May 31, 1966 L. A. WILLIAMS 3,254,013

ELECTROLYTIC CAVITY SINKING APPARATUS

Filed July 27, 1962

Fig. 1.

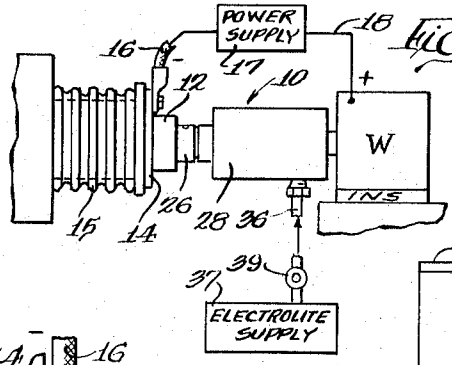


Fig. 4.

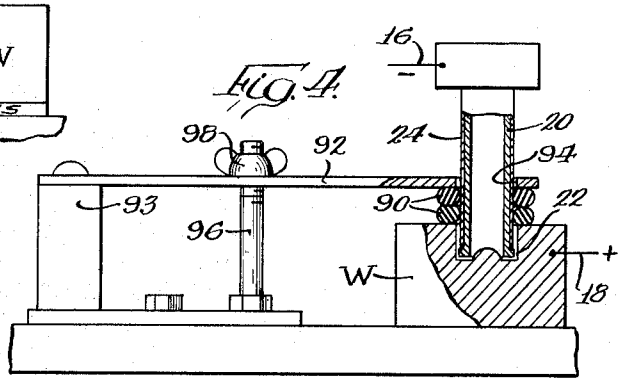


Fig. 2.

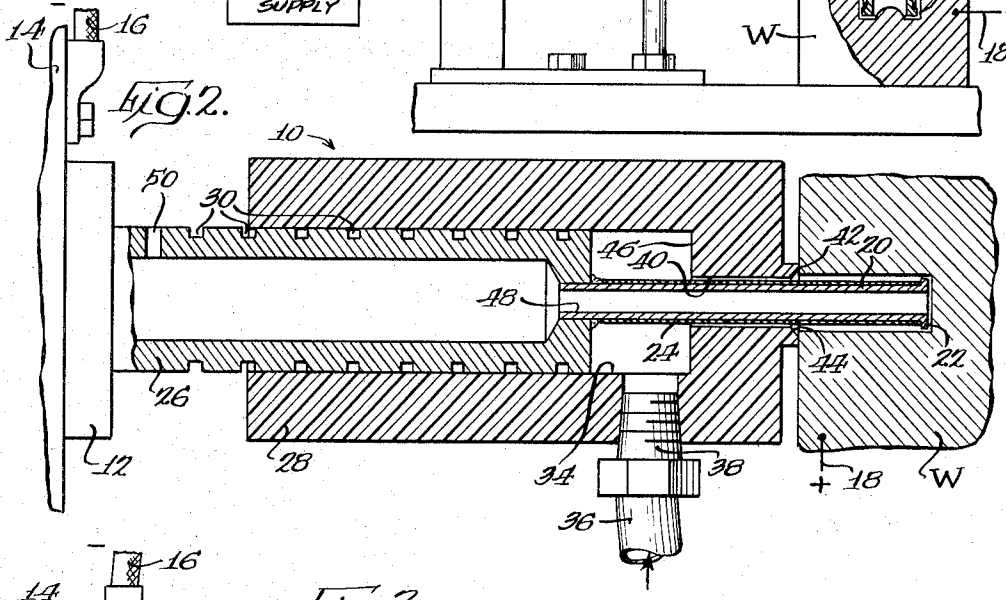
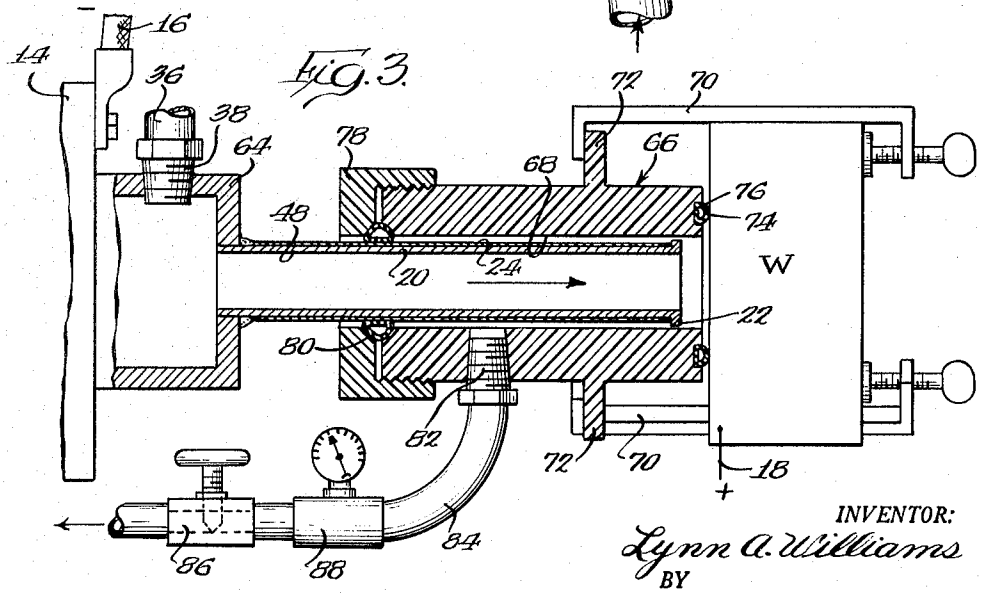


