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ELECTRIC DRILLING OF DIAMONDS AND THE LIKE

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Fig.1. Fig.2. Fig.3. Fig.4.

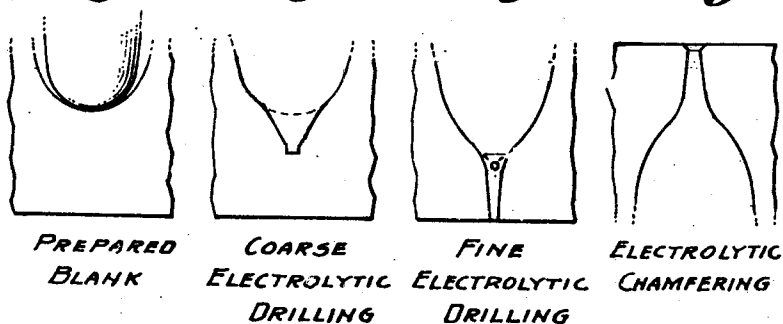


Fig.5.

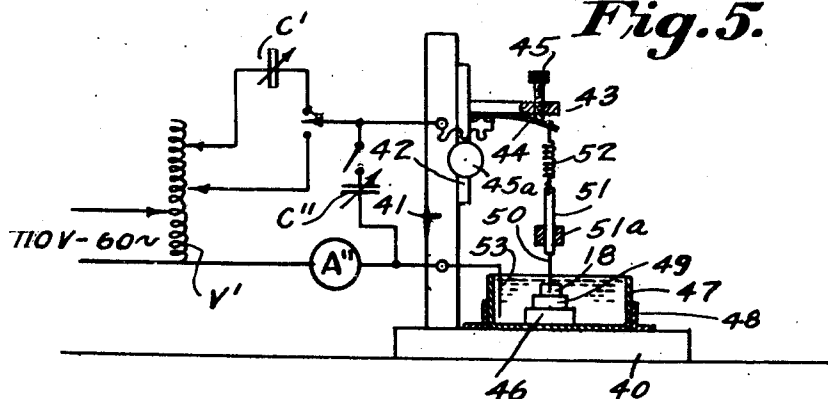


Fig.7.

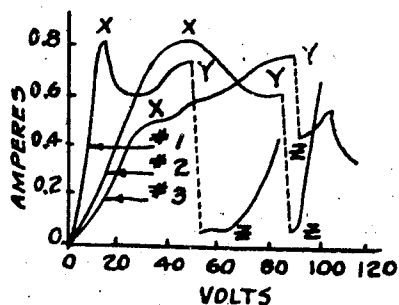
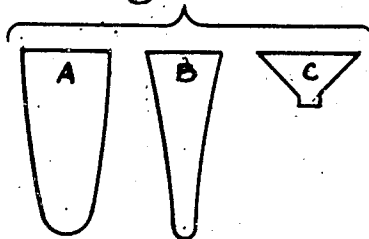


Fig.6.



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UNITED STATES PATENT OFFICE

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ELECTRIC DRILLING OF DIAMONDS
AND THE LIKE

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United States of America as represented by the
Secretary of Commerce

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11 Claims. (Cl. 125—30)

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The invention herein described may be made and used by or for the Government of the United States without payment to us of any royalty therefor.

This invention relates to the drilling of diamonds and the like, and is particularly applicable for the production therein of extremely small holes, as the secondary cones and bearing surfaces of fine wire drawing dies, and to the chamfering of the back-openings of such dies. The invention is based on our discovery of methods and means by which such holes may be formed and countersinking thereof be accomplished by electrolytic drilling so conducted as to control the contour of the hole or chamfer.

The present invention is in part disclosed as a sub-combination of the process of diamond die production forming the subject matter of our co-pending joint application with Chauncey G. Peters, Forest K. Harris, and Karl F. Neffen, now Patent 2,438,941, issued April 6, 1948, wherein the present invention is employed for drilling the secondary cone and bearing in the production of diamond dies. The present invention is likewise in part disclosed in the article published within one year prior to the present application in the American Mineralogist 31:160-163 and entitled "Controlled electrolytic drilling of diamonds" by Walter B. Emerson, one of the present applicants.

