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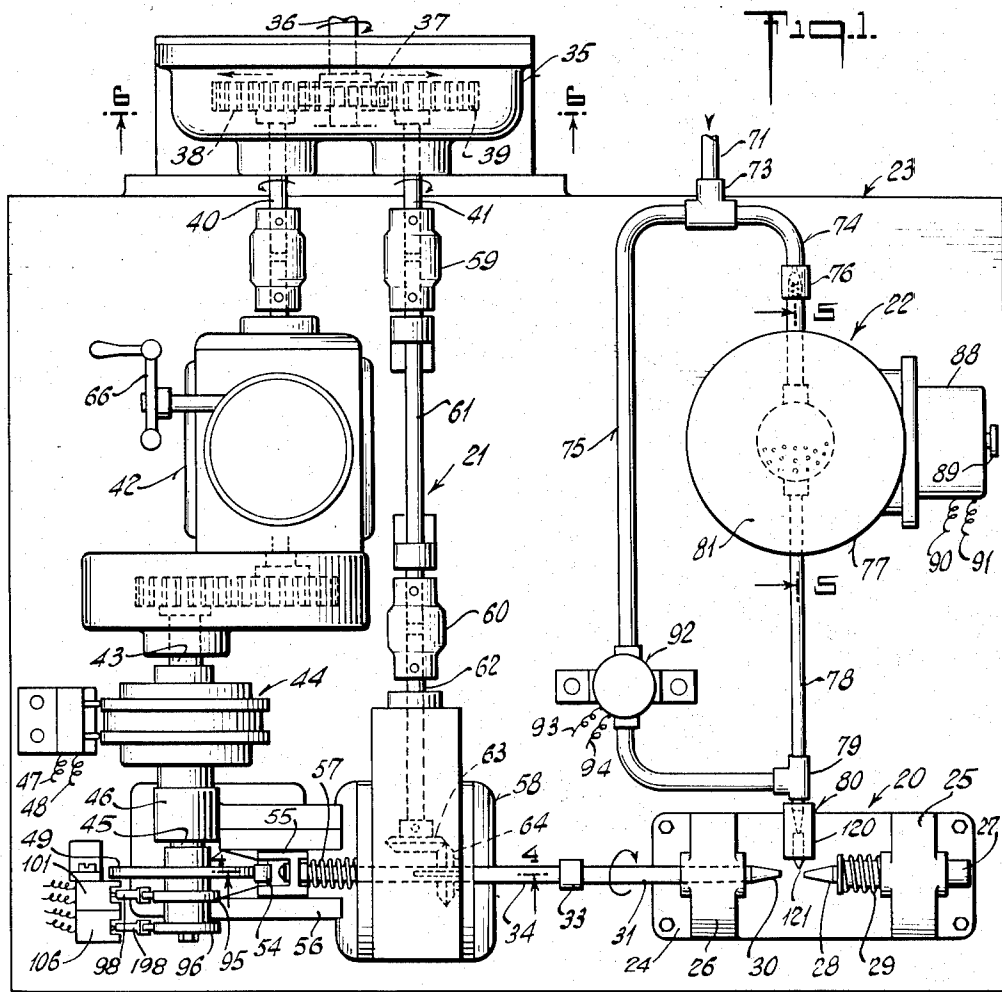
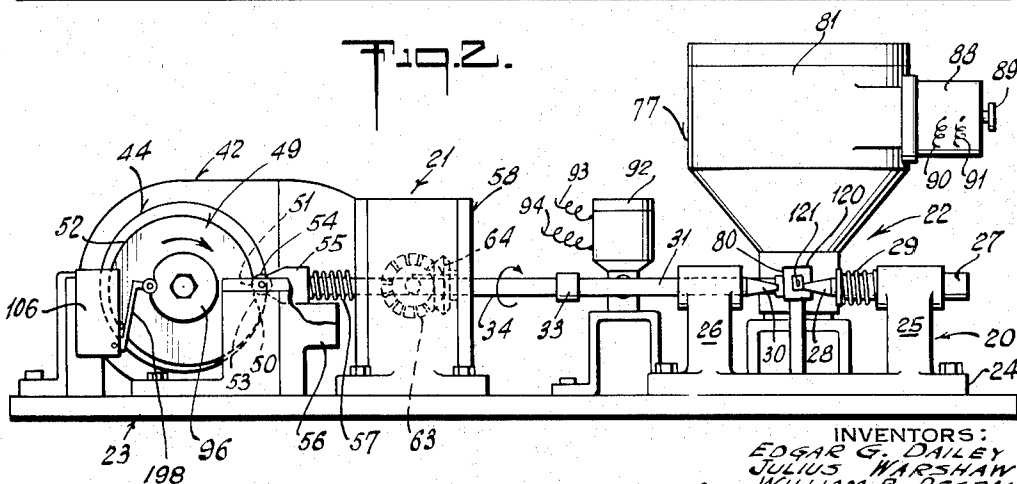
E. G. DAILEY ET AL