Fig. 3.



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ELECTROLYTIC CAVITY SINKING APPARATUS

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6 Claims. (Cl. 204—224)

The present invention relates generally to electrolytic cavity sinking or shaping apparatus and method of the type disclosed in the copending applications of Lynn A. Williams, Serial No. 772,960, filed November 10, 1958, for "Electrolytic Shaping," now issued into Patent No. 3,058,895, dated October 16, 1962, and Lynn A. Williams and James E. Davis, Serial No. 863,246, filed December 31, 1959, now abandoned, for "Control and Operating System for Electrolytic Hole Sinking." This application is a continuation-in-part of the copending applications of Lynn A. Williams, Serial No. 772,960, filed November 10, 1958, for "Electrolytic Shaping" and Serial No. 158,042, filed December 8, 1961, for "Electrolytic Shaping Apparatus," and of the copending application of Joseph L. Bender and Lynn A. Williams, Serial No. 37,766, filed June 21, 1960, for "Electrolytic Cavity Sinking Apparatus and Method."

The present invention is concerned with improving the finish on the walls of the cavity by the use of back pressure on the electrolyte in the work gap.

The present invention is also concerned with controlling the action of the electrode and the electrolyte so as substantially to eliminate or reduce troublesome lateral vibration of electrodes used in both cavity sinking and workpiece shaping operations, and to control the breakthrough of the electrode at the remote side of the workpiece to produce a true hole or opening without irregularities and without excessive sparking between the workpiece and the electrode.

In general, apparatus of the type disclosed in the foregoing applications includes a fixture for securely mounting the workpiece, a hollow electrode having a working tip of electrically conductive material, a ram head mounting the electrode for movement toward the workpiece, an electric power supply connected to the electrode and to the workpiece so as to make the workpiece anodic and the electrode cathodic and capable of delivering a low voltage (4 to 15 volts), high density (100 to 8000 amperes per square inch) direct current, and a source of electrolyte capable of delivering electrolyte at a high velocity in the work gap between the electrode and the workpiece and at a pressure in the range of about 50 to 200 pounds per square inch.

It has been found from practical experience that one of the difficulties in obtaining the maximum rate of penetration of the electrode into the workpiece is that the electrode tends to vibrate laterally, thereby causing short circuiting against one of the side surfaces, either on the internal bore of the electrode or externally, or both. It now has been discovered that one of the things which causes or effects the lateral vibration is the tendency to store energy within the column of liquid inside the electrode. The cause of the oscillation which usually occurs at a frequency within the sonic range appears to be the fact that the electrolyte is being delivered in the work gap at an exceedingly high velocity and under a very high pressure, in the range, as previously stated, of 150 to 200 pounds per square inch. When it is considered that the work gap between the electrode and the surface of the workpiece being acted upon is in the order of .002", it is not surprising that there is a feedback oscillation in the column of liquid in the electrode's passageway. It is a principal object of the present invention to provide means

associated with the electrode and the feed of electrolyte to dampen or break up this oscillation and thereby eliminate the lateral vibration of the electrode within the hole being formed.

