April 21, 1953 F. M. POTTER ET AL 2,635,487

METHOD AND APPARATUS FOR MAKING WIRE DRAWING DIES

Filed June 3, 1949 2 SHEETS—SHEET 1

FIG. 1.

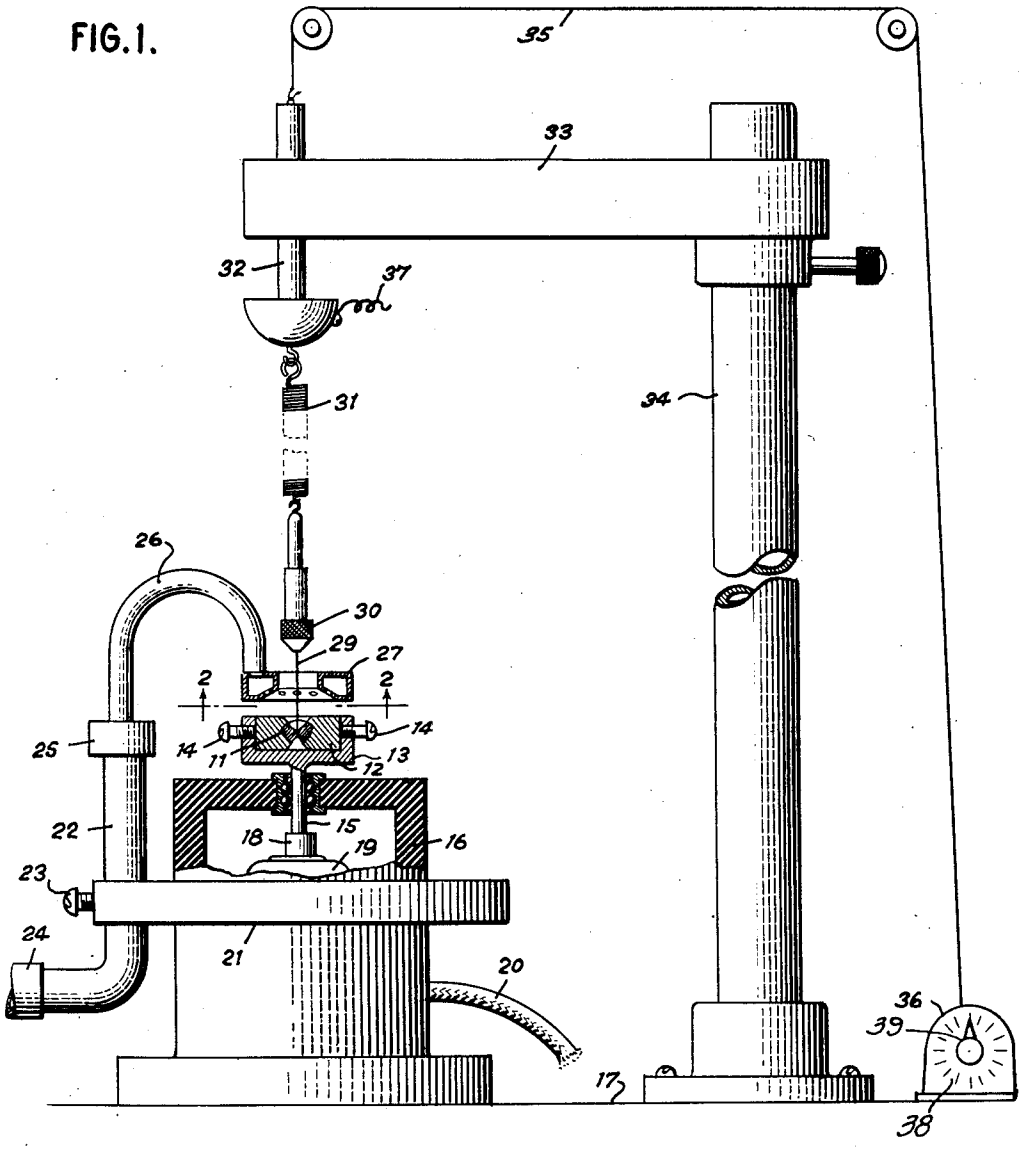


FIG. 2.

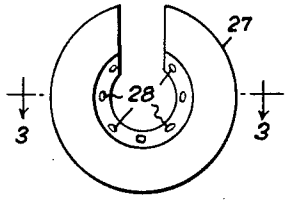
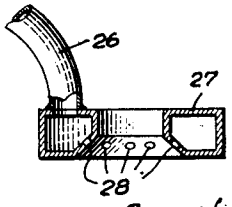


FIG. 3.



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2 SHEETS—SHEET 2

FIG.5.