2,743,554

APPARATUS FOR BLAST ETCHING ELECTRICAL DEVICES

Filed April 19, 1952

3 Sheets-Sheet 1



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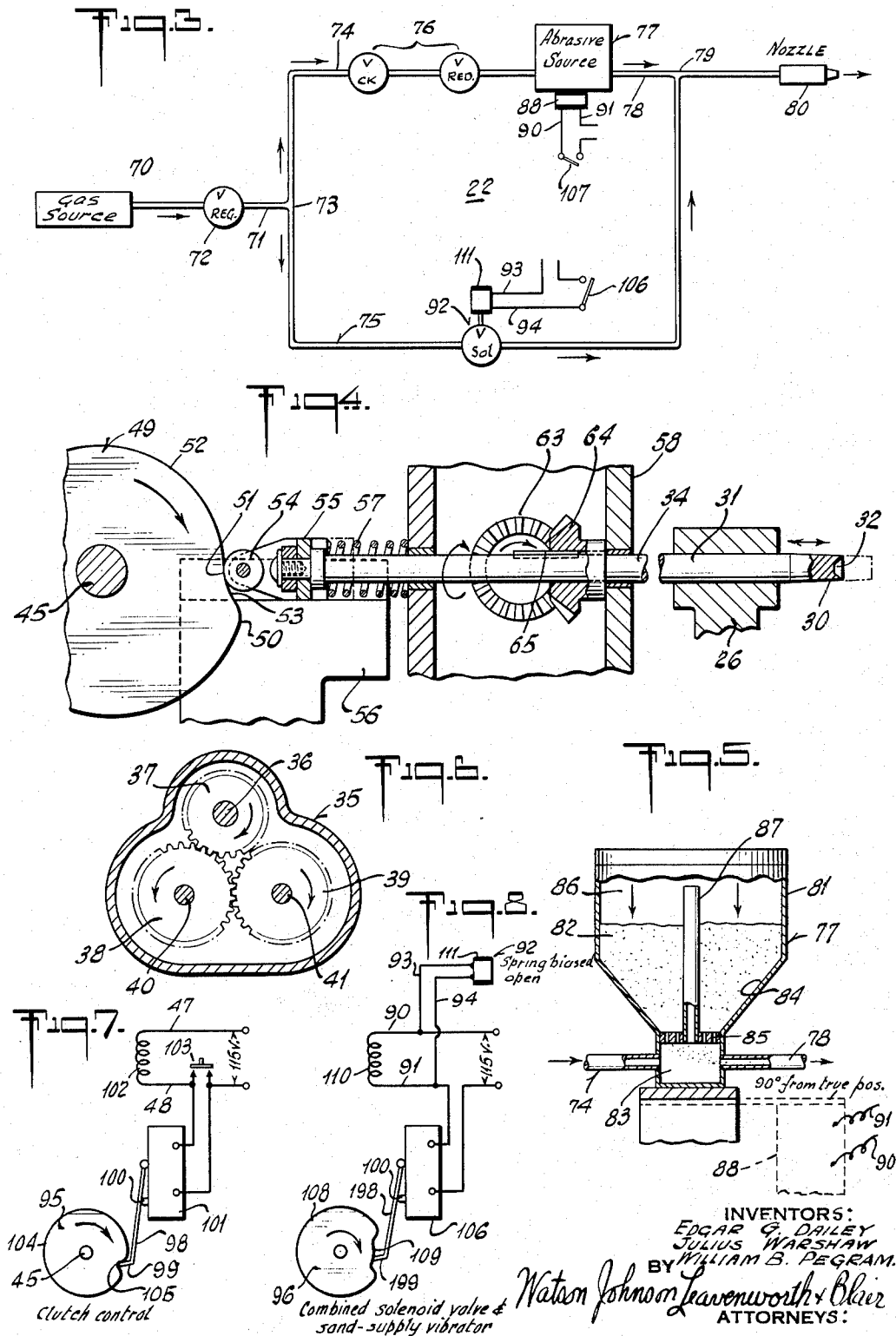
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3 Sheets-Sheet 2



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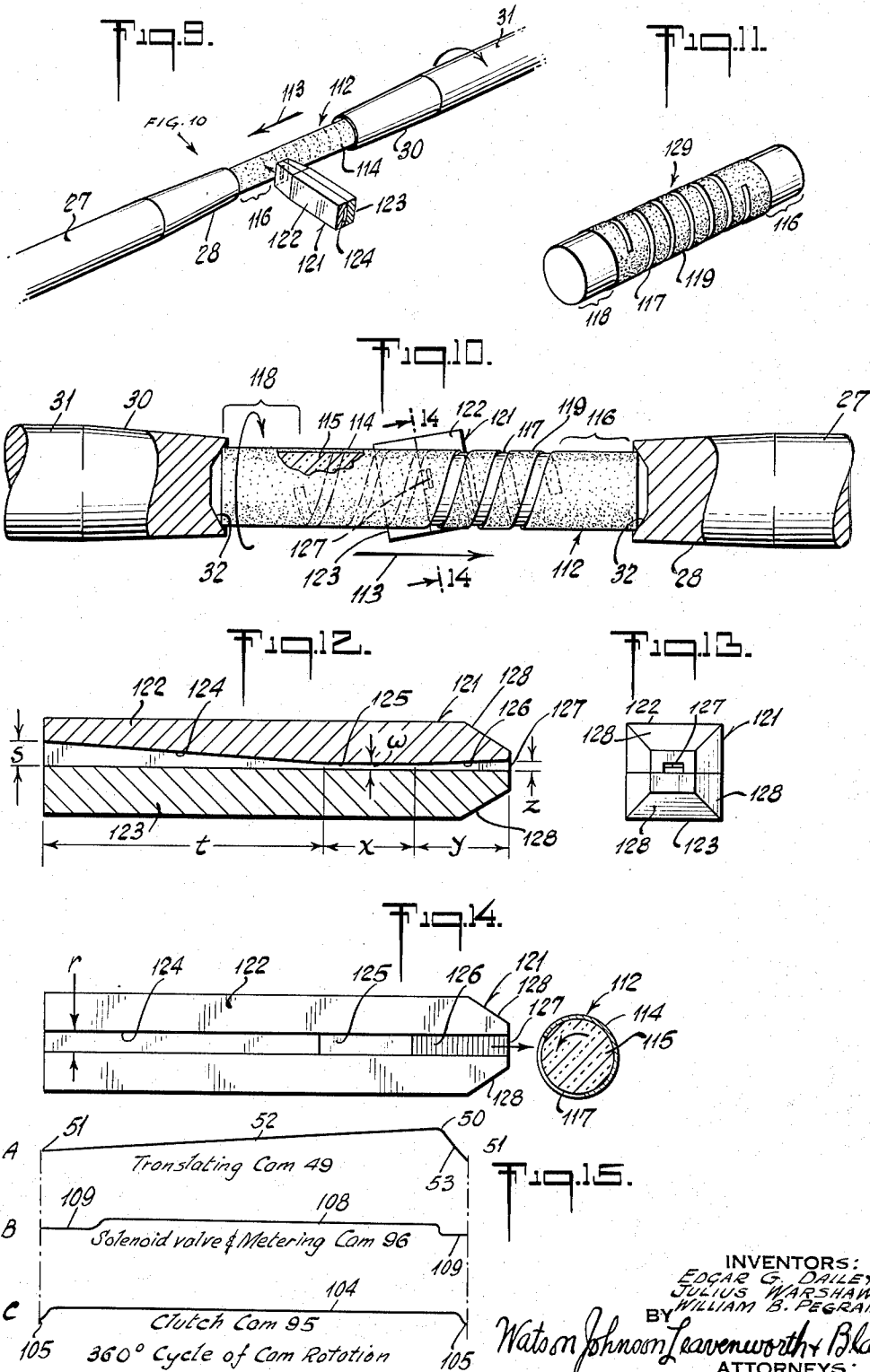
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# APPARATUS FOR BLAST ETCHING ELECTRICAL DEVICES