As the invention is well exemplified by the application thereof to the drilling of the secondary cone and bearing and the chamfering of a diamond die, such application is herein described as illustrative but not restrictive of the invention.

In general, the production of diamond dies involves the following steps: (1) selection and preparation of die blanks; (2) spotting or starting the hole; (3) drilling the bell or primary cone; (4) drilling the secondary cone and bearing; (5) back-opening and relieving, and (6) polishing of the die surface.

The present invention is particularly applicable to the secondary cone and bearing drilling steps, and to the relief of the back-opening in this procedure.

(1) (2) In the practice of the prior art, for dies of .0015 inch diameter, or less, diamonds of $\frac{1}{8}$ to $\frac{1}{4}$ carat, allowing a thickness of 1.3 to 1.8 mm., have been selected. The selected diamond has then been formed into a flat plate having two parallel surfaces spaced apart by the thickness of the die, this being generally accomplished by bruting. This blank has then been mounted and centered in a metal disc which is rotated in a bench lathe while a small conical hole is

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spotted or bruted in one of the flat surfaces of the stone with a diamond chip held in a pair of pliers, to act as a starting point for the drill. The blank is then ready for the drilling operation.

(3) The method and equipment developed in Europe for drilling diamond dies (see Paul Grodzinski, "Diamond and Gem Stone Industrial Production," chap. II, page 169) essentially employ a star-drilling action. The drilling machine has a horizontal, single spindle that rotates at about 3500 revolutions per minute and carries a sewing needle for the drill. The diamond is mounted on a second spindle which oscillates the diamond against the sharpened end of the drill. Diamond dust of different grades mixed with alcohol or oil is used as the abrasive. Domestic machines as heretofore employed have operated on the same principle but usually employ ten vertical spindles to conserve space and facilitate inspection by the operator.

For drilling the primary cone, in the prior art the spotted blank is placed on the rough drilling machine, using a needle of about .040 inch diameter ground to a rather blunt point. Diamond dust of about 60 micron grade (our designation for dust having an average particle size of from 50 to 70 microns) is used for the first part of the operation, and of about 30 micron grade (25 to 35 microns) for the finish. In this way the bell is formed, preferably as a 60 degree cone of about 1 mm. or .040 inch depth.

(4) For drilling the secondary cone, a lighter drilling machine is used with a fine needle ground to approximately the shape of the desired cone. Diamond dust of about 30 micron grade is used at the start followed by grades 12 (8 to 15 micron) and 6 (4 to 8 micron) as the drilling progresses. Frequent regrinding of the needle is required as the pecking action soon blunts the sharp tip. If after many tedious hours the apex of the cone is found to be .001 inch or less in diameter, the drilling is considered complete.

(5) For back-opening according to the prior art, the die in its casing is then returned to the chuck of the bench lathe for counter drilling. In this operation a spherical hole, in line with the die axis, is bruted into the back surface of the die with diamond splints held in sharp-nosed pliers until it reaches the point of the secondary cone. In some shops the bruting is discontinued when the sphere comes within .003 inch of the cone. The final opening is then made on the drilling machine using a needle sharpened to a hemisphere .010 inch in diameter

with 6 micron grade powder to obtain a polish.

(6) The final polish of the cone and bearing is then performed on a light drilling machine or oscillating polishing machine. The needle is sharpened to a long taper and fine diamond dust in oil is the abrasive.

The time required for the star drilling of the secondary cone and bearing by this pecking method on the average amounts to from 75 to 175 hours, while the time for back-opening has amounted to from 6 to 8 hours.

The present invention in this embodiment has for objects severally and interdependently the material reduction of the time heretofore required for forming the secondary cone and bearing, the provision of a new controlled electrolytic drilling method, the provision of a new plural step method of forming the secondary cone and bearings in dies of this sort, and the provision of a new method of chamfering or relieving the back-opening which reduces the time thereof to approximately $\frac{1}{4}$ of that required for effecting the relief in the method of the aforesaid copending application. Further objects and advantages of the invention will be apparent from the detailed description of the illustrated embodiment of method and means incorporating its principles.