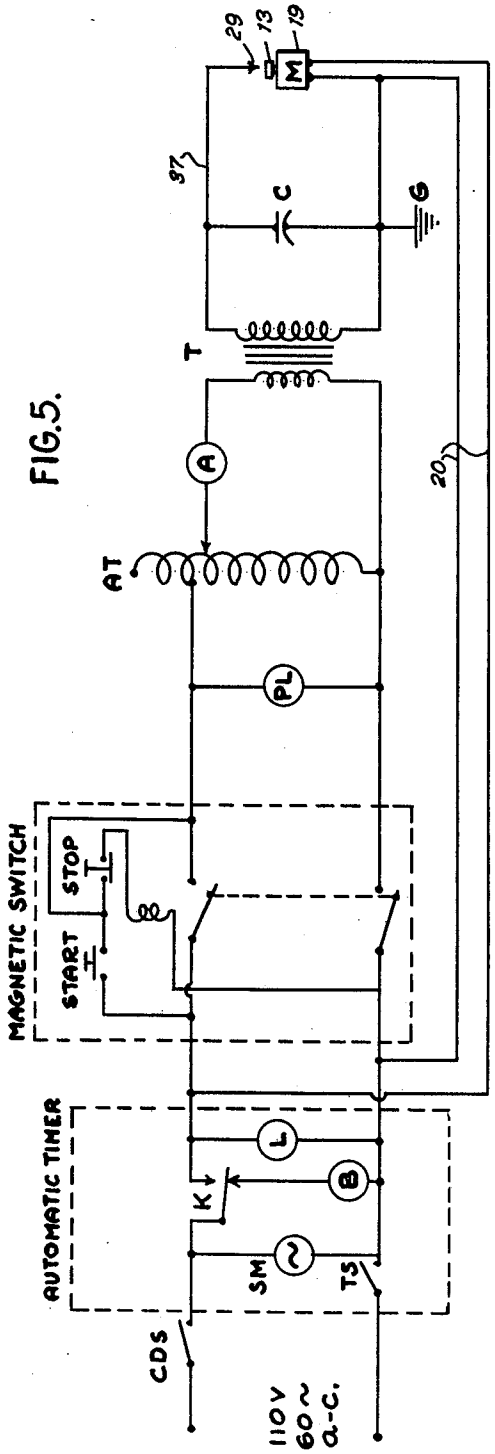
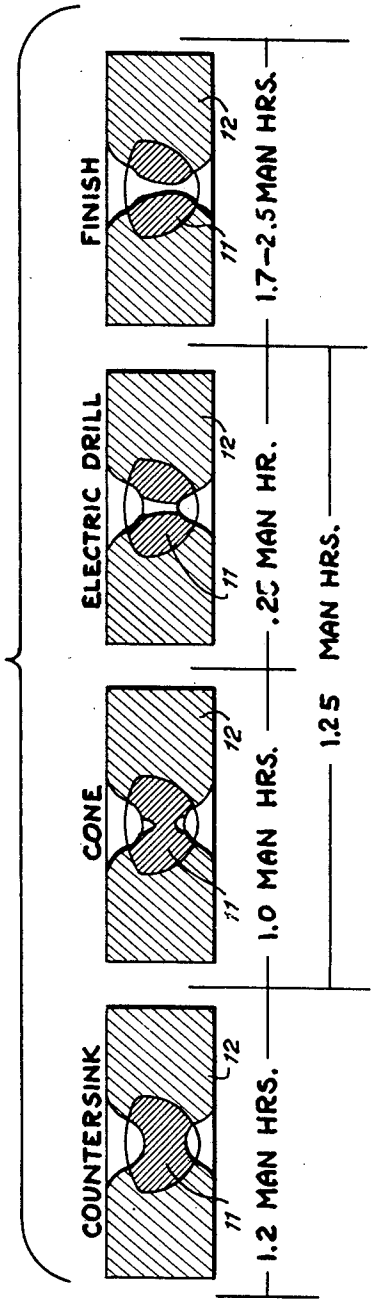


FIG.4.



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METHOD AND APPARATUS FOR MAKING WIRE DRAWING DIES

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Application June 3, 1949, Serial No. 96,988

9 Claims. (Cl. 76—107)

1

This invention relates generally to method and apparatus for producing diamond wire drawing dies, and more particularly to method and apparatus in which the die opening through the diamond is drilled by an electric arc.

It is an object of the invention to provide an improved method of producing diamond wire drawing dies. It is a further object of the invention to provide an improved method of drilling die openings through diamonds with an electric arc. It is another object of the invention to provide an improved method of preparing a diamond for the electric drilling operation. It also is an object of the invention to provide improved apparatus for practicing the improved methods of this invention. Other objects and advantages of the invention will appear hereinafter.

A preferred embodiment of apparatus for carrying out the methods of the present invention has been selected for purposes of illustration and description and is shown in the accompanying drawings, wherein:

Figure 1 is an elevation of apparatus for electrically drilling a die opening through a diamond, certain elements being shown partly in section to disclose the construction more fully;

Figure 2 is a view taken substantially on line 2—2 of Figure 1, but to enlarged scale, showing means for directing currents of gas toward the diamond right at the point of drilling;

Figure 3 is a section taken substantially on line 3—3 of Figure 2;

Figure 4 is a flow diagram of the several steps in the method of drilling and finishing diamond dies according to the present invention; and

Figure 5 is a schematic diagram showing the electrical drilling circuit.

