

June 17, 1969

D. E. SUTTON
FACE MILL GRINDER

3,450,618

Filed Dec. 2, 1966

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FIG. 8

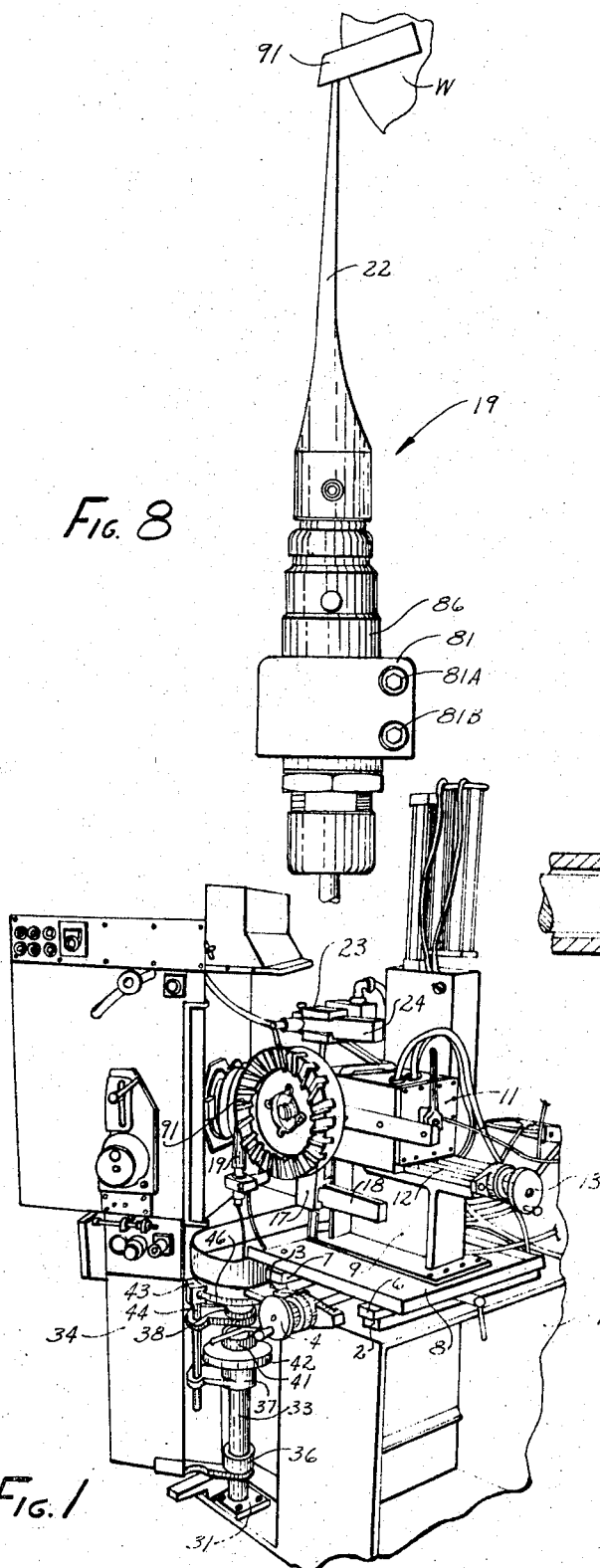
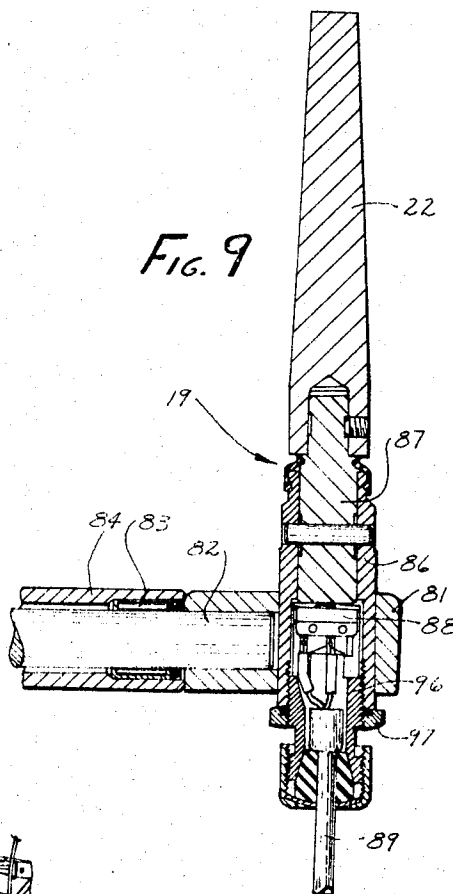


FIG. 9



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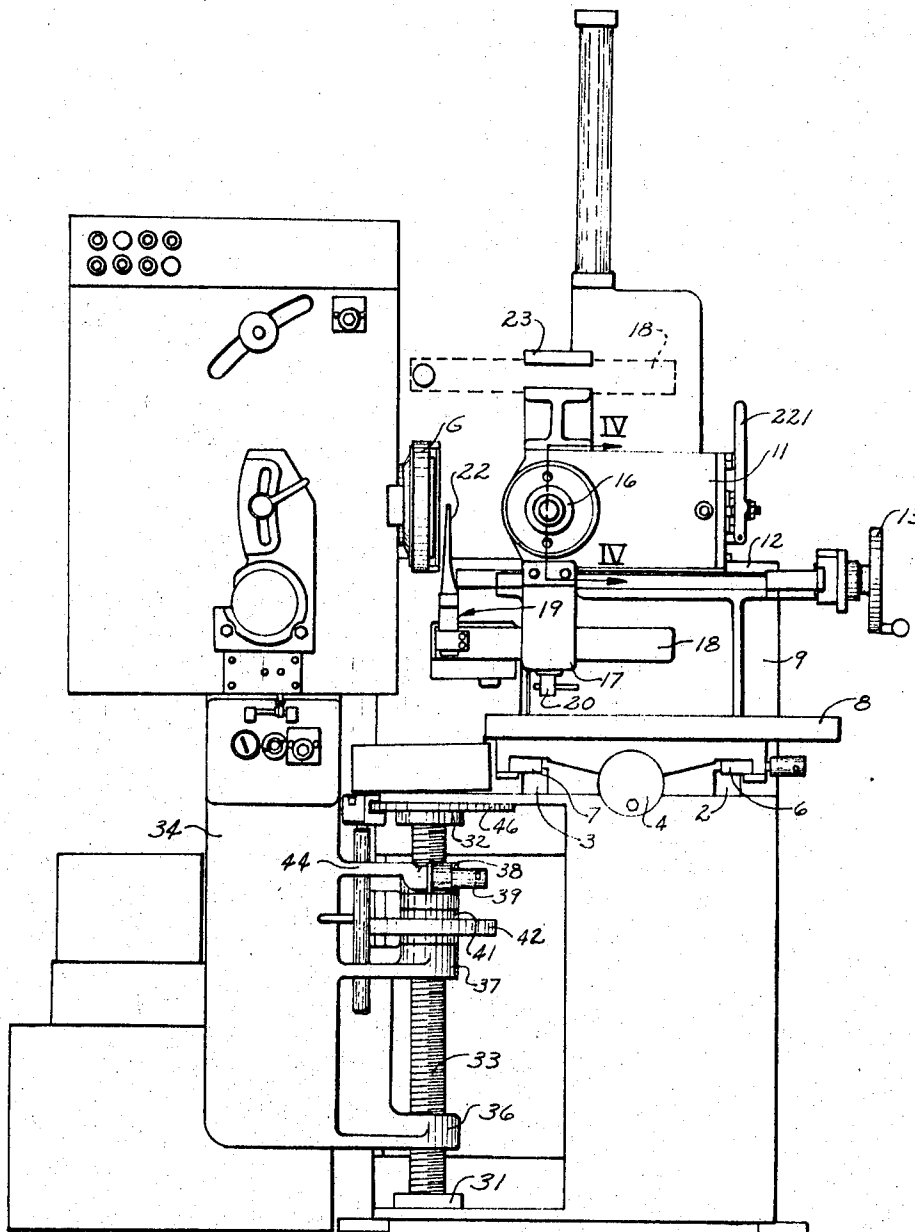