Another problem which has been encountered is in connection with through bores or holes being formed in a workpiece. When the electrolyte is fed to the workpiece through the bore of the electrode, then as the electrode approaches the remote or exit side of the workpiece, it will usually break through in some one area before it breaks through all the way around. This is due to the almost unavoidable irregularities in the surface of the workpiece. When this occurs, the electrolyte then finds its way out through the broken through opening at the exit side, instead of turning back over the working tip of the electrode to return along its axis to the entry surface of the workpiece. This is detected by observing a jet of electrolyte squirting through an opening on the exit surface of the workpiece. In the copending application, Serial No. 772,960, arrangements are disclosed to prevent this. One of them is to provide a dummy piece fastened to the exit surface of the workpiece by some adhesive such as water glass. In another form, a backup material of soft rubber is used. It is obvious that these arrangements involve some inconvenience, and in some cases they are very difficult to use because the exit surface of the workpiece may lead into a more or less closed chamber which is not readily accessible. Unless some form of backup device is used, and unless the electrode is advanced so that its working tip has passed completely through the workpiece and into the backup device, there will be in the cavity adjacent the exit surfaces a sharp inturned lip.

It is therefore another primary object of the present invention to provide a new arrangement for feeding the electrolyte and advancing the electrode which will overcome the difficulties encountered in the breakthrough of the electrode from the exit side of the workpiece.

It should be noted that to a large extent the arrangement for overcoming the lateral vibration also improves the exiting characteristics of the electrode feed.

Another primary object of the present invention is to provide an arrangement for placing a back pressure on the electrolyte exiting from the work gap, thereby to improve the finish on the surfaces subjected to electrolytic action.

Another object is to provide new and improved electrolytic cavity sinking apparatus wherein the electrolyte is fed along the outer surface of the electrode to the work gap to exit through the bore of the electrode.

Another object is to provide a new and improved electrolytic cavity sinking apparatus and method wherein the electrolyte is fed in such fashion that any column of electrolyte within the electrode is inhibited against longitudinal oscillation which will provide lateral vibration of the electrode.

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

FIG. 1 is a schematic view of a portion of an electrolytic cavity sinking apparatus illustrating one form of the present invention;

FIG. 2 is a longitudinal medial section view on an enlarged scale through the electrode guide or bushing;

FIG. 3 is a view similar to FIG. 2, showing another arrangement for placing back pressure on the electrolyte in the work gap and through the exit passages; and

FIG. 4 is a medial sectional view of a further and simple arrangement for placing back pressure on the electrolyte to obtain an improved surface finish.

In the drawing, there has been shown only so much of an electrolytic cavity sinking machine or apparatus as is necessary to an understanding of the present invention. Such apparatus is more completely disclosed in the aforementioned patent applications Serial Nos. 772,960 (Patent No. 3,058,895), 158,042, and 863,246.

Referring to FIG. 1, the apparatus includes an electrode structure, indicated generally by the reference character **10**, which is fastened by a flange **12** to a ram plate **14**. The ram plate is mounted on the forward end of a ram structure **15**, and is insulated therefrom by an insulating block. The ram structure includes a movable member powered from a positively driven screw (not shown) which will advance the electrode **10** at a constant speed into the work W. The machine includes an electric power supply **17** shown diagrammatically, the output of which is connected by a cable or conductor **16** to the ram plate **14** and electrode **10**, and a conductor **18** to the work through the table and work holder which normally supports the workpiece W in place. The power supply is capable of delivering, as previously mentioned herein, a low voltage (4 to 15 volts), high density (100 to 8,000 amperes per square-inch) direct current in a sense to make the electrode **10** negative and the workpiece W positive.

The electrode structure **10** includes the electrode proper at **20** having a working tip **22** of slightly greater diameter than the shank or body of the electrode **20**. The shank or body is coated, at least on its exterior surface, with an insulating material **24**, which may be a vitreous enamel or an epoxy resin. If the electrode is of any substantial diameter, the interior also will be provided with a coating of insulation similar to the insulation **24**.