It has been proposed heretofore to use an electric arc for drilling openings through diamonds which are to be made into wire drawing dies. In some of the prior art disclosures it was contemplated that a part of the electric drilling might be done in the atmosphere, but in all cases with which applicants are familiar it was intended that at least a part of the drilling should be done while the diamond was immersed in an electrolyte.

Some of the prior art teaches that a high voltage should be used for the drilling current, whereas according to other disclosures a low voltage should be used. There appears to be no consensus of opinion on the optimum frequency for the drilling current, some disclosures indicating that radio frequency currents are essential to satisfactory operation, and others disclosing the use of ordi-

2

nary commercial power frequencies. About the only thing common to these prior methods, aside from the teaching that at least a part of the drilling should be done electrolytically, is the thought that the electric drilling should be done prior to mounting the diamond in the metal encasement which is required to hold the diamond during the drawing of wire. This was considered necessary to permit continuous supervision and inspection of the hole during the drilling operation, and also to control the spark discharge, and to prevent overheating of the diamond.

It appears from an examination of the prior patents and other publications available to applicants that what actually takes place in drilling an opening through a diamond by means of an electric arc is not fully understood, or at least is not clearly disclosed in the patents and publications. It appears also that the methods of the prior art all require steps which are unnecessary to applicants' improved methods, and that applicants' improvements which permit the elimination of these steps not only result in savings in the time and cost of die production, but are accompanied by a simplicity and foolproofness of operation which insures the production of uniformly high quality dies with a minimum of supervision and by operators with little or no previous experience in drilling dies.

The necessity for submerging the diamond in an electrolyte during a part or all of the drilling operation introduces a number of problems and serious objections. The heat of the electric discharge at the surface of the diamond causes electrolyte to be rapidly vaporized at that point, and the sputtering and exploding is not conducive to supervision of the drilling operation, considered in the prior art to be necessary, or to drilling a uniformly shaped opening, or to drilling an opening along a straight line, or on a preselected axis. Because of vaporization, the concentration of the electrolyte will vary as the drilling proceeds, requiring constant checking and adjustment in an attempt to obtain uniform drilling. Where an electrolyte is employed it is necessary, of course, to position the diamond within a vessel. The operation would be much simpler if all of the drilling could be done in the atmosphere. Applicants' method eliminates the electrolytic drilling step of the prior art.

According to the published reports on a four year investigation undertaken by the National Bureau of Standards to improve the manufacturing processes and the quality of diamond wire drawing dies, it is difficult in the electric drilling

of diamonds to control the direction and shape of the drilled opening in the diamond. It was considered necessary by the Bureau of Standards researchers that the diamond first be cut into the form of a flat plate having parallel polished faces, and that a third polished face perpendicular to the first two be provided on one edge through which the drilling and polishing of the die could be observed. Otherwise there could be no assurance that the die opening would have either the desired location or desired shape. This preshaping and polishing of the diamond adds substantially to the cost of the die and to the time required for manufacture. Moreover, the necessity for forming the polished faces does not always permit selection of the die axis which would provide the strongest and most efficient die, or which would permit numerous recuttings of the die opening to utilize most effectively the entire diamond for wire drawing.

The limitations in the prior art methods that the diamond be drilled prior to mounting in its final metal encasement increase the difficulty of holding the diamond steady during the drilling operation. This contributes to the necessity for continuous observation of the drilling operation by experienced and skilled operators, so that they can make the necessary adjustments from time to time for controlling the direction and shape of the die opening being drilled.

The danger of fracture of the diamond during the drilling operation is substantially less if the diamond is held in a firm grip over most of its surface. The metal encasement not only supports the diamond, but actually dissipates and radiates heat produced by the electric discharge. There also is much greater danger of breakage in mounting a drilled diamond than in mounting an undrilled diamond. These factors all point to the desirability of permanently mounting the diamond prior to drilling.

Applicants are not prepared to explain just what takes place during their electric drilling operation, and will not attempt to explain or reconcile discrepancies in the teachings of the prior art. Applicants will disclose herein an improved method and apparatus for drilling diamond dies electrically after the diamond has been encased in metal, and without the use of an electrolyte, which method is capable of being practiced by relatively unskilled and inexperienced operators, with a minimum of supervision during the drilling operation, to produce diamond dies of uniformly high quality, economically and in a time which is a small fraction of the time heretofore required for the drilling of diamond dies of comparable quality. The method of this invention is particularly adapted for drilling diamond dies in the size range from about .002 inch to about .032 inch.

Referring now to the drawings, wherein like reference characters denote corresponding parts, Figure 1 discloses means for holding and rotating a metal encased diamond during the electric drilling operation, means for supporting the needle electrode over the diamond, and means for directing a current of air or other gas toward the point of the needle substantially uniformly from all sides during the electric drilling operation.

