence the fluid will be directed on to the fourth section piece which is a spacer. However, opening **60** in the spacer element is also not connected with any opening within that spacer and thence the fluid will pass on through to the fifth element which is again in a section piece. This piece, likewise, does not provide

fluid communication with the central opening. Hence, the fluid passes on to the sixth element where it finds an opening in the form of the notch 58 again leading to the two adjacent pieces where the distribution is carried out as described with respect to the first of the spacer members, with the exception that the section piece to the left in the series feeds not to the atmosphere but to the fourth element spacer and hence to the drain series 52.

It is contemplated that in actual production the numbers of inlet and outlet series will be at least doubled but possibly three or four sets will be used. Hence, eight openings in each of the section pieces 50, and seven openings plus a notice in each of the spacers will provide a series of four entrance openings and four exhaust openings by means of spacing each spacer member one rotary stop from the previous spacer member. The illustration of such an extended series would require an unduly enlarged drawing series and hence only the simplified version is illustrated in the drawing, and those skilled in the mechanical art will readily visualize the lesser rotative spacing of the spacers, rather than the 180 degree spacing as shown in the drawing.

The drawings suggest in FIGURE 3, the usual material for the spacers to be metal. Hence, the entire pack is conductive and only one electrical connection need be made.

However, for some service, it is desirable to provide one portion of the die with a greater or lesser current density than another part. Therefore, an insulating spacer may be inserted to block off areas of the section pieces, and separate power supplied to each group. The division can be extended to the extent of separating each section from the other. Thus, the objective of introducing the electrolyte in the axial direction of the workpiece is achieved, and additionally, each segment of the die may be individually supplied and controlled in current density.

While the instant invention has been shown and described herein in what is conceived to be the most practical and preferred embodiments. It is recognized that departures may be made therefrom within the scope of the invention which is therefore not to be limited to the details disclosed herein but is to be afforded the full scope of the claims.

What is claimed is:

1. An improved electrolytic cathode for the shaping of rod workpiece material comprising:
   (1) a plurality of section pieces each having an opening therethrough defining a portion of a complete die passageway produced by assembly of the pieces in alignment;
   (2) electrolyte supply passageway means providing an inlet supply between selected ones of said sections and an outlet between others whereby a given portion of electrolyte passes into the passageway and is drained from the passageway in a limited period of time;
   (3) spacing and guide means providing a guide path for a workpiece through said die and preventing contact of a workpiece with said die; and
   (4) means for applying a voltage between said die and a workpiece for electrolytic machining of the workpiece.

2. An improved electrolytic cathode die for the shaping of rod workpiece material comprising:
   (1) a plurality of section pieces each having an opening therethrough defining a portion of a complete die passageway produced by assembling of the pieces in alignment;
   (2) a plurality of spacer pieces each having two side arms and a connecting cross bar to provide an open top and a closed bottom with a notch from the periphery to the interior;
   (3) said sectioned pieces and spacer pieces assembled with the section pieces aligned to define said passageway, and with said spacer pieces disbursed between selected ones of said section pieces, the spacer pieces thereby providing fluid communication between the exterior of said die and said passageway;
   (4) header means providing an electrolyte passageway to some of the open tops of said spacer pieces; and
   (5) means for providing a pressurized supply of electrolyte fluid to said header means;
   (6) whereby electrolyte is supplied through some spacer pieces to said passageway and drained from said passageway through other spacer pieces to thus provide a short duration of time of the electrolyte in said die.

3. In the electrolytic cathode defined in claim 2, said spacer pieces being placed with alternate ones facing in opposite directions and the header means supplying all those opening in one direction, to thereby enable the electrolyte to escape through adjacent section pieces to the next spacer pieces and drain from the die.

4. In the electrolytic cathode defined in claim 2, said section pieces and spacer pieces being placed in alternate sequence and with alternate ones of said spacer pieces being placed with the opening facing in opposite directions and the header means supplying all those opening in one direction, to thereby enable the electrolyte to escape through adjacent section pieces to the next adjacent spacer pieces and then drain from the die.

5. In the electrolytic cathode defined in claim 2, said header means of paragraph 4 being a series of through openings in said plurality of section pieces aligned to form a conduit from the end of the die.

6. An improved electrolytic cathode die for shaping of rod workpiece material, comprising:
   (1) a plurality of section pieces each having an opening therethrough defining a portion of a complete die passageway produced by assembling of the pieces in alignment, and each having at least two electrolyte openings also alignable with like openings to define passageways;
   (2) a plurality of spacer pieces each having essentially the identical form as the section pieces and additionally having one of the electrolyte openings enlarged into a notch extending from the periphery of the spacer and into communication with the opening provided for the workpiece die passageway;
   (3) said spacer pieces being rotated axially to various operative positions wherein no notch is in alignment with the notch of the next adjacent spacer;

whereby header means may be provided at the ends of the die.

References Cited

UNITED STATES PATENTS

3,056,734	10/1962	Scott	204—143
3,058,895	10/1962	Williams	204—143

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