FIG. 2

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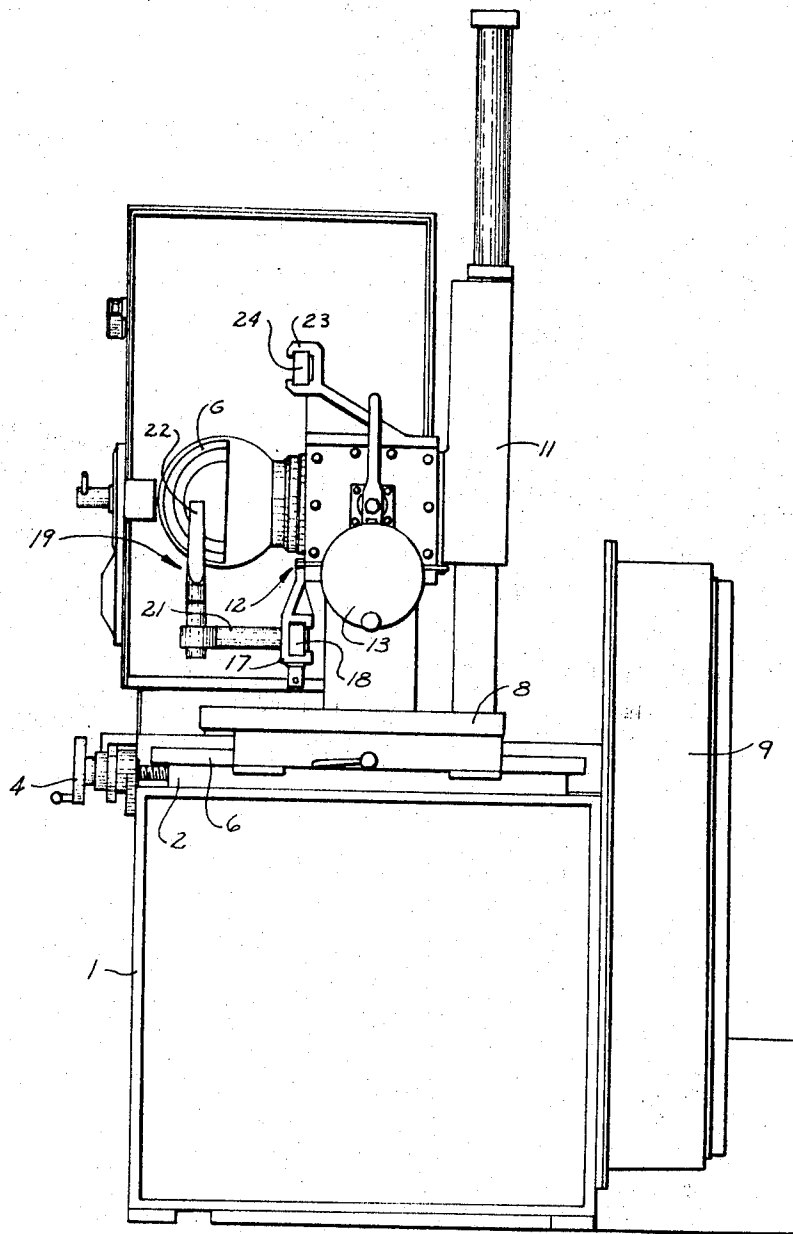


FIG. 3

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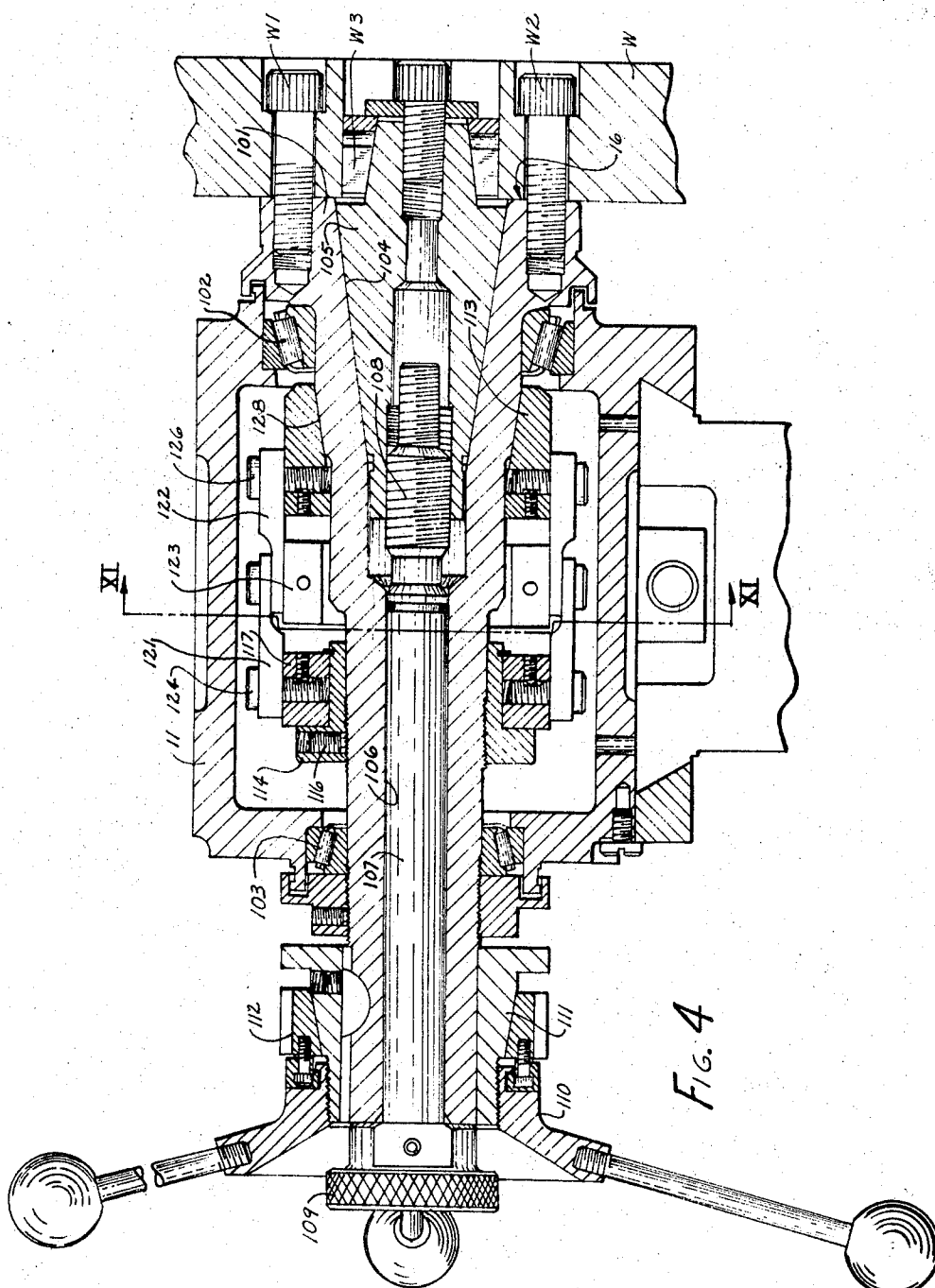