A diamond **11**, completely encased in a metal mounting **12** except for small exposed areas of the diamond at the opposite ends of the preferred die axis, is held firmly centered in the metal cup **13** by means of screws **14**, there preferably being three or four such screws to facilitate accurate centering and holding of the encased diamond in the cup. This cup **13** is secured in suitable manner on the upper end of the spindle **15**, which extends downwardly through and is rotatably mounted in the top of the motor housing **16**, which in turn rests on a table top or other support **17**. This motor housing preferably is made of electric insulating material and may or may not be fastened down on the support **17**, as desired. Ordinarily it will be convenient to provide the housing **16** with an enlarged base for stability, and not fasten it down.

The lower end of the spindle **15** is connected, as by means of coupling **18**, to the shaft of a small electric motor **19**, for example a motor of the type commonly used in household electric clocks. The leads **20** for supplying current to the motor **19** and for grounding the spindle **15** and cup **13** pass through an opening in the wall of the housing **16**.

Secured on the housing **16** is a support **21** for a small tube **22** made of metal or other rigid material. This tube conveniently is in the form of an elbow, one arm of this elbow being held by the support in vertical position parallel to the spindle **15**, as shown. Preferably the tube **22** is adjustable vertically in the support **21**, being held in adjusted position by a set screw **23** or other suitable means.

The lower or horizontally disposed end of the elbow-shaped tube **22** is connected by a rubber or other flexible tube **24** to a pressure tank, pump or other means, not shown, for supplying air or other gas under pressure to the elbow **22** for the purpose which will appear hereinafter. Connected to the upper end of the tube **22** by a suitable swivel joint **25** is one end of an inverted U-shaped tube **26** made of metal or other rigid material.

Secured to the other end of the inverted U-shaped tube **26** is a split air ring **27**, which may be made of suitable metal. By swinging the tube **26** so that it turns about the swivel joint **25**, the split air ring **27** may be positioned directly over the cup **13** with the axes of the ring and the cup in alignment, or the air ring may be moved away from over the cup to facilitate inserting a metal encased diamond in the cup preparatory to drilling, and removing the die from the cup after completion of the drilling operation.

Details of the split air ring **27** will be better understood by reference to Figures 2 and 3. The ends of the split ring are, of course, closed. The under side of the ring **27** is provided with a plurality of small openings **28**, by means of which air or other gas supplied under pressure through the inverted U-shaped tube **26** to the ring may be directed inwardly and downwardly. When the ring **27** is centered over the cup **13** and properly adjusted vertically over the diamond **11** at the beginning of the electric drilling operation, the openings **28** will direct the gas substantially uniformly from all sides toward the very tip of the needle electrode **29**. By loosening the set screw **23** and moving the elbow-shaped tube **22** up or down in the support **21**, this vertical adjustment of the air ring over the diamond may be precisely attained for various sizes of diamonds and their metal encasements.

The upper end of the needle electrode **29** conveniently is held in a pin vise **30**, which is suspended from the lower end of a relatively long tension spring **31**. The spring **31** functions both as the mechanical suspension and as the electrical connection for the needle electrode **29**. In order to facilitate a fine initial adjustment of the

pressure of the needle electrode on the diamond for the start of the drilling operation, and to insure a substantially uniform pressure throughout the drilling operation without further adjustment, it is desirable that the spring consist of a large number of turns of fairly fine and soft wire, for example about 300 coils of #24 A. W. G. enameled soft copper wire wound to a ⅜ inch outside diameter.

The upper end of the spring **31** is secured to the lower end of the vertically disposed rod **32**. The rod **32** has a sliding fit in a suitable bushing at one end of an arm **33**, preferably made of insulating material. The other end of the insulated arm **33** is adjustably secured, by a set screw or other suitable means, near the top of the post **34**, projecting upwardly from the table top **17**.

The upper end of the rod **32** is attached to one end of a flexible non-conductor cord **35**, for example silk or linen, which passes over pulleys to a suitable take-up device **36**, secured to the table top **17** or to other firm support. By adjusting the take-up device **36**, the cord **35** may be payed out or taken in to lower or raise the rod **32** and the connected spring **31** and pin vise **30**, and thus the pressure of the needle electrode **29** on the diamond **11** may be varied.

The take-up device **36** should be designed to permit a fine adjustment and precise control of the pressure of the needle electrode on the diamond. For example, the end of the cord **35** at the take-up device may be secured to and wrapped with a number of turns about an arbor which extends through a graduated dial **38** and has secured to its forward end a knob and pointer **39**. With an arbor diameter of about ¼ inch and a dial diameter of 3 or 4 inches, for example, the pressure of the needle electrode **29** on the diamond **11** may be accurately varied by very small amounts.

Desirably the dial **38** is calibrated directly in terms of needle pressure on the diamond, so that it will show just how much further the rod **32** must be lowered, after the point of the needle electrode **29** seats on the diamond **11**, to apply the exact desired pressure on the diamond. A pressure of .5 gram has been found to be a desirable pressure at the start of the electric drilling operation. The initial pressure is substantially maintained without adjustment during the drilling operation by reason of the long delicate spiral spring suspension for the pin vise **30**.

In electric continuity with the upper end of the tension spring **31** is a high tension lead **37**, by means of which a voltage may be impressed between the needle electrode **29** and the grounded cup **13** for drilling the diamond, as will be more fully described hereinafter.