The electrode **20** is made integral with or commonly mounted in an enlarged tubular piston-like portion **26** which serves as the electrode mount, and which in turn is secured to the flange **12**. Mounted on the electrode mount **26** is a bushing **28** which may be made of a plastic material impervious to chemical deterioration or damage by heat. Experimentally, an acrylic resin has been used and found to be satisfactory, but for a permanent insulation a more durable material, such as Teflon resin, is preferred. The feed bushing **28** is mounted so that it slides easily over the electrode mount **26** and has a clearance therewith in the order of .002". To prevent excessive leakage of electrolyte a number of square bottomed, annular grooves **30** are cut into the external surface of the electrode mount, and they provide a sufficient seal to prevent excessive leakage of electrolyte between the feed bushing **28** and the mount **26**. The feed bushing is made in such a way that at the inner end of its cylindrical bore **32** there is provided an annular opening **34** into which the electrolyte is fed under pressure through a supply line **36** and a fitting **38**. The supply line **36** is connected to a source of electrolyte under pressure shown diagrammatically, which includes a supply tank **37** and pump **39** capable of delivering electrolyte at a pressure in the range of approximately 50 to 200 pounds per square inch.

The bushing **28** is formed with a bore **40** at its exit end which is just large enough to permit being slipped over the working tip **22** of the electrode **20** so that there is a clearance of several thousandths of an inch between the bore **40** of the bushing and the shank of the electrode **20**, thereby permitting the easy and adequate flow of electrolyte along the side wall of the electrode and down over the working tip **22**. At its exit end the guide bushing **28** is relieved to provide a sealing shoulder **42** of reduced cross sectional area to permit sealing against a workpiece, than would otherwise be possible. Within the confines of the shoulder there is a recess **44** which is provided to accommodate the tip **22** of the electrode to prevent its coming into contact with the entry surface of the workpiece W when the electrode is first advanced toward the workpiece and the initial erosion of the workpiece is being effected.

The feed bushing **28** is more or less permanently mounted on the electrode mount **26**, and the entire assembly is then brought into close proximity with the workpiece W with the bushing extended so that its sealing shoulder **42** touches the workpiece while the working tip **22** of the electrode is slightly recessed within the bushing at **44**. As electrolyte is fed through the flexible tube **36** and fitting **38** into the chamber **34**, the effect is to create a hydrostatic force on the surface **46** of the chamber **34**, thus urging the bushing into sealing engagement with the entry surface of the workpiece. Since the area of the frontal surface **46** is substantially in excess of the effective area of the reduced sealing shoulder **42**, the effect of any increase in work pressure from the ram structure is inceased sealing pressure, thereby completely eliminating the need for any mechanical clamp or the like.

The electrolyte is pumped under pressure along the exterior surface of the electrode through the space in the bore **40** between the electrode and the surface of the bore, over the edge of the working tip **22**, and back through the bore **48** in the electrode **20**. The exit path may be valved through a needle valve and gauge if it is desired to observe and adjust the back pressure. In the case of electrodes which are intended to be used many times in repetitive production operations, a simple exit hole may be provided in the electrode at its back end. In this case the bore through the electrode mount is closed, as shown, by the flange **12**. If it is desired to adjust the back pressure, such may be done by an outlet bushing, needle valve, and conduit leading to a drain. By arranging the exit hole **50** so that it opens upwardly and is visible, it is possible to have an excellent visual indication of the rate of electrolyte flow. This can be used for adjusting the in-feed rate of the electrode **20**. The in-feed rate is increased up to the point where the reduction in the height of the fountain stream through the exit hole **50** indicates that the free flow of electrolyte is being impeded by too close a gap between the working tip **32** and the workpiece. This follows the teachings of application Serial No. 772,960 in that the fountain column of liquid constitutes a type of flow meter. The amount of back pressure in the work gap is determined by the size of the exit hole **50**, and this usually will be adjusted so that with an in-feed pressure in the order of 50 to 200 p.s.i., the back pressure at the exit hole **50** will range from approximately one foot head of electrolyte solution to a pressure of the order of a half, or even more than that, of the inlet pressure.

The specific structure illustrated in FIG. 2, while embodying and utilizing and is typical of applicant's basic and sole invention disclosed herein, is the joint invention of applicant and Joseph L. Bender, as set forth in one of the parent applications of this application, namely Serial No. 37,766 filed June 21, 1960, and its divisional application Serial No. 464,045, filed June 15, 1965.