Fig. 4

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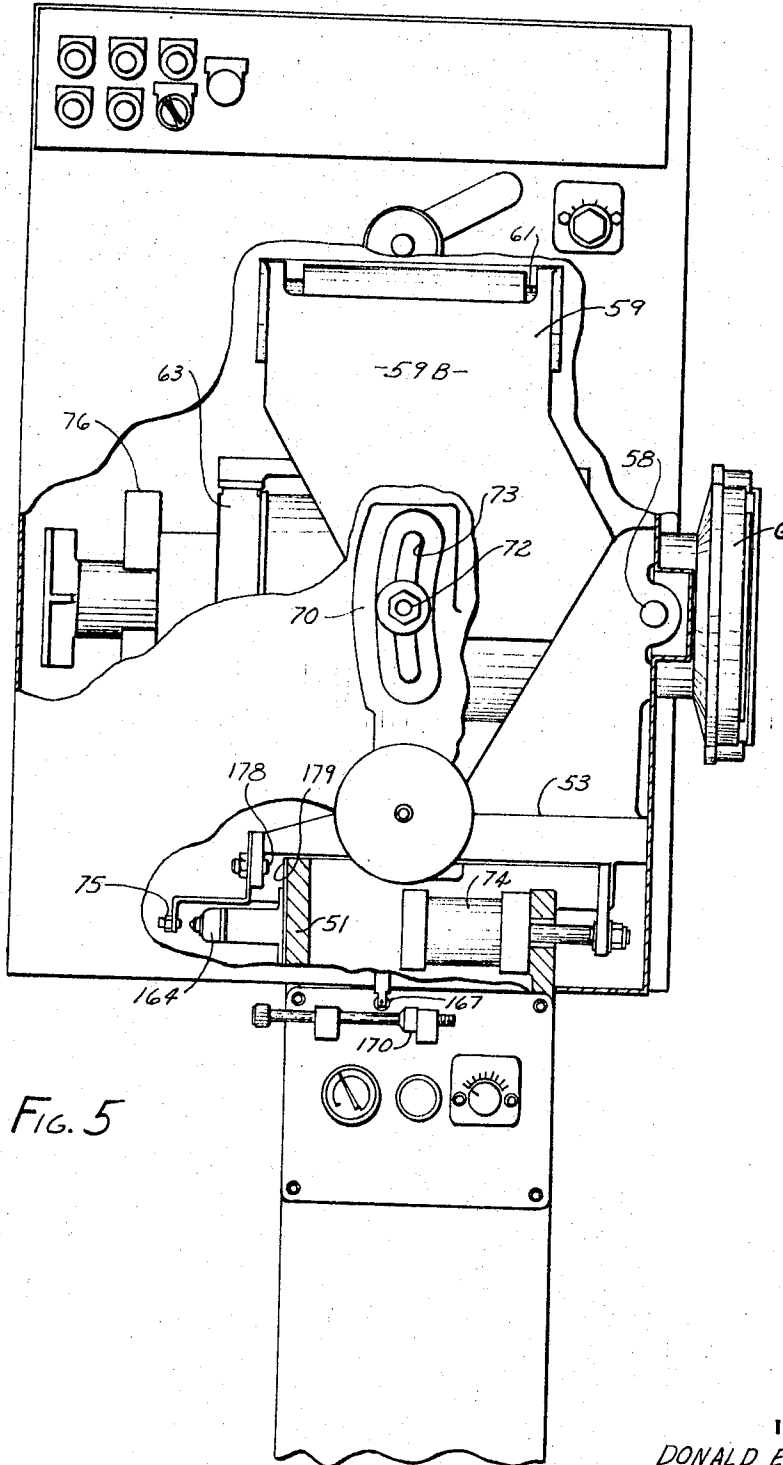


FIG. 5

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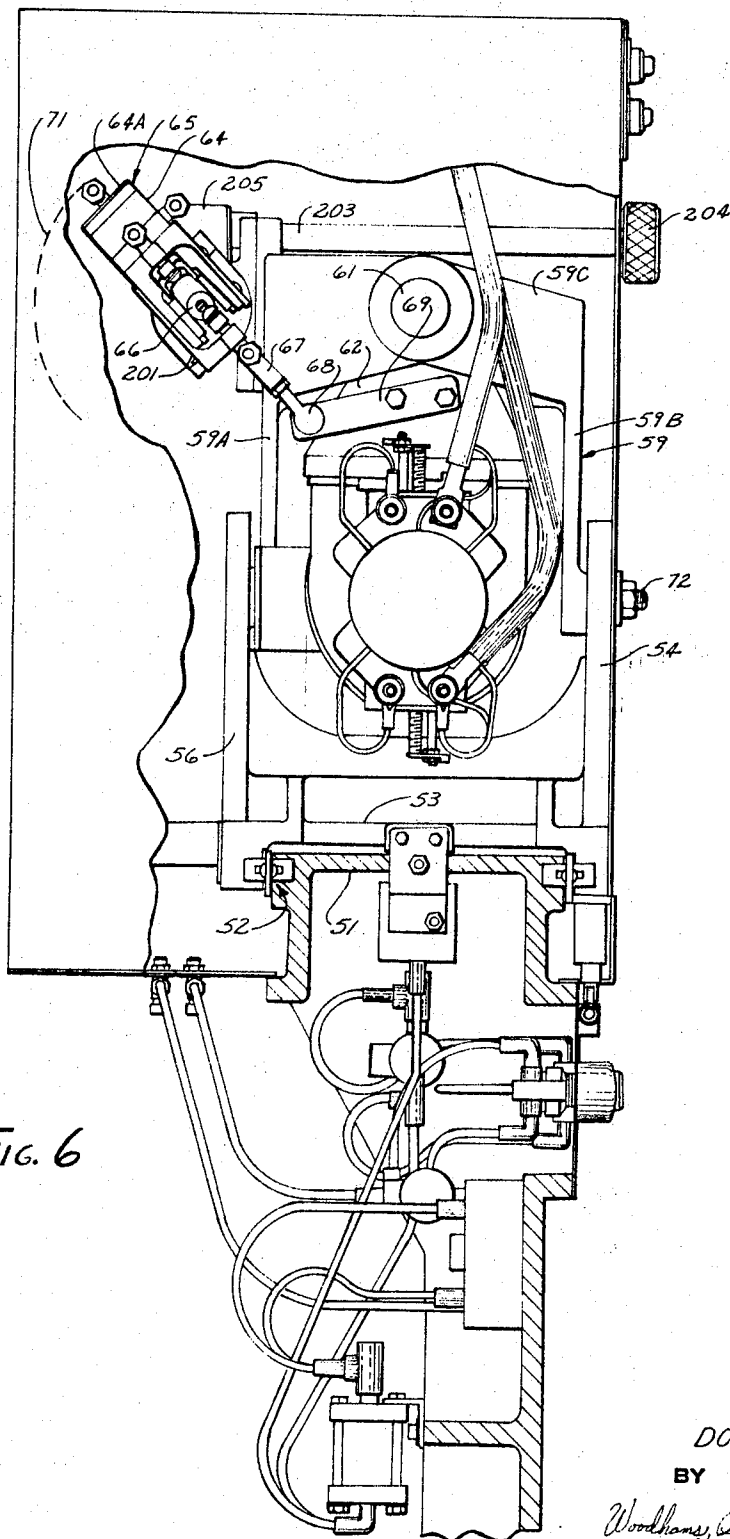