As will appear, a high voltage is employed for the electric drilling of the diamond. For this reason all of the apparatus shown in Figure 1, except for the take-up device **36**, desirably will be enclosed within a suitable cabinet, and access had thereto only through a door. By employing a grounded metal cabinet and an automatic switch for opening the electric circuit whenever the cabinet door is opened, the operator will be protected against electric shock hazard. The take-up device **36** preferably is mounted outside the cabinet to permit adjustment during the drilling operation in the unlikely event that this becomes desirable.

In preparing to use the apparatus shown in Figure 1 to drill a diamond die electrically, the split air ring **27** is swung back away from over the cup **13**, and the needle electrode **29** and pin vise **30** are raised up out of the way by the take-up device **36**. A metal encased diamond prepared for electric drilling in the manner to be hereinafter described is placed in the cup **13** and secured therein by the screws **14** with the axis of the die opening which is to be drilled coinciding with the axis of the cup and the spindle **15**.

Next, the take-up device **36** is adjusted to lower the needle electrode **29** until its point just seats in the small sharp cone at the upper end of the preferred die axis in the diamond. The rod **32** then is lowered the additional distance necessary to apply the desired pressure, for example .5 gram, by the needle electrode on the diamond. If the motor housing **16** is not fastened down on the table top **17**, care should be taken to insure that the small cone in the upper surface of the diamond is directly below the needle electrode before the electrode is lowered into contact with the diamond.

After the needle electrode has been lowered onto the diamond, the split air ring **27** is swung into position, centered over the diamond. The height of the split air ring **27** relative to the exposed upper surface of the diamond **11** then is adjusted so that the jets of gas which will be forced through the openings **28** will be directed toward the needle electrode **29** at the point where the needle contacts the diamond. Then air or other gas under pressure is supplied through tube **24**, elbow **22** and tube **26** to the split air ring, whence it is directed in a plurality of small streams toward the point of the needle electrode, substantially uniformly from all sides.

Before describing the electric drilling operation, the manner of preparing a diamond for drilling by the method and apparatus of the present invention will be described. The diamond first is examined to determine the preferred die axis. The location of the preferred die axis will depend on the size, shape and crystal structure of the diamond, on the size of the die opening which is to be made in the diamond, and on other factors known to experts qualified by long experience in this field. In general, the preferred die axis is the axis which will insure both a strong die and the most efficient utilization of the entire diamond. This means the die axis which will permit a maximum number of recuttings, while at the same time providing the most efficient die profile for the service to which the die will be put.

According to this invention, it is unnecessary to cut any polished faces on the diamond, or otherwise to shape the diamond in any way preliminary to the electric drilling operation. Thus, diamonds of any shape may be used and no limitation is imposed on the selection of the preferred die axis. This makes possible the production of stronger dies and at the same time permits more efficient utilization of the entire diamond for wire drawing purposes.

After the preferred die axis has been decided on, the diamond next is completely encased in a short cylindrical body of metal, for example steel. Preferably this metal encasement is applied to the diamond under considerable pressure and while the metal is in a plastic state, so that the metal will firmly grip the entire surface of the diamond under pressure, after cooling.

This metal encasement affords a convenient means for holding the diamond during the ensuing drilling operations and at the same time

protects the diamond against breakage, both from external blows and from internal stresses which may develop during the drilling operation. Intimate contact between the diamond and the surrounding metal serves to transfer heat more readily and uniformly from the diamond and for this reason also lessens the danger of breakage during the drilling operation. While the electric drilling depends on the production of a very high temperature in the diamond directly under the needle electrode, it is considered desirable to limit the temperature elsewhere in the diamond. This metal encasement constitutes the permanent mounting for the diamond and its application to the diamond before the diamond is drilled is contrary to the teachings of all other methods of electric drilling heretofore proposed and known to applicants.

It is important to the success of the electric drilling operation of this invention that the position of the diamond and the orientation of the preferred die axis within the metal encasement be accurately located and precisely known. Desirably, the preferred die axis should be coincident with the longitudinal axis of the metal encasement. To this end, it is desirable that the diamond be encased in metal by the method disclosed in the H. C. Wyland Patent No. 2,171,323, August 29, 1939.

By use of the Wyland method it is a relatively simple matter to encase the diamond in metal under pressure with the preferred die axis of the diamond precisely located coincident with the longitudinal axis of the cylindrical metal encasement. Thus, even though the diamond is completely surrounded by metal at this stage of the manufacturing operation, this fact offers no difficulties to carrying out the ensuing steps in the die manufacturing operation.

Next, the opposite ends of the cylindrical metal encasement are opened to expose relatively small areas of the diamond at the two ends of the preferred die axis. The diamond remains firmly gripped by the metal everywhere except for these small exposed areas at the ends of the die axis.

The two exposed areas of the diamond then desirably are countersunk to provide shallow concavities at the two ends of the preferred die axis, with the lowest points of the concavities located on the preferred die axis. At this stage the diamond will generally resemble the left hand view in Figure 4 of the drawings. Countersinking the diamond on what is to become the entrance side of the die facilitates drilling the small cone which serves to locate the needle electrode at the start of the electric drilling operation.