It will be appreciated that this arrangement maintains a solid column of liquid all the way around the perimeter of the working tip **22**. In consequence of this, the amount of side action is increased over that which occurs when the electrolyte is applied to the bore of the electrode. The result is to increase the overcut; that is, the excess of the size of the hole in the work with respect to the size of the electrode working tip. Accordingly, either the electrode must be advanced more rapidly, the supply voltage of direct current must be lowered, the width (in the direction of advance) of the working tip must be narrowed, or some other means, such as an increase in allowance for the amount of overcut, must be taken.

When the electrolyte is fed around the outside of the electrode, the problem of breakthrough at the exit side is minimized, at least in those instances where the plane of the working tip and the plane of the exit surface are generally parallel. What happens is that, during the operation, with the electrolyte passing completely around

the outside of the electrode and back through its bore and with the electrode approaching the exit surface, a breakthrough may be achieved by the electrode at one point prior to another, but the liquid electrolyte will continue to pass over the entire active area of the working tip on its way to either of the exit paths; that is, the exit path through the bore **48** of the electrode, or through the newly created opening in the exit surface. In this way the electrode can be advanced so that the working tip passes entirely through the workpiece, eliminating any inturned lip.

It has also been found that with this arrangement the electrode **20** is less subject to lateral vibration or oscillation, as the solid column of liquid surrounding it tends to dampen an oscillating tendency and to absorb feedback energy sufficiently to prevent regeneration of oscillatory impulses.

Another arrangement is shown in FIG. 3, wherein the electrode **20** is connected to a header **64** carried on the ram plate **14**. The flexible supply conduit **36** is connected to the header **64** by the fitting **36**. The electrode **20** projects through a bushing **66** having a bore **68** therein of slightly larger diameter than the tip **22** of the electrode, so that there is a passageway along the outer surface of the electrode and past the tip **22** for the free and easy flow of electrolyte. The bushing **64** is clamped against the entry surface of the workpiece W by a plurality of C-shaped clamping devices **70** engaging wings **72** on the bushing, and is sealed thereagainst by an O-ring **74** carried in a groove **76** in the forward end of the bushing **66**. At its opposite end, the bushing **66** has a cap **78** threaded thereon to compress a sealing ring **80** in conical recesses in the cap and the inlet end of the bushing at **66**. The compression of the ring **80** is such as to cause it to seal against the outer surface of the electrode and to prevent the escape of electrolyte confined within the bore **68**.

The electrolyte is pumped under a pressure of 50 to 200 pounds per square inch in the customary manner through the bore **48** of the electrode **20** toward the workpiece W, around the tip **22**, and back through the bushing bore **68** and the external surface of the electrode. It exits through a fitting **82** connected to a conduit **84** having an adjustable needle valve **86** therein and a pressure gauge **88** to measure the back pressure of the electrolyte in the tube and at the work gap.

By use of the needle valve **86** the back pressure of the electrolyte can be regulated for three purposes. First, it can be regulated to the point where an undesirable longitudinal oscillation does not take place within the bore **48** of the electrode. Furthermore, it provides a cushion along the outer surface of the electrode which inhibits any lateral vibration of the electrode and therefore any contact between the working tip **22** and any other uninsulated part of the electrode, and the bore being formed in the workpiece W. Thirdly, the back pressure on the electrolyte in the work gap and in the exit passage surrounding the electrode has been found to give the cavity wall an improved finish over those cavities formed where no back pressure is placed on the electrolyte.

Referring to FIG. 4, there is shown a simple arrangement used to impart a high spectral finish on the walls of the cavity. Around the electrode **20** there are placed one or more synthetic rubber gaskets **90**, such as the two O-rings shown. These are soft enough to seal against the face of the work W and are formed to fit closely the contour of the electrode **20**. A clamp plate **92** is mounted on a pedestal **93** at one end and has a clearance opening **94** to surround the electrode **20** at its opposite end. A stud **96** passes through a central clearance hole in the clamping plate **92** and is fitted with a wing nut **98** by which the clamping plate **92** may be bent downwardly to clamp and compress the gaskets **90** so that they seal against both the face of the work W and the body of the electrode **20**. The clamping pressure is adjusted to permit escape of electrolyte which is pumped through the bore of the electrode at a pressure of 100 p.s.i., for example, but yet holding the electrolyte under some pressure after it passes the tip **22** of the electrode. The electrode is insulated at **24**, as previously described, and is advanced into the cavity, preferably by a positive mechanical drive which is not influenced in its rate of advance by the friction of the seal.