Fig. 6

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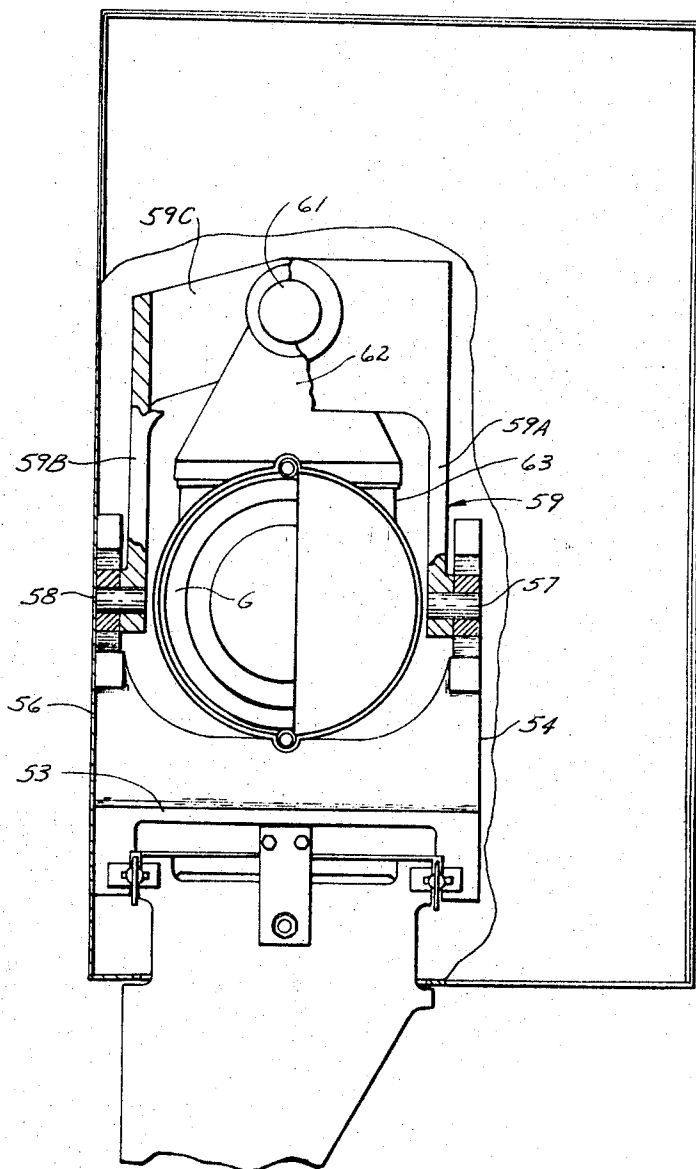