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3 Sheets-Sheet 3



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## APPARATUS FOR BLAST ETCHING ELECTRICAL DEVICES

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Application April 19, 1952, Serial No. 283,202

6 Claims. (Cl. 51—15)

The present invention relates to a method of and apparatus for helical cutting of electrically conductive coatings on substantially cylindrical electrical units and, more particularly, to the production of spiralled electrical resistors, such as those of the deposited carbon type.

General objects of the invention are to provide an efficient method of and simple but effective apparatus for precision cutting away of electrical conductive material coating from substantially cylindrical core surfaces to leave thereon spiral strips of the conductive material characterized by clean-cut side edges capable of being of substantially uniform electrical characteristics per unit length throughout and free of bridges and breaks; and a unique flow control device thereof for instantaneously initiating and stopping high velocity impingement on workpieces by etching abrasive-laden gaseous medium.

A more specific object of the invention is to provide a unique method of and simple but practical apparatus for readily producing spiralled electrical resistors by a new abrasive blast technique assuring rapid production on a commercial basis of such units having desired accurate operating characteristics.

Another object of the invention is to permit efficient manufacture on a mass production basis of miniature deposited carbon spiralled electrical resistors by an abrasive blast procedure and means with attainment of unusual accuracy in production to standard specifications.

An additional object of the invention is to provide in such apparatus an abrasive blast conduit and nozzle system and means to control emissive flow of particle-laden gaseous medium from the nozzle which permits instantaneous initiation and stopping of that flow by control means through which the particle-laden gaseous medium does not flow thereby effectively avoiding destructive etching thereof, and without requiring that flow of gaseous medium be stopped.

A further object of the invention is to replace diamond wheel spiralling in spiralled resistor production with an abrasives blast operation, while effectively eliminating undesirable features of the diamond wheel procedure. Such undesirable features include use of a liquid coolant requiring racking and oven drying and extra handling attendant thereon; undesirable response to machine and external sources of vibration and friction in bearings causing changes in wheel-to-work spring-biased contact resulting in inaccurate cutting with formation of shorting bridges; and tedious, costly and time wasting machine maintenance work including careful periodic adjustments, wheel dressing, etc.

A still further object of the present invention is to provide structural embodiments of the abrasive blast spiralling apparatus of the present invention which may be readily constructed and permit efficient and simple use and operation thereof.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect

2

to each of the others, and the apparatus embodying features of construction, combinations of elements and arrangements of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 is a plan view, with parts broken away, of an embodiment of the present invention particularly designed for cutting by an abrasive blast a helical groove in an electrically conductive coating on a substantially cylindrical core of insulating material and arranged for cyclic operation;

Fig. 2 is an elevational end view of the apparatus shown in Fig. 1;

Fig. 3 is a schematic showing of the conduit system of the apparatus shown in Figs. 1 and 2;

Fig. 4 is an enlarged detail, with parts in section and parts broken away, taken substantially on line 4—4 of Fig. 1, more clearly explanatory of details of the axial translating mechanism thereof;

Fig. 5 is an elevational section of a part of the abrasive supply device used in the conduit sub-assembly of Figs. 1, 2 and 3, and taken substantially on line 5—5 of Fig. 1;

Fig. 6 is a sectional view taken substantially on line 6—6 of Fig. 1;

Fig. 7 is a diagrammatic view of a modification of the cam-operated electrical control circuit for the electromagnetic clutch which may be used in the translating drive of the apparatus of Figs. 1 and 2;

Fig. 8 is a diagrammatic showing of the cam-operated electrical control circuit for the abrasive blast control valve of the conduit system shown in Fig. 3 which may be used advantageously in the apparatus of Figs. 1 and 2;

Fig. 9 is a detail perspective of the work-supporting chucks of the apparatus shown in Fig. 1 illustrating axial translation and rotary motion of the work relative to an etching blast produced by the jet nozzle, parts of which are indicated therein;

Fig. 10 is a greatly enlarged elevational view, with parts broken away and in section, of the structure shown in Fig. 9 as viewed from the side opposite the mouth of the jet nozzle, and illustrating, by way of example, etching of a helical groove in the electrically conductive coating as formed during about one-half of the working portion of a cycle of operation of the apparatus shown in Figs. 1 and 2;