Under these conditions with most electrolytes suitable for the particular work material involved, the side walls of the cavity show a bright lustrous finish characteristic of electropolishing. As a typical example, a cavity was sunk in a piece of super-alloy material AMS 5537, sometimes designated L605 or Stellite 25. Its composition is given as follows: 20% Cr, 10% Ni, 15% W, balance Co.

The electrolyte consisted of the following in 15 gallons of tap water:

	Ounces
Potassium nitrate	23.3
Rochelle salt	13.3
Sodium nitrite	18.6
Potassium chloride	28.0
Calgon Banox	4.8

Calgon Banox is the trade name for a phosphate type corrosion inhibitor.

It is believed that the electropolishing action may be caused by relatively high velocities and pressure over the work surface. The high velocities may tend to reduce the polarizing or passive film which is always tending to form on the anode at high current densities. But this reduction in thickness of the anodic film is much more marked on any protuberance or minute point of the surface and much less marked at any depressed portion, thus tending to attack the high points more rapidly. It has been proposed to use rotating discs as cathodes, but there are severe limitations on the practical usability of this means of attaining high velocity in the electrolyte. For example, many irregular shapes of work can scarcely be approached to a rotating member in a uniform manner. But, so far as is known, the use of high pressure pumping to attain high velocities for electropolishing is new. With the high velocity, the use of pressure of several atmospheres permits operating at current densities which might cause excessive gassing and even boiling which, of course, prevents good polishing. As far as is known, it is new to use high pressure in an electrolyzing system to permit attainment of high current densities either for electropolishing or for rapid mass metal removal.

It is clear from the foregoing that the objectives which have been claimed for this invention at the outset of the specification have been attained.

While preferred embodiments of the new and improved electrolytic cavity sinking apparatus constituting the present invention have been shown and described, it will be apparent that numerous modifications and variations thereof may be made without departing from the underlying principles of the invention. It is therefore intended, by the following claims, to include all such variations and modifications by which substantially the results of this invention may be obtained through the use of substantially the same or equivalent means.

What is claimed as new and desired to be secured by United States Letters Patent is:

1. In an electrolytic cavity sinking apparatus for forming cavities in an electrically conductive and electrochemically erodible workpiece, the combination comprising, a hollow electrode having an electrically conductive working face, the bore of said electrode forming a first electrolyte passage, means mounting said electrode and the workpiece for movement relatively toward each other, electric power means connected to said electrode work-

ing face and the workpiece to pass a low voltage, high density direct current between said electrode working face and the workpiece in a sense to make the workpiece anodic, a bushing having a bore therethrough through which said electrode movably extends with the outer surface of said electrode and the inner surface of said bushing bore defining a second electrolyte passage, means sealing said bushing against the entry face of the workpiece at that end of said bushing bore from which said electrode working face projects, means holding said bushing and said sealing means against the entry face of the workpiece to hold them relatively stationary as said electrode is moved relatively into and through said bushing during the cavity sinking operation, an electrolyte inlet to one of said electrolyte passages, means connected to said inlet for pumping an electrolyte through both said passages and a work gap between said electrode working face and the workpiece under superatmospheric pressure, an electrolyte outlet from said other passage, and means at said outlet to restrict the electrolyte flow therethrough, thereby to place a back pressure on the eletrolyte in the work gap.

2. In an electrolytic cavity sinking apparatus for forming cavities in an electrically conductive and electrochemically erodible workpiece, the combination comprising, a hollow electrode having an electrically conductive working face, the bore of said electrode forming a first electrolyte passage, means mounting said electrode and the workpiece for movement relatively toward each other, electric power means connected to said electrode working face and the workpiece to pass a low voltage, high density direct current between said electrode working face and the workpiece in a sense to make the workpiece anodic, a bushing having a bore therethrough through which said electrode movably extends with the outer surface of said electrode and the inner surface of said bushing bore defining a second electrolyte passage, means sealing said bushing against the entry face of the workpiece at that end of said bushing bore from which said electrode working face projects, means holding said bushing and said sealing means against the entry face of the workpiece to hold them relatively stationary as said electrode is moved relatively into and through said bushing during the cavity sinking operation, an electrolyte inlet to one of said electrolyte passages, means connected to said inlet for pumping an electrolyte through both said passages and a work gap between said electrode working face and the workpiece under superatmospheric pressure, an electrolyte outlet from said other passage, and adjustable valve means at said outlet to restrict the electrolyte flow therethrough, thereby to place a controllable back pressure on the electrolyte in the work gap.