Briefly, in applying the present invention in the production of small diamond dies, following the preparation of the blank and formation of a primary cone therein by any suitable methods, for example, those of the copending application above mentioned, we form the secondary cone and bearing by our controlled electrolytic drilling method preferably as a two-step process insuring centering thereof relative to the apex of the primary cone. The die may then be back-opened and internally polished by any suitable methods, those of the above mentioned copending application being preferred. The present invention may then be employed for effecting a bevelled relief of the edge of the back-opening to the extent of one-half a thousandth of an inch, more or less.

In the accompanying drawings of the illustrated embodiment.

Figs. 1 to 4 are diagrammatic illustrations on a greatly enlarged scale of the steps of forming the secondary cone and relieving the back-opening in accordance with this invention.

Fig. 5 is a diagram of the electrolytic drilling method and means.

Fig. 6 is a diagram of hole-contours produced by various electrolytes.

Fig. 7 is a diagram illustrating the voltage-current relationships characteristic of respective electrolytes.

As indicated in Figs. 1 to 3, by our new procedure after the die blank has been prepared, as by cutting and polishing its facial surfaces and forming the primary or bell cone therein, an initial coarse drilling of the secondary cone is effected (Figs. 1 and 2) followed by fine drilling of the bearing portion thereof (Fig. 3). By this procedure the tedious and time consuming star drilling operation, which is the basis of prior methods, is eliminated, and the strains, flaws and fractures, and other damage to the bearing surfaces frequently resulting from preparing the blank and spotting and back-opening the die by bruting is avoided. When the die has been back-opened by any of the methods described in the aforesaid copending application, the present invention may be applied to effect relief of the back-opening by electrolytic chamfering, as illustrated

in Fig. 4. Considering these operations in more detail:

(1) Preparing the blank

In applying the present invention in the production of small diamond dies of the type disclosed in the above mentioned copending application, as the first step the blank is preferably prepared with two polished parallel surfaces and a polished window face at right angles thereto, and the primary cone is drilled therein perpendicular to one of the parallel faces. Any desired methods may be employed for so preparing the blank, those disclosed in the above mentioned copending application being preferred.

For forming the secondary cone in accordance with the present invention, apparatus exemplified in Fig. 5 may be employed.

(2) Electrolytic drilling apparatus

In the arrangement illustrated in Fig. 5, a 110 volt 60 cycle source is connected to the input terminals of a 0 to 270 volt output adjustable ratio autotransformer V', such as a variac. The secondary of the variac is connected to a capacitor C' of about 20 microfarads and an A. C. ammeter A'' of about 1 ampere range. The circuit may be arranged as shown to enable the capacitor C' to be excluded, or enable a parallel capacitor C'' to be employed. A wooden base 40 and pillar 41 forms the support for the diamond and electrolytic drilling apparatus. The pillar 41 is provided with suitable means for raising and lowering the drill, preferably in the form of a 5 inch rack 42 which carries a bar 43 provided with a flexure strip 44 and an adjusting screw 45 for fine adjustment. The rack is raised and lowered in any suitable manner as by rotation of the thumb screw 45a. A glass plate or block 46 is placed in a shallow evaporating dish 47 supported on the base 40, which may be provided with suitable centering elements, as three or four angle members 48, for correctly positioning the dish 47. A small flat plate of glass or the like 49 is preferably cemented to the center of the block 46 to form the supporting pillow for the die blank 18. The drilling needle 50 is fastened into the lower end of a pendulous rod 51 which may be weighted at its lower end, as by a collar 51a. In the illustrated embodiment the needle 50 is made from 0.020 inch diameter hard drawn 70 per cent platinum 30 per cent iridium wire. The pendulous rod 51 is connected to the flexure strip 44 by a light coiled spring 52 which may comprise 75 turns of number 30 enameled copper wire wound under slight tension on a 7 mm. diameter mandrel, for example. Platinum suspension hooks or other attaching means may be soldered to the ends of the coil to insure good electrical contact. This particular form of coil will apply a load of about 0.1 gram to the diamond when the electrode is lowered 1 mm. after contacting the diamond, and about 0.2 gram when it is lowered 3 mm. after such contact. This loading ratio may be increased by using larger wire or by decreasing either the diameter or the number of turns of the coil. The weight of the pendulous rod is preferably adjusted when using the coil described so as to extend the spring 52 approximately 20 to 30 mm. In the form shown the end of the drill needle 50 is preferably ground to a cone having a 10 degree taper and an .002 to .003 inch spherical tip. The electrode and spring assembly is lowered by means of the rack 42 and its operating knob 45a until the tip of the needle 50 comes nearly into contact with