Fig. 11 is an enlarged perspective view of a finished deposited carbon miniature spiralled electrical resistor after application of a pair of terminals following completion of the spiralling illustrated in Figs. 9 and 10;

Fig. 12 is an enlarged longitudinal section of the jet nozzle which may be employed to advantage in the apparatus of Figs. 1 and 2;

Fig. 13 is an end elevational view of the nozzle of Fig. 12 looking into the mouth of the jet passage;

Fig. 14 is a sectional view taken substantially on line 14—14 of Fig. 10, showing a longitudinal section of the nozzle taken in a plane substantially normal to the plane of section of Fig. 12; and

Fig. 15 is a diagrammatic layout of the surfaces of the chuck axial translating cam, the cam of Fig. 8 for simultaneously controlling of the electrical circuits of the blast control valve and the abrasive metering device, and the cam of Fig. 7 for operating the electrical control circuit of the electromagnetic clutch.

Prior to the present invention, miniature spiral electrical resistors of the carbon coated or pyrolytic deposited

type have been commercially spiralled by expensive complicated spiralling machines using diamond or other abrasive cutting wheels. An approved type of such machine employs a water cooled, metal bonded, diamond wheel clamped on a shaft revolving about a fixed axis in rigidly fixed precision bearings. With the use of a fixed lead screw a carriage is advanced past the edge of the cutting wheel with a low-mass yoke on the carriage supporting chucks holding therebetween a suitably coated work unit; the chucks are rotated at a fixed speed relative to that of the carriage-advancing lead screw. The yoke is pivotally mounted on the carriage and is biased by a light spring to swing the work into and hold it in contact with the edge of the diamond cutting wheel. Such a machine requires apparatus for supplying water coolant during grinding and subsequent racking and oven drying with attendant extra handling. The light spring biasing of the yoke to maintain contact between the work and the edge of the cutting wheel may be adversely affected by vibration from the machine or from external sources. As a result, continuous effective cutting is precarious and shorting bridges between adjacent conductive helical turns of retained coating or breaks in the latter frequently result. Despite the fact that expensive precision ball bearings are employed, friction therein has been found to alter the contact pressure between the work and the cutting wheel resulting in variations in the cutting which has also been found at times to leave shorting bridges. Abrasive wheel action involves impact which may chip the core material and the delicate carbon coating resulting in rough edges on the retained helical strip of coating. This results in undesirable noise in audio circuits or other undesirable effects. Such a machine requires frequent tedious and time-consuming adjustments and accurate dressing of the grinding wheel in an effort to maintain suitable cutting action. Accurately cylindricity of ceramic cores is a critical requirement of the grinding wheel procedure. The apparatus of the present invention eliminates these and other difficulties and requirements, for the abrasive blast method of the present invention is simpler, more economical and may be more effectively operated while requiring much less servicing and maintenance skill.

Briefly, the method and apparatus of the present invention are instrumental in etching the conductive coating in a helical path by way of an abrasive particles-laden blast of gaseous medium while the work is axially translated and rotated at predetermined speeds past a relatively fixed blast or jet nozzle. The necessity for using coolant liquids is eliminated due to the fact that the blast inherently has a cooling characteristic. There is no mechanical contact between the blast nozzle and the workpiece, and use of simpler rigid bearings and mountings is possible. Maintenance of precise relative positions of the workpiece and the cutting tool is not required since the surface of the work may run slightly eccentric without deleteriously affecting the etching cut produced by the abrasives blast. Simple control of metering of the quantity of abrasive particles relative to the quantity of gaseous medium carrier replaces the diamond cutting dressing operations.

A fuller understanding of the method and apparatus of the present invention and the advantages accruing from the practice and use thereof will be had by reference to the drawings, in which like numerals identify similar parts throughout. As shown in Figs. 1 and 2, an embodiment of the apparatus of the present invention particularly designed for blast etching spiralled paths on cylindrical ceramic cores having deposited carbon coatings, comprises a chuck device 20, drive mechanism 21 to translate the chucks axially and to rotate at least one of them, and an etching blast producing sub-assembly 22, all suitably mounted upon a machine frame 23.

The chuck device 20 comprises a base 24 suitably mounted upon the machine frame 23 and carries a pair

of spaced uprights or standards 25 and 26. A through horizontal bore or fixed journal in standard 25 reciprocally and rotatively carries a tail stock 27 supporting on its inboard end a collet type of chuck 28 biased to the left, as viewed in Figs. 1 and 2, by means of a helical compression spring 29. Another collet type of chuck 30 is carried in opposed alignment with chuck 28 by a driven shaft or spindle 31 reciprocally and rotatably supported in a through bore or fixed journal in standard or spindle housing 26. As best seen in Fig. 10, each of the collet type chucks 28 and 30 is provided in the free end thereof with an axially arranged tapered socket 32 to receive and hold in substantially concentric relation the end of a cylindrical workpiece with the biasing spring 29 urging chuck 28 toward chuck 30.

Since the chucks 28 and 30 with a workpiece held therebetween are to be translated axially at a predetermined speed from left to right as viewed in Figs. 1, 2 and 10, with clockwise rotation at a predetermined speed by means of spindle 31, the driving mechanism 21 has suitable driving connection at 33 with the spindle through a rotating and reciprocable shaft 34. The driving mechanism 21 includes a gear case unit 35 suitably supported on machine base 23 and having a driven or input shaft 36 suitably connected to a power source or electric motor (not shown). A driving gear 37 suitably keyed to input shaft 36 in the gear case 35 is meshed with a driven gear 38 which, in turn, is meshed with another driven gear 39, both located in the gear case, as best seen in Fig. 6. Driven gear 38 is suitably splined to driven shaft 40, and driven gear 39 is suitably splined to driven shaft 41, with the shafts respectively designed to drive the chuck translating and chuck rotating devices.