3. In an electrolytic cavity sinking apparatus for forming cavities in an electrically conductive and electrochemically erodible workpiece, the combination comprising, a hollow electrode having an electrically conductive working face, the bore of said electrode forming a first electrolyte passage, means mounting said electrode and the workpiece for movement relatively toward each other, electric power means connected to said electrode working face and the workpiece to pass a low voltage, high density direct current between said electrode working face and the workpiece in a sense to make the workpiece anodic, a bushing having a bore therethrough through which said electrode movably extends with the outer surface of said electrode and the inner surface of said bushing bore defining a second electrolyte passage, means sealing said bushing against the entry face of the workpiece at that end of said bushing bore from which said electrode working face projects, means holding said bushing and said sealing means against the entry face of the workpiece to hold them relatively stationary as said electrode is moved relatively into and through said bushing during the cavity sinking operation, an electrolyte inlet to one of said electrolyte passages, means connected to said inlet for pumping an electrolyte through both said passages and a work gap between said electrode working face and the workpiece under superatomspheric pressure, and an electrolyte outlet providing a flow restriction from said other passage, thereby to place a back pressure on the electrolyte in the work gap.

4. In an electrolytic cavity sinking apparatus for forming cavities in an electrically conductive and electrochemically erodible workpiece, the combination comprising, a hollow electrode having an electrically conductive working face, the bore of said electrode forming an electrolyte inlet passage, means mounting said electrode and the workpiece for movement relatively toward each other, electric power means connected to said electrode working face and the workpiece to pass a low voltage, high density direct current between said electrode working face and the workpiece in a sense to make the workpiece anodic, a bushing having a bore therethrough through which said electrode movably extends with the outer surface of said electrode and the inner surface of said bushing bore defining an electrolyte outlet passage, means sealing said bushing against the entry face of the workpiece at that end of said bushing bore from which said electrode working face projects, means holding said bushing and said sealing means against the entry face of the workpiece to hold them relatively stationary as said electrode is moved relatively into and through said bushing during the cavity sinking operation, an electrolyte inlet to said electrolyte inlet passage, means connected to said inlet for pumping an electrolyte through both said passages and a work gap between said electrode working face and the workpiece under superatmospheric pressure, an electrolyte outlet from said outlet passage, and means at said outlet to restrict the electrolyte flow therethrough, thereby to place a back pressure on the electrolyte in the work gap.

5. The combination claimed in claim 4 wherein said electrolyte outlet flow restricting means comprises an adjustable valve to place a controllable back pressure on the electrolyte in the work gap.

6. In an electrolytic cavity sinking apparatus for forming cavities in an electrically conductive and electro-chemically erodible workpiece, the combination comprising, a hollow electrode having an electrically conductive working face, the bore of said electrode forming an electrolyte outlet passage, means mounting said electrode and the workpiece for movement relatively toward each other, electric power means connected to said electrode working face and the workpiece to pass a low voltage, high density direct current between said electrode working face and the workpiece in a sense to make the workpiece anodic, a bushing having a bore therethrough through which said electrode movably extends with the outer surface of said electrode and the inner surface of said bushing bore defining an electrolyte inlet passage, means sealing said bushing against the entry face of the workpiece at that end of said bushing bore from which said electrode working face projects, means holding said bushing and said sealing means against the entry face of the workpiece to hold them relatively stationary as said electrode is moved relatively into and through said bushing during the cavity sinking operation, an electrolyte inlet to said electrolyte inlet passage, means connected to said inlet for pumping an electrolyte through both said passages and a work gap between said electrode working face and the workpiece under superatmospheric pressure, and an electrolyte outlet providing a flow restriction from said outlet passage, thereby to place a back pressure on the electrolyte in the work gap.

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