Preferably this countersinking is done mechanically according to known methods, using a blunt coarse needle and relatively coarse diamond powder. In the manufacture of diamond dies in the size range from .002 inch to .032 inch, the average time required for countersinking both exposed areas of a diamond, using multiple spindle machines, will be approximately 1.2 man hours.

A small sharp cone then is drilled in the countersunk area which is to be the entrance side of the die. This cone is located precisely on the preferred die axis. The opposite countersunk area preferably will be back-drilled to approximate roughly the desired exit cone for the die and to reduce the thickness of the diamond on the preferred die axis to about .010 inch to .025 inch, for the die sizes mentioned. The diamond then will resemble the second view in Figure 4, the size and proportions of the drilled openings being somewhat exaggerated to disclose clearly the steps described. As in the case of the countersinking operations, these drilling operations preferably are performed mechanically, using a sharpened needle and a somewhat finer grade of diamond dust for the small cone. The time required for these drilling operations, using multiple spindle machines, will average approximately 1.2 man hours per die in the size range described.

It is suggested that the countersinking and drilling operations just described be performed mechanically by the methods well known in this art, because no particular difficulties are involved and these coarse drilling operations can be performed quite rapidly and economically by relatively inexperienced operators. It is the drilling of the small diameter secondary cone which, by the known mechanical methods, takes so long and requires the services of an experienced and highly skilled operator to produce a die of the desired size and contour.

The diamond now is ready for the electric drilling operation. Before actually describing the drilling operation it will be in order to consider the electric circuit to be employed.

Figure 5 is a schematic wiring diagram of a preferred electric circuit for drilling diamonds according to the present invention. At the left is the connection to the source of electric current, suitably 110 volt, 60 cycle A.-C. In one lead is the cabinet door switch CDS which interrupts the electric circuit whenever the door of the cabinet housing the high voltage equipment is opened.

The current source is connected through an automatic timer to a main switch, preferably a magnetic switch of known design. Desirably the timer is of the manual reset type which opens the circuit at the end of the elapsed time for which it has been set and simultaneously with the opening of the circuit signals the operator, either visually, or audibly, or both.

Such a timer circuit is shown schematically in Figure 5, in which: TS is the timer switch; SM is the synchronous motor driving unit; K is the switch which is closed in its upper position when the timer is set at the start of the timing operation, and which switches to the lower position at the end of the preset time interval; B is a buzzer or other signal device; and L is a pilot light. A suitable timer for the purpose is the International Timer Corporation Model S-1H, which is calibrated in minutes, with a maximum interval of one hour.

From the main switch, connections are made through a "Variac" or autotransformer AT to the primary winding of a high voltage transformer T. Inclusion of the autotransformer provides means for varying the voltage of the drilling current. A pilot light PL may be included between the main switch and the autotransformer to show when the high voltage circuit is energized, and an ammeter A may be included in one of the output leads from the autotransformer.

Connected in parallel across the secondary winding of the high voltage transformer T is a condenser C. A lead to one of the transformer secondary terminals is grounded, as at G, and also connected electrically to the cup 13 which holds the metal encased diamond during the electric drilling operation. The other secondary terminal is connected by lead 37 to the upper end of the spring 31 (not shown in Figure 5) to energize

the needle electrode 29. The transformer T desirably raises the voltage from 110 volts to about 12,000 volts. Applicants have found no reason for including spark gaps in the secondary circuit, as taught by the prior art, and such use is unnecessary to the present invention.

Leads 20 connect the motor M (designated 19 in Figure 1), to the 110 volt current source, preferably between the automatic timer and the magnetic switch. This motor will be energized and the cup 13 will start rotating as soon as the timer switch TS has been turned on and the switch K closed by setting the timer for the desired timing interval. We have found a speed of 30 R. P. M. to be suitable for our method.

In drilling a diamond according to the present invention, the diamond 11 will be encased in metal 12 and prepared for drilling in the manner hereinabove described. The metal encased diamond then will be mounted in the cup 13, with the preferred die axis coincident with the axis of the spindle 15 and directly under the needle electrode 29. The needle electrode will be lowered by the take-up device 36 until its point rests in the small cone in the upper countersunk area of the diamond, and the rod 32 will be lowered an additional amount to provide the desired pressure of the needle electrode on the diamond.

The split air ring 27 then will be swung into position over the diamond and adjusted vertically, if necessary, so that when air is supplied thereto through the tubes 24, 22 and 26 the air will be directed substantially uniformly from all sides toward the very tip of the needle electrode. The door of the cabinet in which the high voltage equipment is housed may then be closed, thus closing the switch CDS.

The automatic timer switch TS then is closed and this is followed by manually setting the timer for the desired time interval. Setting the timer moves the switch K to its upper position and current is supplied through leads 20 to start the motor 19, causing the die holding cup 13 to rotate the diamond about the preferred die axis.