The chuck axial translating drive includes an infinitely variable-speed transmission unit or gear box 42 suitably coupled to shaft 40 and having its output shaft 43 coupled through an electromagnetic clutch 44 to a cam shaft 45 suitably journaled through a fixed bracket 46 mounted on machine base 23. The electromagnetic clutch 44 of standard construction has terminals, diagrammatically represented as pigtailed 47 and 48, to connect its electrical operating means to a suitable electrical control circuit, as will be explained later. Cam shaft 45 carries a plate cam 49 of the uniform rise type. As best seen in Figs. 2 and 4, the peripheral edge of cam 49 is contoured to provide a thrust lobe 50, a "start" low point 51, and the intervening synclinal cam surface thrust and retard portions respectively referenced 52 and 53, as is best seen from the diagrammatic cam lay-out curve A in Fig. 15. Cam follower roller 54 is rotatably mounted upon slide or crosshead 55 slidably supported upon slide guides provided by grooved bracket 56. The slide or crosshead 55 is rotatably connected to one end of reciprocative and rotary shaft 34 by any suitable means, and is spring biased to the left as viewed in Figs. 1, 2 and 4 by helical spring 57 to maintain contact between cam follower roller 54 and the peripheral edge of the cam 49. Shaft 34 is mounted through bevel-gear housing or case unit 58, as shown in Figs. 1, 2 and 4, with one end of biasing helical spring 57 abutted against the left end of the bevel-gear unit, as there shown.

Rotary motion is given to spindle 31 and its chuck 30 by means of shaft 34 which is suitably connected to driven shaft 41 by couplers 59 and 60, a bearing-supported intervening shaft extension 61 and bevel-gear unit 58, with the latter parts suitably mounted on machine frame 23, as shown. Input shaft 62 of the bevel-gear unit 58 carries a bevel-gear 63 fixed or splined thereto and meshed with another bevel-gear 64 which is slidably keyed to shaft 34 in such manner as to permit relative axial motion, such as by a feather key 65 (Fig. 4), so that the shaft may be translated axially by the cam 49 as it is rotated by the bevel-gears 63 and 64. Rotary drive of spindle 31 from the same power unit which translates it axially properly synchronizes the rotary and axial motion given

to the workpiece-supporting chucks, and the ratio of the axial translation speed to the speed of rotation may be changed at will by adjustment of the variable-speed transmission unit 42, such as by means of control hand crank 66. Such ratio, of course, determines the pitch and width of a helical strip of the coating left on the workpiece core by the blast etching of an intervening helical path, as is more fully explained hereinafter.

The abrasive blast equipment or sub-assembly 22 of the apparatus of Figs. 1 and 2 may comprise a suitable source of gaseous medium under pressure, such as dry nitrogen, carbon dioxide or air (not shown in Figs. 1 and 2 but diagrammatically illustrated at 70 in Fig. 3), connected to supply duct or pipe 71 preferably through a suitable pressure regulator diagrammatically illustrated at 72 in Fig. 3. Supply pipe 71 is connected through a suitable T-fitting 73 to two parallel conduits 74 and 75 which, respectively, will be broadly termed the abrasive supply branch and the valved bypass branch.

The abrasive supply branch 74 of the conduit system 22 includes in series a pressure reducing device 76 and an abrasive supply 77 connected through a pipe section 78 and T-fitting 79 to a suitable blast nozzle 80. The pressure reducing device 76 may be in the form of a differential pressure regulator or flow restricting means to provide a fixed predetermined pressure drop, but preferably comprises a spring-biased check valve incorporating flow resistance to obtain the pressure drop.

The abrasive supply 77, as best seen in Fig. 5, may comprise a closed hopper 81 to contain a quantity 82 of particulate alumina or other suitable abrasive particles having a bottom pick-up chamber 83 through which gaseous medium flows to pipe section 78. The pick-up chamber 83 is defined from an upper storage chamber 84 by means of a perforated partition 85 having a plurality of holes through which the abrasive particles may fall into the pick-up chamber. Space 86 above the quantity of abrasive particles 82 is connected to the pick-up chamber 83 by means of a standpipe 87 serving as a pressure equalizer tube so that there will be no retardation of free fall of abrasive particles due to gaseous medium pressure. The rate at which abrasive particles are supplied through the perforated partition 85 into pick-up chamber 83 is controlled by an electrically-operated vibrator 88, shown in full lines in Figs. 1 and 2 and diagrammatically indicated in dotted lines in Fig. 5, since in the latter showing it is normal to the position illustrated in Figs. 1 and 2. Variation of the vibration controls at the rate of feed of abrasive particles and thus suitable means may be provided for altering the rate of vibration, such as a manual control 89. Terminals for the purpose of connecting the vibrator 88 into its electrical control circuit are illustrated by pigtails 90 and 91 in Figs. 1, 2 and 5. As the abrasive particles fall into the pick-up chamber 83, they are entrained by the flow of gaseous medium therethrough to be carried by pipe section 78 to the blast nozzle 80.

Flow of gaseous medium through the bypass branch 75 to T-fitting 79 is controlled by a suitable solenoid valve 92 of well-known construction and of the type which closes a through flow passage when its magnetic coil is energized, the valve being biased to open position by a spring. Terminals to connect the magnetic coil of solenoid valve 92 to its control circuit are illustrated by pigtails 93 and 94 in Figs. 1 and 2.