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the apex of the bell cone previously formed in the diamond. The spring 51 is then lowered to contact and an additional 2 to 3 mm. therebeyond by operation of the flexure screw 45 until the load on the needle tip is approximately 1 gram, or less. An electrolyte such as a 5 per cent aqueous solution of commercial KNO_3 (salt peter) may be employed. This is poured into the evaporating dish 47 until the liquid level is about 1 mm. above the top surface of the diamond. The leads from the variac-ammeter series capacitance circuit are connected to the flexure strip 44 and to a platinum electrode 53 which dips into the solution in the dish 47 to a depth 4 to 5 mm. greater than that of electrode 50. With the variac set for 210 volts, the current is applied. Under these conditions the ammeter should indicate about 0.5 ampere. If the current is greater than that, the liquid level is lowered. If less, the level is raised. Under these conditions a secondary 16 degree cone 0.008 inch deep, 0.0015 inch diameter at the bottom, may be drilled in about eight minutes.

This drilling step may also be practiced by using a 10 per cent by weight aqueous solution of KNO_3 as the electrolyte and applying 85 volts across the electrode terminals. If at the start the drilling electrode 50 has a 10 degree taper and a tip diameter of 0.001 inch, the cone produced in 40 minutes will be 0.006 inch deep and have top and bottom diameters of approximately 0.002 inch and 0.0004 inch, respectively. The tapered electrode will have shortened about 2 mm. during the drilling operation, and its tip will have the shape of the hole and be of somewhat smaller dimensions. If a more blunt electrode is used, the resulting cone will have the same general shape but will be less deep; the shortening of the electrode will be less, and its final profile will show a broad shoulder above its tip. This seems to indicate that drilling is retarded by the time required for the electrolytic etching of the electrode.

(3) Factors controlled in drilling

Variables that affect the drilling are well within the control of the operator, thereby permitting surprisingly close duplication of results. The factors which affect the drilling include the composition, diameter and shape of the electrodes, the composition and concentration of the electrolyte, the applied load on the drilling point, the drilling period, the capacitance in the circuit, and the voltage-current relationships for various electrolytes.

Both electrodes should be of a noble metal, or an alloy of noble metals, to withstand the electrolytic action. The composition of the deep-dipping electrode is less critical than that of the drilling electrode. The most satisfactory material for the latter thus far discovered is hard drawn 70 per cent platinum 30 per cent iridium wire. Hard drawn platinum wire drills fully as rapidly as this alloy but gives cones of greater diameter. The preferred diameter of the electrode is 0.020 inch. The platinum-iridium electrode of this diameter is sufficiently rigid to retain its shape during the pointing operation, and electrodes of this diameter are more economical to use than those of larger size. The electrode tip is preferably ground with an 8 to 10 degree taper to a tip diameter of about 0.001 to 0.002 inch. The rate of drilling is retarded if the tip diameter is large. The bottoms of the cones tend to be somewhat irregular when tips less than 0.001 inch in diameter are used.

From tests of aqueous solutions of 40 electro-

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lytes, including salts, bases, acids, and several combinations of salts, it has been discovered that potassium nitrate (KNO_3) is the most desirable for drilling diamond die secondary cones, and particularly the bearing portions thereof.