Then the main magnetic switch is closed to energize the autotransformer AT and its associated high voltage circuit, thus applying a high difference of potential between the needle electrode 29 and the metal encasement 12 which surrounds the diamond 11.

An electric arc will be produced at the point of the needle electrode, spanning the gap to the metal encasement 12. The tip of the needle electrode becomes very hot and the autotransformer should be adjusted until the needle is just red, and the voltage then reduced slightly. Once adjusted to the desired condition, the setting of the autotransformer will require no further attention during the drilling of this or subsequent diamonds, as long as other changes are not made in the circuit.

As the electric discharge continues, the small cone in which the tip of the needle rested initially is gradually deepened. This small cone holds the needle accurately located on the preferred die axis at the beginning of the electric drilling. Continuous rotation of the diamond during the drilling operation, and the jets of gas directed toward the tip of the needle uniformly from all sides insure that the drilled opening will be uniform in shape and will continue straight down along the preferred die axis.

What actually takes place under the tip of the needle electrode is not fully understood, but it is believed that the concentrated heat under the needle tip causes the diamond to be oxidized. By supplying air or other oxidizing gas directly to the tip of the needle this effect is accelerated.

At the same time, the gas helps to cool the needle electrode, thus permitting use of a higher current and fatter spark to produce a higher temperature in the diamond directly under the tip of the platinum or platinum-iridium alloy needle without harmful or objectionable overheating of the needle itself. We have found that the current will be about 30 milliamperes, measured in the secondary circuit.

Directing the gas toward the needle point in a plurality of jets substantially uniformly from all sides is important to the production of a straight hole, and one which is uniform around the die axis. Directing gas toward the needle from one or two sides only is undesirable, because it affects the electric arc and the drilling and may be expected to produce a non-uniform hole in the diamond.

Applicants prefer to direct air through the openings of the split air ring toward the point of the needle electrode and have found that the air pressure for satisfactory drilling is fairly critical. Preferably the air pressure should be about 7 inches of mercury, although some departure from this value is permissible. However, if the pressure exceeds about 8 inches of mercury, the air, even though directed against the needle substantially uniformly from all sides, will cause such a severe vibration of the needle as to interfere with the drilling operation. On the other hand if the air pressure drops below about 6 inches of mercury there will be insufficient cooling of the needle to permit satisfactory drilling.

Once the magnetic switch has been closed to start the electric drilling operation, no further action is required of the operator until the diamond has been pierced, or until the automatic timer opens the circuit at the end of the time interval for which it has been set. Desirably the electric circuit includes means for automatically shutting off the drilling current when the diamond is pierced. It may be desirable to regrind the needle electrode during the drilling operation, and the setting of the automatic timer is made with this in mind. While there is considerable leeway, the following conditions produce satisfactory results.

In drilling a die which is to finish under about .0063 inch, it will be desirable to start the electric drilling with a .020 inch needle and to set the automatic timer to drill for 5 minutes. Then a sharp .010 inch needle will be substituted and the timer will be set for 10 minutes. In most cases this will be sufficient to pierce the diamond, but if not, the needle should be reground and the timer set for an additional 10 minutes. For larger dies it will be satisfactory to make consecutive 10 minute settings with the .020 inch needle until the diamond is pierced, sharpening the needle as necessary between the 10 minute runs.

Upon completion of the electric drilling operation, the opening through the diamond will resemble generally the showing in the third view of Figure 4. The pierced diamond will be finished in the usual manner. Since the opening which has been drilled electrically is centered on the preferred die axis and is uniform around the axis, the finishing operations will require about the same time as for a die drilled by the well-known mechanical methods.

Figure 4 of the drawings is a flow diagram showing the several steps in the method of drilling and finishing diamond dies according to this invention. This drawing has already been referred to and, with its legends, is believed to require little additional explanation. The times shown on the drawing are average for the manufacture of diamond wire drawing dies in the size range from .002 inch to .032 inch.

It will be evident from the foregoing description that applicants have provided a new and improved method and apparatus for the manufacture of diamond wire drawing dies wherein the diamond may be pierced electrically in a few minutes. The method represents an important simplification of the electric drilling methods previously available and permits the drilling of uniform die openings in diamonds of any shape by relatively inexperienced operators.

It will be understood that various modifications may be made in the described method and apparatus without departing from the spirit of the invention.

We claim:

1. The method of producing a diamond wire drawing die which comprises the steps of encasing the diamond in a relatively short cylindrical body of metal which surrounds and firmly grips the entire surface of the diamond with the preferred die axis coincident with the longitudinal axis of the cylindrical body, opening opposite ends of the metal encasement to expose only relatively small areas of the diamond at the two ends of the preferred die axis, drilling a small sharp cone on the preferred die axis in one of the exposed surfaces of the diamond, and subjecting the exposed surface of the diamond to an electric spark at the end of a needle electrode having its point accurately centered in the bottom of the cone, in an oxidizing atmosphere, the spark arcing across the gap from the end of the needle electrode to the surrounding edge of the metal encasement to drill an opening entirely through the diamond on the preferred die axis.