In operation of the abrasive supply and blast system 22 dry gaseous medium at a pressure preferably of about 50 p. s. i. g. is supplied to the feed pipe 71 with the pressure drop across the device 76 or combined check valve and pressure reducing flow restriction being about ten percent (10%). The pressure differential obtained at the T-fitting 79 where the abrasive supply branch 74 and the bypass 75 are interconnected will instantaneously stop flow of gaseous medium through the abrasive supply branch 74. This condition obtains, of course, when the

solenoid valve 92 is open or de-energized. The check valve at 76 eliminates any possibility of transient back flow. Its spring is loaded preferably an amount approximately ten per cent (10%) greater than the pressure drop experienced by gaseous medium stream passing around through the bypass branch line 75 and its solenoid valve 92, so that the pressure differential is insufficient to allow the check valve to open. However, upon energization of the solenoid valve 92 to close it, the check valve at 76 will be opened and gaseous medium is allowed to flow through the pick-up chamber 83 there to entrain abrasive particles and carry them through pipe section 78 to the blast nozzle 80. Accordingly, electrical switch control of solenoid valve 92 provides efficient control of the flow to the blast nozzle 80 of gaseous medium in which the abrasive is entrained. Emission of an abrasive blast from the nozzle can be instantaneously started and stopped by closing and opening a switch in the electrical operating circuit of the solenoid valve 92, and this abrasive supply and blast system has the added advantage of automatically flushing the blast nozzle to prevent accumulation of abrasive particles therein when the solenoid valve is opened.

Semi-automatic control of the apparatus illustrated in Figs. 1 and 2 and synchronized operation of the magnetic clutch 44, abrasive supply vibrator 88 and solenoid valve 92 is had by a bank of cams, illustrated in Figs. 1 and 2 comprising rotary disc cams 95 and 96 fixedly mounted on rotatable cam shaft 45. Clutch control cam 95 may be peripherally contoured similar to that shown in Fig. 7 and diagrammatically illustrated by curve "C" in Fig. 15 with a biased lever 98 having a cam follower nose 99 biased to continuous contact with the cam periphery. Swing of the lever 98 depresses to closed position spring-biased operating button 100 of a microswitch unit 101 connected in series with operating magnet 102 of clutch 44 in a suitable electrical power supply circuit. Microswitch 101 is shunted by a manually operable switch 103, preferably of the push button type, spring-biased to the open position. Cam disc 95 is substantially circular so that the major portion 104 of its peripheral edge constitutes means to hold the switch operating lever 98 to the right, as viewed in Fig. 7. Lever 98 thus continues to hold the microswitch button 100 in closed position so that the microswitch 101 maintains the electrical supply circuit of the clutch 44 closed through the major portion of a cycle of operation of the apparatus shown in Figs. 1 and 2. However, a low point 105 in the periphery of cam 95 permits lever 98 to swing to the left to allow microswitch 101 to open by its biasing means at the cam position shown in Fig. 7. The timing of cam 95 is also synchronized to the timing of the axial translating cam 49 to provide for opening of the clutch circuit when axial translation of the chuck 30 has passed through one complete cycle. Such cycle includes first a slow movement to the right as viewed in Figs. 1 and 2 when the spiral path is being cut, and then a rapid retraction to the "start" position when the clutch circuit is opened.

A similar solenoid microswitch 106 controls the operation of the abrasive hopper vibrator 88 and the solenoid valve 92. As previously described, solenoid valve 92 is closed when energized and at the same time vibrator 88 is energized to facilitate feed of abrasive into the gas which flows through pipe section 78 to nozzle 80. Conversely, when blast etching is not desired, vibrator 88 is deenergized as is solenoid valve 92 which is thus spring-biased to its open position. Thus, it is possible to control both solenoid valve 92 and vibrator 88 with one cam-switch arrangement, although separate cams and switches may be employed for control of the solenoid valve and vibrator.

As shown in Fig. 8, cam follower nose 199 of switch operating lever 198 engages the rotating cam 96 to open and close microswitch 106 as dictated by the peripheral shape of the cam. Coil 110 of vibrator 88 is connected

in parallel with coil 111 of solenoid valve 92, the coils being in turn connected to a suitable source of power through switch 106. Cam 96 has a large substantially circular portion or lobe 108 for switch closing and a smaller low portion 109 to permit switch opening. As is diagrammatically indicated in lay-out curve "B" of Fig. 15 preferably the large portion 108 of cam 96 comprises approximately 300° of the cam surface. Accordingly, when cam follower nose 199 engages the large portion 108 of cam 96 to close the switch 106, coils 110 and 111 will be energized so that vibrator 88 operates and valve 92 is closed. Conversely, when cam follower nose 199 engages the low portion 109 of cam 96 to permit switch 106 to open and deenergize coils 110 and 111, the vibrator is inoperative and valve 92 is opened by its biasing spring. As can be seen from a comparison of the cam lay-out curves A and B of Fig. 15, the low portion 109 of cam 96 is so related to the surface of the translating cam 49 that switch 106 remains open at the start of axial feed translation of the workpiece 112 and re-opens the switch at least by the time axial retraction commences, it being understood that no blast etching takes place when switch 106 is opened. The limit of axial feed translation is appreciably short of the workpiece end held in translating cam 30, and it follows that no spiral path will be cut in the end portions of the workpiece so that the carbon coatings at these points may be utilized for terminal capping.

Alternatively, it is possible to control energization of coils 110 and 111 of the vibrator 88 and valve 92 by mechanism other than cam 96 to achieve different results. For example, electrical mechanism (not shown) may be employed for measuring the resistance of the helical strip of carbon coating being spirally cut during the blast etching operation, which mechanism may open the circuit to the vibrator and valve at the instant the desired resistance value has been obtained. In this manner, the exact resistance values desired may be more easily achieved. However, for many purposes, the cam operated switch illustrated in Fig. 8 is suitable to achieve desired results.