FIG. 7

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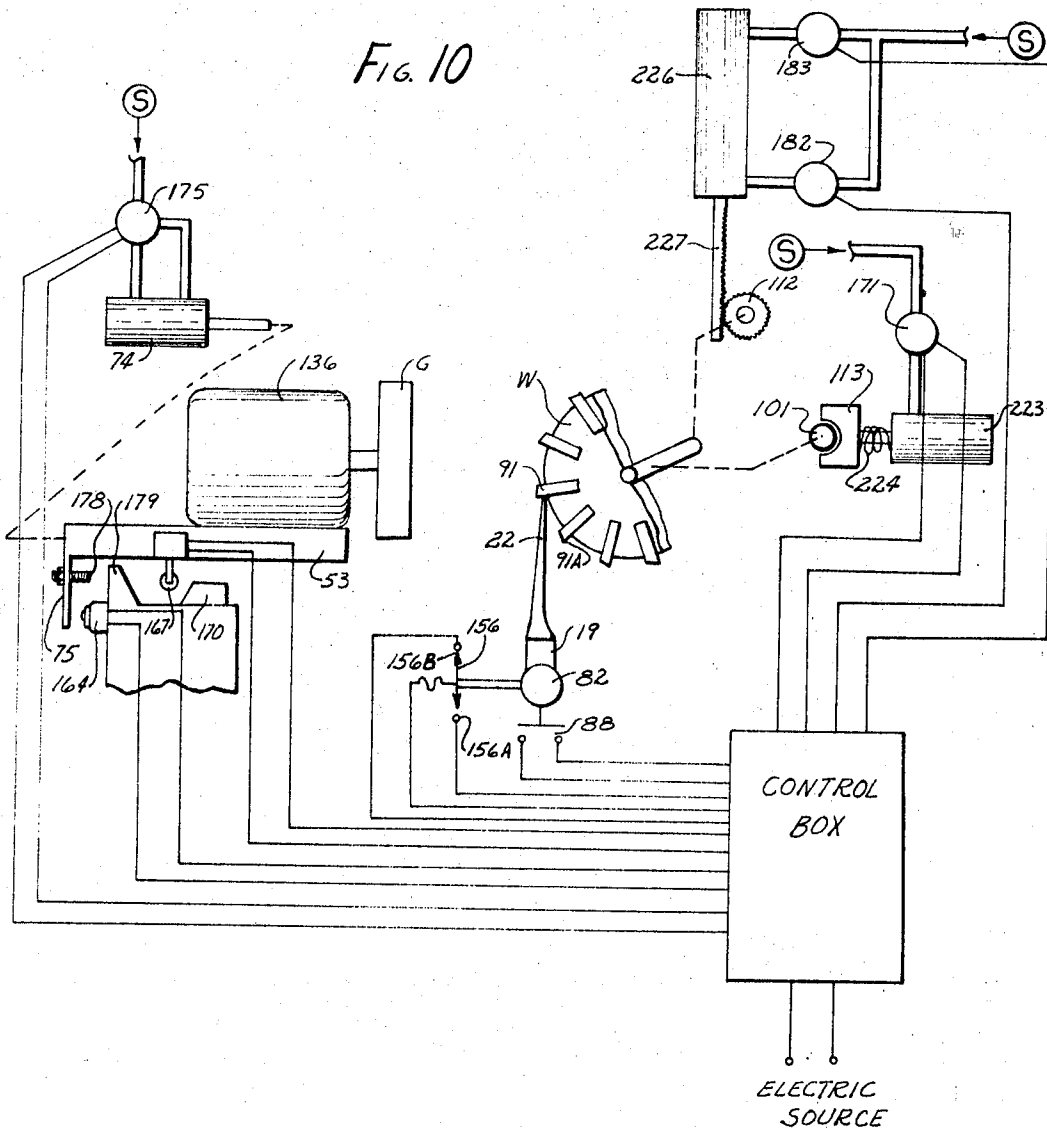
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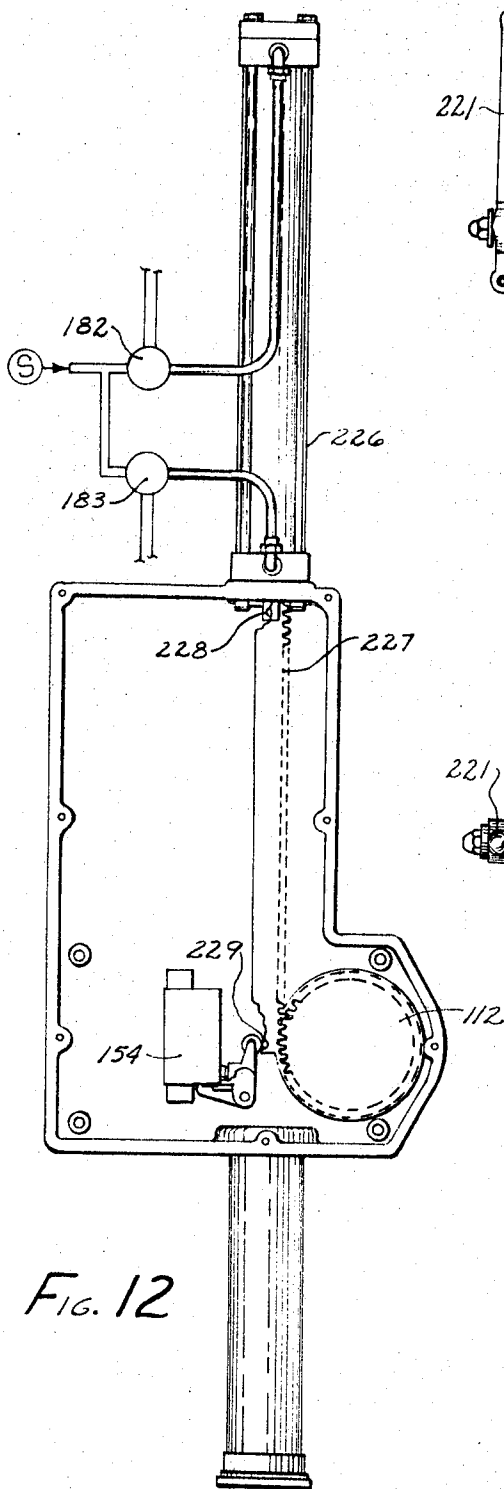


FIG. 12

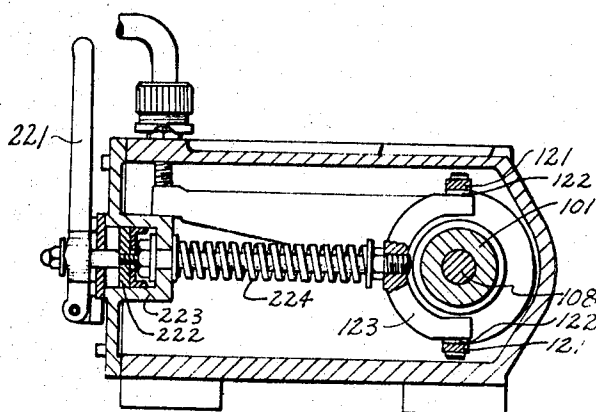


FIG. 11

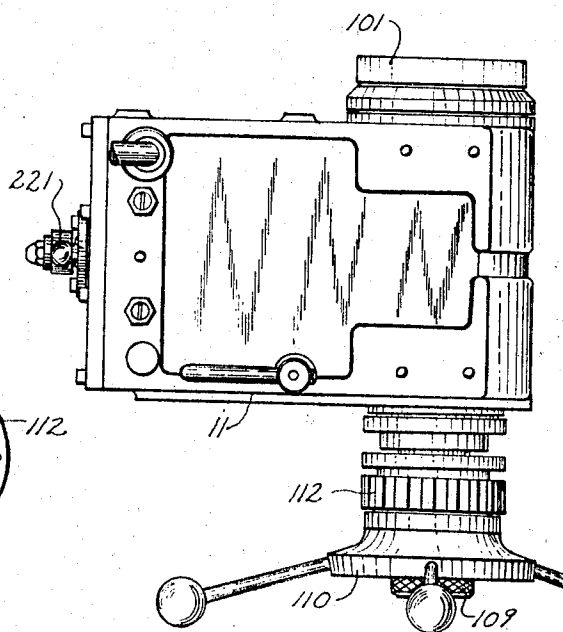


FIG. 14

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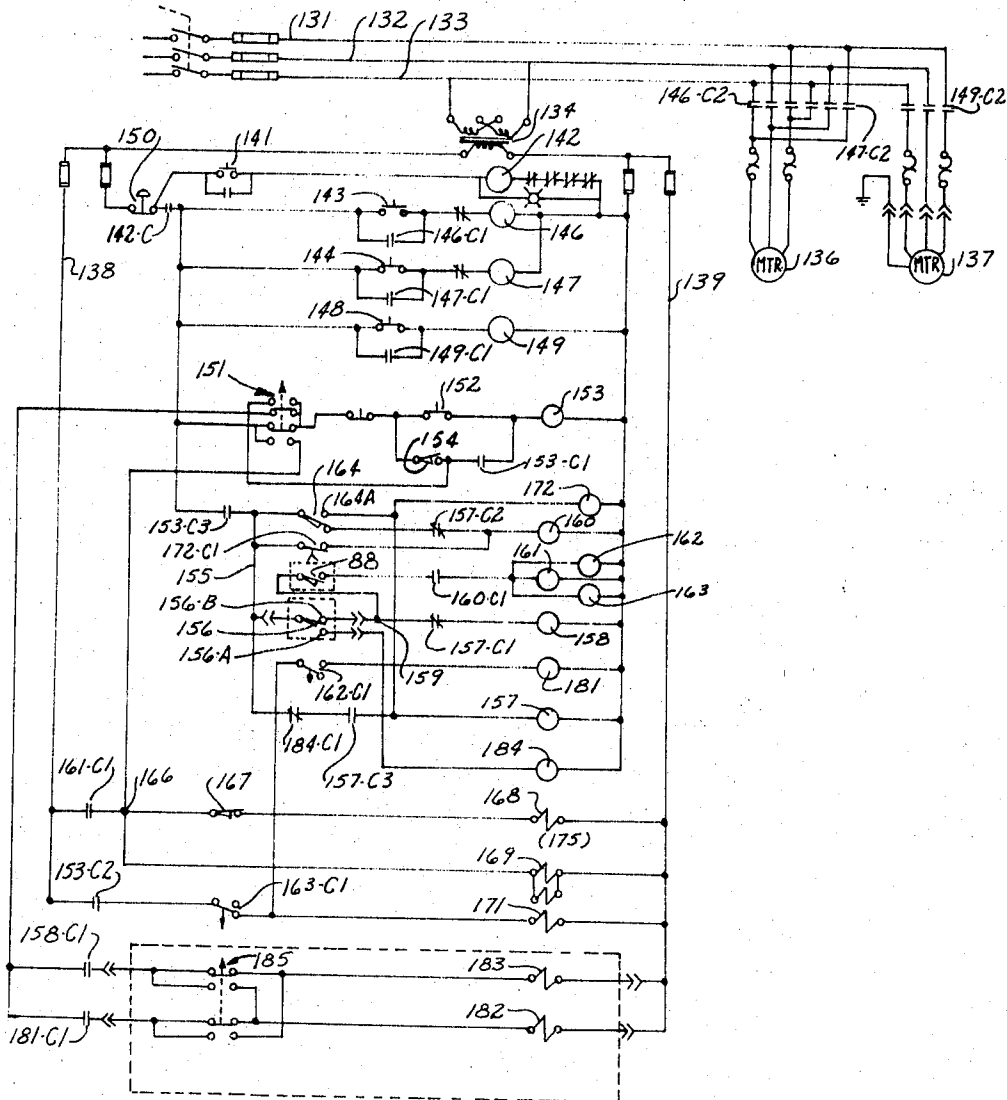