Although drilling is possible with other electrolytes, most of them have one or more disadvantages, including slowness of drilling, inability to drill deep cones, production of roughness or irregularity of the cones, release of irritating fumes, critical requirements for duplication of drilling, and unsatisfactory contour of the resulting cone. The majority of electrolytes give cones of contour A (Fig. 6) as opposed to the desirable shape B (Fig. 6) for die secondary cones produced with KNO_3 . One electrolyte, NaCl , gives a funnel-shaped cone C (Fig. 6) which is useful in obtaining axial alignment of the secondary cone with the primary cone of the die. Slight impurities in the electrolyte do not effect the drilling appreciably, but it is well to use distilled water. The addition of a small quantity (say 0.2 per cent) of aerosol to the solution reduces the spray from the liquid without interfering with the drilling.

Excellent drilling may be made with 3 to 10 per cent KNO_3 concentrations (see Figs. 3 and 4) and with 3 to 6 per cent NaCl concentrations when the proper corresponding voltages and currents are used. Lower concentrations are less desirable from the standpoint of quality of the cones produced, while greater concentrations do not appear superior.

In general, the magnitude of the load applied by the electrode to the diamond affects the diameter and depth of the cone. A load of 0.1 to 0.2 gram is used to drill dies of less than 0.001 inch diameter. Dies of somewhat larger diameter are produced by increasing the weight. Drilling is not as rapid with the larger loads, however, and to drill a cone of the required depth with a 2 gram load may necessitate re-sharpening the electrode and re-drilling for an additional 40 minute period. The contour of the lower part of the cone tends to be irregular when loads of less than 0.1 gram are used.

The rate of drilling seemingly obeys the law of diminishing returns. By the above procedure cones 0.006 inch deep may be produced in the first 40 to 45 minutes after which the drilling proceeds rather slowly. The best procedure when deeper drillings are required is to remove and re-sharpen the electrode after a 40 minute drilling. The second 40 minute drilling will then increase the cone depth to about 0.0075 to 0.008 inch. Additional drilling with re-sharpened needles will produce cones of greater depth.

Two beneficial effects were discovered when a capacitor C'' of 5 to 10 microfarads capacitance is placed in parallel with the electrodes: (a) the shape of the bottom of the cone is improved, and (b) decomposition of the electrolyte is reduced so that little, if any, attention is needed to maintain the solution at its proper level. One disadvantage noted in drilling very small dies with parallel capacitance is that a second drilling usually increases the diameter 0.0001 inch to 0.0003 inch.

The drilling rate is greatly accelerated by placing 20 microfarads series capacitance C' in the circuit and increasing the potential to 210 or even 220 to 230 volts, as indicated in Fig. 5. With this arrangement cones 0.006 to 0.008 inch deep and 0.0012 to 0.0015 inch in diameter can be drilled in 15 to 20 minutes. These more rapidly drilled cones employing series capacitance tend to be

somewhat irregular in shape, however, and to wander from the die axis. Therefore, for the most accurate work, it is preferred to drill without a series capacitance at the present time, although the increased drilling speed effected by its use has value, particularly in the initial stages of drilling a secondary cone.

The voltage-current relationship for effective drilling varies with different electrolytes. In general, as the voltage is increased from zero a first current peak is reached for each electrolyte at which visible sparking begins. Usually a current drop results from further increase in the voltage, and the sparking becomes more vigorous up to a second critical point at which the current suddenly becomes much lower.

Fig. 7 illustrates this phenomena with respect to three electrolytes as follows, the curves being based on an applied load of 0.12 gram in these diagrams:

(#1) An aqueous solution comprising 25 percent by weight sulphuric acid (H_2SO_4).

(#2) An aqueous solution comprising 8 percent by weight ammonium chloride (NH_4Cl).

(#3) An aqueous solution comprising ten percent by weight potassium nitrate (KNO_3).

The first peak above mentioned is indicated on each of these curves at X, the point Y is that at which the current suddenly becomes much lower, and the point Z is the point at which sparking again resumes when the voltage is increased above that of the point Y. The decrease in sparking at the point Y for curve #3 (KNO_3) is much less evident than that for the other electrolytes, possibly because the current increases immediately after the transformation at Y.

Drilling of the diamond appears to begin at X and increases in rate until Y is reached. Between Y and Z the drilling electrode becomes highly polished and little, if any, drilling takes place. Beyond Z the electrode becomes pitted and rapidly deteriorates.