In describing typical operation of the apparatus, it will be assumed that the drive shaft 36 is suitably connected to a continuously operating power source and that the supply pipe 71 is suitably connected to a source of dry gaseous medium at a pressure of about 50 p. s. i. g. with emission of the gaseous medium from the nozzle 80. Chuck 30 is continuously rotated at a uniform speed throughout operation of the machine by means of its separate drive from the drive shaft 36. The direction of rotation will be in opposite directions for right and left hand spiralling.

An operator may then successively produce miniature spiralled resistors in the following manner. A carbon coated cylindrical ceramic core element, such as that shown at 112 in Fig. 9, is loaded between the chuck 28 and slowly rotating chuck 30 which biasing spring 29 readily permits. The operator then depresses starter button 103 (Fig. 7) to close the circuit of the magnetic clutch magnet 102 so that rotation of translating cam 49 in a clockwise direction as viewed in Fig. 4 will be initiated. As a result, feed cam surface 52 slowly commences to push cam follower roller 54 to the right at a uniform speed. Since the electromagnetic clutch control cam 95 is synchronized with the translating cam 49, it will promptly close the electromagnetic clutch circuit by way of microswitch 101 so as to maintain translating drive after the operator has released the starter button 103.

After the workpiece 112 has been axially translated a short distance in the direction of the arrow 113 shown in Fig. 9, the lobe 108 of cam 96 closes microswitch 106 (Figs. 1, 2 and 8) to start the vibrator 88 and close valve 92. Thus, gaseous medium, preferably at a pressure of about 45 p. s. i. g., passes through abrasive pick-up chamber 83, supply branch 78, and T-fitting 79 to the blast

nozzle 80. Etching commences over a small portion of workpiece coating 114 and it will be noticed that this leaves the end portion 116 unetched to serve as a terminal means.

As the axial translation of workpiece 112 continues in the direction of arrows 113 of Figs. 9 and 10, and its rotation continues, the blast of abrasive-laden gaseous medium emitted from the nozzle mouth against the carbon coating 114 traverses a helical path about the workpiece to etch a helical path or groove 117 free of carbon coating. At a point short of the other end of the workpiece or before the limit of axial translation is reached by way of cam lobe 50, low portion 109 of cam 96 engages follower 199 to open microswitch 106 stopping vibrator 88 and opening valve 92. Thus, the gas bypasses pick-up chamber 83 by way of pipe 75. Because pipe 75 is connected to T-fitting 79 all flow of abrasive-laden gas immediately ceases at a point short of the end of the workpiece in chuck 30 to leave an unetched zone 118 at that end thereof for the other terminal. The resulting helical strip 119 of coating left on the core 115, connected at opposite ends to terminal zones 116 and 118 constitutes the finished spiralled resistance except for terminal capping, insulating or applying protecting covers, etc.

As indicated in Figs. 1 and 2, nozzle 80 comprises a holder 120 having a two-part core 121. Nozzle core 121 may be in the form of a pair of elongated matching rectangular blocks 122 and 123 (Fig. 12) of tungsten carbide, or other suitable hard abrasive-resistant material. Nozzle core piece 122 has a suitable longitudinally-extending groove to serve as a flow passage therethrough, which, as best seen in Fig. 12, includes an entrance portion 124, a throated section 125 and an expansion portion 126 terminating in mouth 127.

By way of example, nozzle core pieces 122 and 123 may be formed from elongated rectangular pieces of tungsten carbide about five-eighths of an inch long ( $\frac{5}{8}$ " l.), about one-eighth of an inch wide ( $\frac{1}{8}$ " w.), and about one-tenth of an inch deep ( $\frac{1}{10}$ " d.). The width of the groove (dimension *r*, Fig. 14) is uniform and may be about 0.025". The depth of the entrance portion 124 (dimension *s*, Fig. 12) may be about one thirty-second of an inch ( $\frac{1}{32}$ "). The length of the entrance portion 124 (dimension *t*, Fig. 12) may be about fifteen thirty-seconds of an inch ( $\frac{15}{32}$ "). The depth of the throat section 125 (dimension *w*, Fig. 12) may be about 0.005" and the length thereof (dimension *x*, Fig. 12) may be about one-eighth of an inch ( $\frac{1}{8}$ "). The length of the expansion portion 126 (dimension *y*, Fig. 12) may also be about one-eighth of an inch long ( $\frac{1}{8}$ " l.), and the mouth 127 (dimension *z*, Fig. 12) may have a width of about 0.0062". The throat section 125 preferably should not be smaller than approximately three times the abrasive particle size which preferably is about twenty-two microns (22 $\mu$ ).

At the indicated pressure drop preferably employed, there is induced supersonic gas velocity of about 1,300 to 1,400 feet per second. The throat section 125 and exhaust portion 126 are so designed that the expansion energy of the gas is substantially matched so that the gas stream has no side expansion upon leaving the nozzle mouth 127. The abrasive particles are thus permitted to attain maximum velocity without "explosion" of the gas upon emission from the nozzle mouth 127, which would otherwise result due to sudden release of pressure. Thus, the margins of the blast substantially in the shape of a ribbon are sharply defined so as to precision cut the impinged surface in etch areas with clean-cut side edges and to produce a clean blast path or helical groove 117 for efficient production on a commercial scale of miniature resistors having quiet characteristics.