2. The method according to claim 1, including the step of continuously rotating the encased diamond about the preferred die axis during the electric drilling operation, so that the die opening will be drilled on the preferred die axis.

3. The method of producing a diamond wire drawing die which comprises the steps of embedding a diamond in a body of metal with the preferred die axis precisely located within the metal which is to constitute the permanent die mounting, removing portions of the encasing metal to expose only two small areas of the diamond surface at the two ends of the preferred die axis, mechanically countersinking the two exposed areas of the diamond surface, mechanically drilling a small sharp cone in one of the countersunk areas of the diamond, subjecting the point of the small cone to an electric spark discharge from a needle electrode pressed into the cone to drill an opening through the diamond, and rotating the encased diamond about the preferred die axis during the electric drilling operation, so that the opening will be drilled on the preferred die axis.

4. The method of producing a diamond wire drawing die which comprises the steps of encasing the diamond in a relatively short cylindrical body of metal which firmly grips the diamond with the preferred die axis coincident with the longitudinal axis of the cylindrical body, opening opposite ends of the metal encasement to expose only relatively small areas of the diamond at the two ends of the preferred die axis, subjecting one of the exposed surfaces of the diamond to an electric spark at the end of a needle electrode having its point accurately located on the preferred die axis, in an oxidizing atmosphere, to drill an opening through the diamond on the preferred die axis, and directing streams of an oxidizing gas toward the point of the needle substantially uniformly from all sides during the electric drilling operation to supply oxygen to the diamond directly under the needle point and to cool the needle.

5. The method of producing a diamond wire drawing die which comprises the steps of encasing the diamond in a relatively short cylindrical body of metal which firmly grips the diamond with the preferred die axis coincident with the longitudinal axis of the cylindrical body, opening opposite ends of the metal encasement to expose only relatively small areas of the diamond at the two ends of the preferred die axis, subjecting one of the exposed surfaces of the diamond to an electric spark at the end of a needle electrode having its point accurately located on the preferred die axis, in an oxidizing atmosphere, to drill an opening through the diamond on the preferred die axis, and directing streams of air under a pressure of from 6 to 8 inches of mercury to the point of the needle substantially uniformly from all sides during the electric drilling operation.

6. The method of producing a diamond wire drawing die which comprises the steps of encasing the diamond in a relatively short cylindrical body of metal which firmly grips the diamond with the preferred die axis coincident with the longitudinal axis of the cylindrical body, opening opposite ends of the metal encasement to expose only relatively small areas of the diamond at the two ends of the preferred die axis, subjecting one of the exposed surfaces of the diamond to an electric spark at the end of a needle electrode having its point accurately located on the preferred die axis, in an oxidizing atmosphere, to drill an opening through the diamond on the preferred die axis, and directing streams of air under a pressure of 7 inches of mercury to the point of the needle substantially uniformly from all sides during the electric drilling operation.

7. Apparatus for electrically drilling a wire drawing die opening through a diamond which has been encased in its permanent die mounting with only two small areas of the diamond surface at the two ends of the preferred die axis exposed, comprising, in combination, means for holding the encased diamond so that the axis of the die opening to be drilled is vertical, means for rotating the holding means about the preferred die axis, means for resiliently suspending a needle electrode over the diamond with the needle initially in pressure contact with the upper exposed area of the diamond, means for adjusting the pressure of the needle electrode on the diamond, means for applying an alternating current voltage across the needle electrode and the holding means to drill an opening through the diamond, and means for directing currents of air uniformly from all sides toward the point of the needle electrode during the drilling operation.

8. In apparatus for electrically drilling a wire drawing die opening through a diamond by the use of a needle electrode initially pressed against the diamond, means for directing air uniformly from all sides toward the point of the needle electrode during the electric drilling operation, said means comprising, in combination, a ring shaped tubular collar surrounding the needle electrode a short distance above the diamond, a pipe connection for supplying air under pressure

to the interior of the tubular collar, and openings around the wall of the tubular collar directed inwardly and downwardly toward the point of the needle electrode when it is in drilling position, characterized by the fact that the ring shaped tubular collar has a pivotal connection to the pipe which supplies air thereto, and further characterized by the fact that the collar is in the form of a split ring, whereby the collar may be swung about the pivotal connection into position over the diamond during the drilling operation, and swung away from the needle at other times.

9. The method of producing a diamond wire drawing die which consists of the steps of encasing the diamond in a relatively short cylindrical body of metal which surrounds and firmly grips the entire surface of the diamond with the preferred die axis coincident with the longitudinal axis of the cylindrical body, opening opposite ends of the metal encasement to expose only relatively small areas of the diamond at the two ends of the preferred die axis, countersinking the two exposed areas of the diamond to provide shallow concavities at the two ends of the preferred die axis, drilling a small sharp cone on the preferred die axis in the countersunk area which is to become the entrance side of the die, subjecting the exposed surface of the diamond having the small sharp cone to an electric spark at the end of a needle electrode having its point centered in the bottom of the cone, in an oxidizing atmosphere, to drill an opening entirely through the diamond on the preferred die axis, and finishing the pierced diamond.

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