Our investigations have thus led to the discovery that the most effective drilling may be accomplished by employing a potential just below that which produces the sudden current drop at Y (Fig. 7).

For a given applied voltage the current increases with the depth of immersion of the drilling electrode, and the concentration of the electrolyte. With concentrations ordinarily used shallow immersions giving currents less than 0.3 ampere at transition Y (Fig. 7) are unsatisfactory because the drilling action becomes irregular. Also deep immersions giving currents greater than 1 ampere at transition Y (Fig. 7) are unsatisfactory because the drilling electrode becomes pitted. Immersions giving currents of 0.5 to 0.7 ampere just below transition Y (Fig. 7) have proven the most satisfactory.

As above mentioned, drilling is most rapid for voltage values in the region just below the point Y (Fig. 7) immediately before the transformation occurs. The voltage for best drilling increases as the concentration of the electrolyte is reduced, and increases to a lesser degree with decrease of the applied load on the needle 50, and with increase in the depth of immersion of the electrode 50. With electrolyte KNO_3 , 0.2 gram of applied load and 0.5 to 0.7 ampere current, excellent cones are obtained by using 85 to 90 volts for 10 percent concentrations, 95 to 100 volts for 5 percent concentrations, and 110 volts for 4 percent concentrations. Excellent funnel-shaped holes are produced with electrolyte NaCl by using 90

to 95 volts and 110 volts, respectively, with 5 percent and 4 percent solutions. By following the principles herein set forth, the proper concentration for a given electrolyte may be selected so that maximum drilling will take place at line voltage, thereby eliminating the need for a variable ratio transformer, such as V' (Fig. 5). Such transformer, however, permits greater flexibility in drilling operations.

(4) Preferred practice

In the illustrated practice of the invention exemplified in Figs. 1 to 4, we have found it advantageous to initiate the drilling of the secondary cone with electrolyte NaCl and drill all but the initial portion of the secondary cone and bearing with electrolyte KNO_3 . The electrolyte KNO_3 produces a relatively long, narrow cone of correct size and shape for the secondary cone of a small die. If the primary cone has a broad unpointed or irregular bottom, however, and drilling with KNO_3 is initiated immediately following the primary coning operation, there is a tendency for the secondary cone to lie slightly to one side of the primary cone axis. Excellent alignment and better blending of the primary and secondary cones is obtained by making a first drilling with the sodium chloride electrolyte and completing the drilling with KNO_3 . The following drilling procedure is therefore preferred:

The diamond 18 (Fig. 5) having been cemented on the post 49, is placed beneath and in the axis of the electrode 50. This electrode is ground with an 8 degree to 10 degree taper to a tip diameter of approximately 0.002 to 0.003 inch. This tip is preferably hemispherical (see Fig. 1), but may be simply flat. The electrode is lowered after contacting the bottom of the primary cone by an amount sufficient to give it about an 0.2 gram pressure on the diamond. The electrode 53 (Fig. 5) should dip 4 to 5 mm. deeper in the container than the drilling electrode. A 5 percent aqueous solution of sodium chloride is then poured into the container, immersing the diamond sufficiently (about 2 mm.) to give a current of about 0.7 ampere when 60 cycle alternating current of 90 volts potential is applied to the circuit. This gives a sharp apex to the cone, as shown in Fig. 2. The next drilling operation is performed with a 10 percent aqueous solution of potassium nitrate, and the tip diameter of the drilling electrode is somewhat smaller (0.001 to 0.0015 inch) for more rapid drilling. The same current and voltage values may be used. Greater voltages will be required for rapid drilling if lower electrolyte concentrations are employed. At the end of a 40 to 45 minute drilling period the drill will have produced a smooth bore cone having a length of about 0.016 inch and a diameter at the bottom of 0.0005 to 0.0006 inch. When this cone is drilled through to pierce the back face of the die, or when the back face is lapped off to the cone tip in accordance with the above mentioned copending application, the general appearance of the die is as shown in Fig. 3. If the initial distance between the bottom of the primary cone (Fig. 1) and the back of the die was greater than 0.005 inch, additional drilling with KNO_3 may be required using a re-sharpened needle.