Also, as best seen in Fig. 10, the nozzle core 121 preferably is so arranged with respect to the pitch of the intended path which its blast traverses on workpiece 112

that its long dimension is substantially parallel thereto (but not necessarily for some types of spiralling). This produces very narrow grooves. In fact, a nozzle mouth 127 of a width of 0.0062" will give a cut of about 0.0066" wide when the nozzle mouth is arranged about one thirty-second of an inch ( $\frac{1}{32}$ ") from the work. Such nozzle design and arrangement have been successfully employed in cutting from twenty to fifty-five groove turns per inch, and holder 120 may be provided with suitable adjusting means (not shown) to align the nozzle mouth 127 with the desired pitch. The nose of the nozzle core 121 is preferably tapered on all four sides, as indicated at 128 in Figs. 12, 13 and 14, for free gas escapement after impingement to prevent turbulence and interference with the main stream or blast emitted further to assure clean, sharp cutting.

Also, as proposed in Fig. 14, the blast preferably impinges at a point on the work which is off-center with respect to the axis of rotation so that the gas and abrasive will ricochet away. A suitable hood structure (not shown) may be provided over the work area to exhaust the abrasive therefrom.

Operation of the blast system sub-assembly 22 has been found to be efficient in the commercial production of spiralled resistors over a wide abrasive to gas ratio, although generally the abrasive loading in practice is light. The spacing of the nozzle mouth from the work surface is not highly critical so that efficient operation may be had even though there may be some slight eccentricity of rotating surface being etched.

Such spiralled resistors may have their unetched end zones 116 and 118 silver coated and the resulting units 129 shown in Fig. 11 may then be finished for use by capping their silver-coated ends with suitable terminals and coating with baked varnish or other protective coating.

The resulting resistors are found to be uniformly free of shorting bridges and the edges of the spiral path are even and regular. Thus, a resistor is produced which is exceptionally quiet in performance, even though produced on a mass commercial basis. Since this blast etching is so accurate and may be instantaneously initiated and stopped as desired, this method of spiralling has been found to permit repeated and rapid production to predetermined resistivity with remarkable precision and accuracy of spiral resistors of superior characteristics in sizes, for example, of the order of  $\frac{1}{8}$ " in diameter and  $1\frac{1}{32}$ " long with the spiralled length being about  $\frac{3}{32}$ ".

It will thus be seen that the objects set forth above, among those made apparent from the preceding description are efficiently attained and, since certain changes in carrying out the above process and in the construction set forth, which embody the invention, may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described our invention, what we claim as new and desire to secure by Letters Patent is:

1. Apparatus for making electrical resistors from a cylindrical core of insulating material with at least a portion of its surface coated with a layer of resistance material comprising, in combination, a relatively fixed nozzle to deliver a blast of abrasive-laden gaseous medium along a relatively fixed and narrow path having substantially sharply defined margins; a pair of opposed, axially slidable and rotatable chucks for receiving and holding therebetween said core; spring means biasing said chucks in one axial direction to a starting position and simultaneously one toward the other; a cam follower on one of

said chucks; a rotary cam against which said spring means biases said cam follower and contoured to slide said cam follower-carrying chuck forward transverse of the path from the starting position in the opposite direction against the spring biasing; drive means to rotate one of said chucks at a predetermined speed in all axial positions; a common power source for said rotating means and said cam to synchronize the operation thereof; speed change means interposed between said power source and said cam to vary the speed of the latter relative to the speed of the rotating means; a gang of cam-operated electrical switch means having a plurality of operating cams coaxially mounted and rotatable in synchronism with said chuck-driving cam; a conduit system for supplying abrasive laden gaseous medium to said nozzle and including a solenoid control valve selectively to permit and cut off flow of abrasive-laden gaseous medium through said nozzle; and an electrically operated clutch located between said cams and power source; one of said cam-operated switch means being adapted to control operation of said solenoid valve and another of said cam-operated switch means being adapted to control operation of said clutch, whereby said chucks are reciprocated cyclically and while emission of abrasive-laden gaseous medium through the nozzle is prevented during spring return movement of said chucks.

2. Apparatus for making electrical resistors from a cylindrical core of insulating material with at least a portion of its surface coated with a layer of resistance material comprising, in combination, a relatively fixed nozzle having a passage therethrough shaped to deliver a blast of abrasive-laden gaseous medium along a relatively fixed and narrow path having substantially sharply defined margins; means providing a supply passage for delivering particle-laden gaseous medium to said nozzle passage at a predetermined pressure; means providing a second supply passage for delivering unladen gaseous medium to said nozzle passage at a higher predetermined pressure; valve means controlling fluid flow in said second supply passage so that when said valve means permits flow through the latter the differential in pressure stop flow of particle-laden gaseous medium from said first supply passage to said nozzle passage and upon said valve means stopping flow through said second supply passage flow of particle-laden gaseous medium from said first supply passage to said nozzle passage is permitted; support means to rotate said core at a predetermined speed; and means axially to translate said rotating core across said path at a predetermined speed so that a clean-cut groove will be etched through said layer along a helical path about the core.

3. The apparatus as defined in claim 2 characterized by a common source of gaseous medium under pressure for both of said supply passages with a pressure reducing means in said first passage providing the flow-checking pressure differential, and means to feed entrainable particles into said first supply passage.

4. The apparatus as defined in claim 3 characterized by the provision of check valve means in said first supply passage to prevent back flow with higher pressure flow through said second supply passage.

5. The apparatus as defined in claim 4 characterized by the provision of said pressure reducing means and said check valve means in said first supply passage located upstream of the connection of said entrainable particles feeding means to that passage.

6. The apparatus as set forth in claim 2 characterized by said valve means controlling fluid flow in said second supply passage being a solenoid control valve, and a cam-operated electrical switch means having an operating cam driven by the core axially translating means, said cam-operated switch means adapted to control operation of said solenoid valve.

## 11

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