FIG. 13

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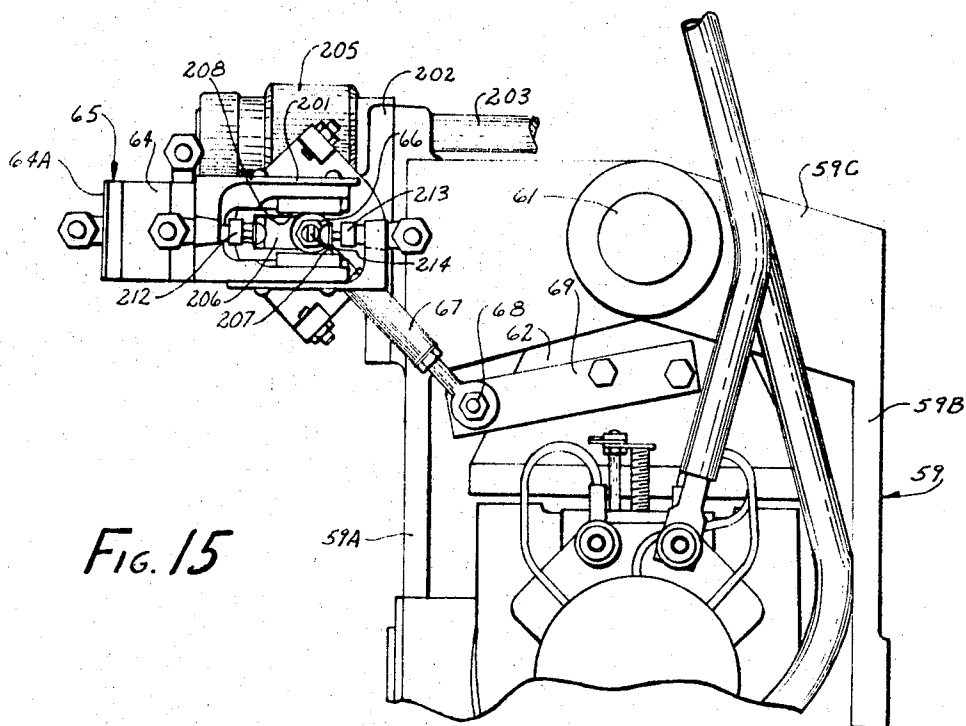
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FACE MILL GRINDER

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Filed Dec. 2, 1966, Ser. No. 598,806

Int. Cl. B23p 1/14, 1/02

U.S. Cl. 204—199

21 Claims

This invention relates to an electrolytic grinding machine and particularly to one adapted for grinding a plurality of spaced surfaces circumferentially arranged around a circular body, such as the cutting elements of a face milling cutter.

While the apparatus of the invention is adapted for use with any workpiece requiring the grinding of areas spaced, not necessarily equally, circumferentially around a generally circular body and accessible to the face of a grinding wheel, same was designed primarily for use in grinding face milling cutters and will accordingly be described in connection with and as applied to such use.

Such grinding, both in the original manufacture and the resharpener of face milling cutters, has long been carried out by conventional grinding methods and apparatus. These methods and apparatus, while acceptable so long as nothing better was available, have always presented a considerable number of well-recognized problems which have been in the past the subject of much attention.

Such problems being well known to people acquainted with the manufacture and maintenance of various types of cutters, particularly face milling cutters, there have been many attempts to eliminate or minimize as many of same as possible. One of the most promising of these attempts has been to utilize the well-known advantages of electrolytic grinding (as set forth in the U.S. Patent to Keeler No. 2,826,540) and some machines using this method have already been introduced to the market. Particularly, a major advantage of such procedure, as well understood by those skilled in the art, is the reduction of consumption of abrasive grain to a very low value where the machine is properly operated. Further advantages include carrying out the grinding operation without the development of heat and thereby minimizing, or virtually eliminating, the danger of cracking of the carbide during the grinding operation. A still further advantage of electrolytic grinding is that a better edge is obtained than a usually obtained as a practical matter by conventional grinding, not necessarily better than can be obtained by a skilled operator working carefully, but better than is normally actually obtained in practice by conventional grinding. However, insofar as I am aware, all of the machines thus far so introduced have been essentially conversions to the electrolytic processes of substantially conventional machines. This presents all of the problems, both electric and mechanical, normally encountered when a conventional grinding machine is converted to electrolytic operation of which there may be mentioned only as example the supplying of electrolyte, cleaning and recycling electrolyte, protection of bearing and other parts from corrosion by the electrolyte, introduction of electrical current to the critical parts of the machine at an acceptably low voltage without uncontrollable power losses therein and the erratic grinding resulting therefrom.

Therefore, the mere adaption of conventional face mill cutter grinders to electrolytic operations is not wholly adequate and, instead, a completely reorganized machine has been required for this purpose. This, however, produces further problems.

For example, in conventional grinding, particularly

for the grinding of face milling cutters, it is normal to utilize edge and/or peripheral grinding techniques and accordingly to feed the work in such a manner that the individual surfaces being ground are presented to the periphery, or to a corner edge, of the grinding wheel. On the other hand, in electrolytic grinding it is far preferable, and often essential, for the work to be presented to the face of the grinding wheel by utilization of plunge grinding techniques. This requires that the work feeding means operate in a direction parallel to the axis of the grinding wheel rather than, as in conventional grinding of face milling cutters, in a direction perpendicular to such axis. While broadly speaking this method of feeding work is already well known in connection with electrolytic grinders of general application, same has not previously, so far as we are aware, been applied to grinders for face milling cutters and hence a complete redesign of such grinders is necessary for the proper application of electrolytic principles thereto.