The sharp edge formed at the intersection of the secondary cone and the back surface of the die (Fig. 3) is preferably relieved by electrolytic chamfering in accordance with the present invention, as illustrated in Fig. 4. This may be accomplished by inverting the die beneath the

drilling electrode 50 and drilling electrolytically from the back of the die using a 5 percent sodium chloride electrolyte. The electrode is ground with a 30 degree taper to a fine tip for insertion in the bottom of the secondary cone in this operation. Sufficient back relief is obtained with a 4 or 5 minute drilling at a 60 cycle A. C. potential of 70 volts and 0.5 to 0.7 ampere. This produces a relief bevel of approximately 0.0005 inch.

From the foregoing detailed description, it is apparent that the present invention provides a controlled electrolytic drilling process, effective apparatus for performing the same, and suitable electrolytes for providing diamond die secondary cones and bearings of most effective shape and excellent axial alignment. As indicated, the method and apparatus herein disclosed is illustrative and not restrictive of the invention which contemplates modifications and variations falling within the scope of the appended claims. Reference is made to the aforesaid copending application and publication for further discussions of the practice and advantages of the invention.

What is claimed is:

1. A method of electrolytically coning diamond dies and the like which consists in immersing the diamond in an electrolyte, resting against the diamond an electrically conductive needle point, and applying across the electrolytic contact thereof an alternating current potential larger than that at which sparking at the needle tip commences, and lying immediately below that at which a sudden decrease of current flow occurs.

2. A method according to claim 1, in which the electrolyte consists essentially of an aqueous solution of potassium nitrate.

3. A method according to claim 1, in which the electrolyte consists essentially of an aqueous solution of sodium chloride.

4. A method according to claim 1, in which the alternating current is applied across the electrolyte contact and a capacitor of the order of 20 microfarads capacitance in series therewith.

5. A method according to claim 1, in which the alternating current is applied across the electrolyte contact and a capacitor of the order of 5 to 10 microfarads capacitance in parallel therewith.

6. A method of electrically coning diamond dies and the like by immersing the diamond in an electrolyte, resting against the diamond an electrically conductive needle point, and applying across the electrolytic contact an alternating current potential at least as large as that at which sparking at the needle tip commences and no greater than that at which a sudden decrease of current flow occurs, which method is especially adapted for extending the secondary cone of the die from the bottom of a previously formed primary or bell cone, in which the extended coning

is initiated with an electrolyte consisting essentially of an aqueous solution of sodium chloride, and attenuated with an electrolyte consisting essentially of an aqueous solution of potassium nitrate.

7. A method of electrically coning diamond dies and the like by immersing the diamond in an electrolyte, resting against the diamond an electrically conductive needle point, and applying across the electrolytic contact an alternating current potential at least as large as that at which sparking at the needle tip commences and no greater than that at which a sudden decrease of current flow occurs, which method is especially adapted for extending the secondary cone of the die from the bottom of a previously formed primary or bell cone, and in which the secondary coning is initiated with a needle point of hard drawn 70 percent platinum 30 percent iridium wire having a diameter of about 0.020 inch and tapered at about 10 degrees to a tip diameter of about 0.002 to 0.003 inch.

8. In an apparatus for electrolytic drilling of diamonds and the like, a pendulous drilling electrode, an elastic suspension means for the electrode, and adjusting means for resting the electrode tip on a diamond to be drilled so that the electrode is supported in part by the diamond and in part by the elastic suspension means.

9. In apparatus according to claim 8, in which the elastic suspension means comprises a coil spring from which the electrode is hung, said coil spring being suspended from a movable support, and in which said adjusting means comprises means for moving said support.

10. An apparatus according to claim 8, in which said drilling electrode is formed of a hard drawn 70 percent platinum 30 percent iridium wire having a diameter of about 0.020 inch and tapered to a tip diameter of about 0.002 to 0.003 inch.

11. An apparatus according to claim 8, in which said drilling electrode is formed of a hard drawn 70 percent platinum 30 percent iridium wire having a diameter of about 0.020 inch and tapered to a tip diameter of about 0.002 to 0.003 inch, with its tip generally hemispherical in shape.

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