Further, conventional grinders for the grinding of face milling cutters have been largely designed with relatively small cutters in mind. This, and other reasons, have caused such grinders to be arranged so that the relative motion by which the workpiece and the grinding wheel are caused to approach each other is brought about by movement of the workpiece toward the grinding wheel. This is satisfactory where the cutters are small and of inconsequential weight. However, where the cutters are large, this procedure is unsatisfactory in that (1) the weight of the cutter makes it difficult to move the workpiece quickly into the grinding position and to retract same quickly and accurately therefrom, and (2) the fact that such cutters are large, but are nevertheless of greatly differing weight from one cutter to the next, means that whatever devices are provided for feeding the work will be subjected to substantial but varying inertia loads, whereby to place differing amounts of strain on the mechanical parts and requiring differing controls for same. It is thus desirable to provide a feeding system in which not only the lighter portion of the grinding system will be moved for feeding purposes, but also wherein the part moved for feeding purposes will be of substantially constant weight. Both of these last-named objectives are attained by causing the wheel and not the workpiece to be the moving member for establishing a grinding relationship.

Further, where the workpiece is large and heavy as is the face milling cutters abovementioned, it becomes complicated and therefore difficult to arrange the work feeding means in such a manner as to move the work into the various angular positions required for providing the proper grinding of the several cutter faces. Instead, it is desirable to arrange the grinding wheel for effecting such angular adjustment, both since it is the lighter of the two cooperating components and since it is of constant weight and size and hence needs to be under the control only of adjustment means adapted for the handling of apparatus of constant weight and size.

A still further problem of generally similar nature arises from the fact that the part which reciprocates into and out of position for making grinding contact desirably has both a positive stop for limiting its movement into position for making grinding contact and a limit switch, which is actuated upon its attaining such position. Where the workpiece is the part to be so reciprocated, such positive stop and limit switch combination must be adjustable in harmony with the adjustment of the feeding mechanism for determining stock removal and this further complicates the apparatus. If on the other hand such positive stop and limit switch means may be placed upon the wheel support means and left at a single fixed point, then the stock

work support and will be greatly simplified.

Further, some face milling cutters are sufficiently large and heavy as to require handling by cranes or other mechanical equipment and this can present difficulties in the use of some present grinding machines. For example, at least two types of conventional face milling cutters which are well known to industry require the placement of the cutter onto a vertical spindle located well inwardly from the side of the machine. Where the cutter involved is small this presents no great problem but where it is of such size as to require handling by mechanical aids, such placement of the cutter is at best difficult.

Accordingly, the objects of the invention include:

(1) To provide an electrolytic grinding machine adaptable for the grinding of a succession of flat areas circumferentially spaced around a generally circular workpiece.

(2) To provide apparatus, as aforesaid, which will result in a substantial saving of abrasive material with respect to a given grinding operation.

(3) To provide apparatus, as aforesaid, which is particularly adaptable to the electrolytic grinding of the cutting elements of a face milling cutter.

(4) To provide apparatus, as aforesaid, which will operate by a plunge grinding process rather than by line or edge grinding processes, whereby the entire surface to be ground is ground at a single time rather than by a series of repeated passes of the grinding tool across the surface.

(5) To provide apparatus, as aforesaid, in which the movement required to bring the grinding wheel and the workpiece into operating contact with respect to each other is obtained by movement of the grinding wheel rather than by movement of the workpiece whereby such feeding is of the element having a constant weight and inertia characteristics.

(6) To provide apparatus, as aforesaid, wherein the angular adjustment required to apply the grinding wheel to the various angles of the cutter teeth is carried out by angular movement of the wheel rather than of the workpiece whereby such movement is applied to the lighter of said cooperating parts and the one of constant weight.

(7) To provide apparatus, as aforesaid, wherein the positive stop means limiting the relative feeding of the grinding wheel and workpiece and the means adjusting the extent of such feeding are both applied to the carrier for the grinding wheel rather than to the support means for the workpiece whereby same are applied to the lighter of the two cooperating parts and to the one thereof which is of constant size and weight.

(8) To provide apparatus, as aforesaid, which can be easily, rapidly and accurately adjusted for the proper grinding of areas through a wide variety of sizes, angular positions and circumferential spaces.

(9) To provide apparatus, as aforesaid, wherein the workpiece is held substantially stationary during the grinding operation subject only to adjustment for grinding depth and wherein adjustment for the angular position of the grinding surface is provided in the means mounting the grinding wheel.

(10) To provide apparatus, as aforesaid, in which the relative motion required for moving the grinding wheel and the workpiece relatively into and out of mutually contacting relationship is obtained by movement of the grinding wheel mounting means.

(11) To provide means particularly adapted to the electrolytic grinding of face milling cutters wherein adjusting means are placed in association with the grinding wheel mounting means whereby to minimize the adjusting devices required in connection with the mounting structure for the workpiece, said latter being the larger and heavier of the two components comprising the grinding wheel-workpiece combination.

(12) To provide apparatus, as aforesaid, wherein the

removal adjustment may conveniently be placed on the and demounted, which mounting and demounting may, if desired, include handling of the workpiece by mechanical means such as an overhead crane or gantry.

(13) To provide apparatus, as aforesaid, which may be either automatically or manually indexed and which a given machine can be readily converted by the operator as desired from one mode of control to the other.

(14) To provide apparatus, as aforesaid, which will impart oscillation to the grinding wheel in the plane of the face surface being ground thereon but will do so without creating wobbling, vibration or other undesired spurious motions in the apparatus.

(15) To provide apparatus, as aforesaid, wherein the oscillation of the grinding wheel is subject to easy amplitude adjustment.

(16) To provide apparatus, as aforesaid, insuring a positive locking of the workpiece in position before the grinding head is permitted to advance into grinding contact with the workpiece.

(17) To provide apparatus, as aforesaid, eliminating brushes or similar devices for transmitting current to a moving workpiece spindle but instead combining the functions of a current transmitting shoe and a brake shoe so that current is transmitted to the spindle only when said spindle is stopped. This assures a minimum of losses, both mechanical and electrical (such as resistive losses in the electrical circuitry or mechanical losses such as that resulting from the dragging of conventional brushes on the spindle of the indexing work holder).

(18) To provide an apparatus, as aforesaid, simple, compact, light weight, and easily adjustable means for effecting the oscillation of the grinding wheel with respect to the workpiece.

Other objects and purposes of the invention will be apparent to persons acquainted with apparatus of this type upon reading the following specification and inspection of the accompanying drawings.

In the drawings:

FIGURE 1 is an oblique, over-all view of apparatus embodying the invention, showing both the typical workpiece and grinding wheel utilized therewith.

FIGURE 2 is a front view of the machine in FIGURE 1.

FIGURE 3 is a side view of said machine.

FIGURE 4 is a cross-sectional central view of the workpiece spindle taken on the lines IV—IV of FIGURE 2.

FIGURE 5 is a somewhat enlarged side view of the grinding wheel supporting section shown in FIGURE 1.

FIGURE 6 is a rear view of the grinding wheel support section showing some of the supporting means for the grinding wheel spindle.

FIGURE 7 is a front, partially broken, view of the grinding wheel supporting means, showing particularly some of the support mechanism for the grinding wheel spindle.

FIGURE 8 is an enlarged side elevational view of the workpiece locating finger shown in FIGURE 1.

FIGURE 9 is a central sectional view of the locating device shown in FIGURE 8.

FIGURE 10 shows a schematic diagram of the apparatus by which the operation thereof can be readily followed.

FIGURE 11 shows a section taken on line XI—XI of FIGURE 4.

FIGURE 12 is a somewhat schematic view taken from the rear of the machine and indicating one means for automatically indexing the workpiece.

FIGURE 13 is a schematic of the electrical circuitry by which the apparatus is operated when same is used for automatic operation.

FIGURE 14 shows a top view of the workpiece holding means.

FIGURE 15 is a detail showing the wheel reciprocating

ing mechanism on a larger scale than shown in FIGURE 6 and in a different position of adjustment.

GENERAL DESCRIPTION

In general, the apparatus comprises a workpiece supporting section having a rotatable spindle for reception of the workpiece together with spindle supporting means which are adjustable both parallel to and transversely of the spindle axes by any convenient adjusting means such as manually rotated screws. Suitable brake means, preferably a cone-type brake, is arranged for engagement of the spindle during each dwell, which includes each grinding period, between successive indexing operations for same nonrotatably with respect to the frame of the machine. Said brake is preferably made of good electrically conductive material for, simultaneously with the braking function, the introduction of electrical current therethrough to the workpiece supporting spindle in connection with the operation of the apparatus.

A grinding wheel head supporting section is mounted for pivoting with respect to said workpiece supporting section around a vertical axis which axis passes close to the areas to be ground when same are in grinding position. A rotatable grinding wheel and head means supporting same are mounted in a wheel head section and are arranged in a hanger suitable for effecting both oscillating movement of said grinding wheel in the plane of its face and angular adjusting movement of the grinding wheel around a substantially horizontal diameter thereof.

Such grinding wheel support means and workpiece support means will enable the grinding wheel to be positioned in any position required for proper grinding of the work surface, particularly for each of the three surfaces usual in connection with face milling cutter teeth, as well as proper positioning of the workpiece itself with respect to the grinding wheel.

A locator device is provided for bearing against one of the cutter teeth, preferably the tooth being ground at a given moment, or other reference means, and arranged with suitable controls for locking the workpiece spindle and advancing the grinding head when and only when the workpiece surface to be ground is in the proper position for receiving the grinding head.

Further details and advantageous features will be brought out in the hereinafter following description.

DETAILED DESCRIPTION

The embodiment of the invention here selected for illustrative purposes has a base structure 1 which may be fabricated or of cast metal as desired, and which supports at its upper surface a pair of ways 2 and 3. These ways support through cooperating ways 6 and 7 a table 8 on which is rigidly mounted a lower spindle support 9. Suitable mechanism, which can be controlled by a hand wheel 4, is provided for adjusting the table 8 with respect to the base 1 along the ways an upper spindle support 11 is mounted on the lower spindle support 9 through suitable ways, generally indicated at 12 and along which spindle support 11 is adjustable with respect to the lower spindle support by means of the hand wheel 13. The upper spindle support is provided with suitable bearings 102 and 103 (FIGURE 4) in which the spindle 16 is rotatably supported for rotation about a substantially horizontal axis. Suitable means are provided for applying one side of an electric potential onto spindle 16, said means being any convenient type such as that shown in U.S. Patent to Robischung and Sutton No. 3,115,454 or to Fisher and Ward No. 3,176,254 but preferably being as hereinafter further described. The upper spindle support 11 (FIGURES 2 and 3) also carries a slideway 17 in which is supported a slide 18, the latter being held at a selected position in the slideway by any convenient means, such as a set screw or a manually operable clamp 20. At the free end of said slide 18 there is provided a sensing device 19 pivotally supported at 21 on said slide

and terminating at its upper end in a finger 22. Further details of said sensing device will be given below.

The slide 18 is positioned as shown in FIGURE 2 for right-hand cutters. A further slideway 23 is provided on the upper side of the upper spindle support 11 which supports the slide 18 (dotted lines) in position for left-hand cutters, said slide 18 being selectively fixable therein by a set screw or clamp means as desired. The leftward free end of said slide 18 (dotted lines) is provided with means for mounting said sensing device 19 under circumstances discussed below.

Suitable brackets 31 and 32 are mounted on and fixedly with respect to the base 1 for support in this embodiment of a post 33. The grinder support base 34 is pivotally connected to the post 33 by the bearing 36, 37 and 38. One of said bearings, such as the bearing 38, is preferably split and clampable by suitable means such as the threaded rod 39 so that the grinder base support 34 may be fixed in predetermined relationship as desired to the post 33. Preferably, the upper part of said post 33 is threaded and a nut 41 is cooperable with said threads and rotatable by suitable means such as a hand wheel 42 whereby the entire grinder support base 34 may be vertically adjusted as desired with respect to the base 1. A pointer 43 is preferably carried on the upper end of a rod 44 which in turn is carried fixedly with respect to the base 34, said pointer 43 cooperating with a suitable scale, such as a degree scale carried on a disk 46, whereby to indicate the angular position of the grinder support base 34 with respect to the machine base 1. The grinder support base 34 supports at its upper end a support plate 51 (FIGURES 5 and 6) which acts through suitable ways, generally indicated at 52, to support a grinder base plate 53. The base plate 53 is arranged to support the grinder spindle in any convenient manner by which same can be caused to oscillate and which will be otherwise adjustable as desired. In the particular embodiment herein shown, the base 53 has a pair of uprights 54 and 56, which are connected through bearings 57 and 58 to support a hanger 59. The hanger consists of a pair of uprights 59A and 59B and a crossbar 59C. In the crossbar there is provided pivot means 61 from which is suspended by an intermediate hanger 62, the bearing 63 of the grinder spindle.

Any suitable reciprocal means can be provided to effect oscillation of the bearing structure 63 around the pivot 61. One particularly advantageous unit for this purpose is shown in operation position FIGURE 6 and in greater detail in FIGURE 15. Referring to these figures there is provided a mounting frame 201 arranged for rotatable movement around the horizontal axis, the bearings supporting same being fixed with respect to a frame structure 202 which in turn is fixed with respect to the hanger 59 (FIGURE 15). Said mounting frame is adjustably rotatable through suitable means, such as a gear and worm combination (not shown but contained within the housing 205) operable through the shaft 203 from the knob 204. A slider 206 is reciprocally mounted between suitable guides 207 and 208 for a reciprocation in response to reciprocation of a rod (not shown) operable from a pressure cylinder 64. Suitable means are provided for effecting reciprocation of said rod, such as by the poppet bleeder valves 212 and 213 operable by the lug 214 riding on the slider 206. Alternate actuation of said poppet valves by said lug 214 may then act through conventional control means, not shown, for effecting alternate energizing of the opposite ends of said pressure cylinder 64 and consequent reciprocation of said rod and slider 206.

A pitman 67 is pivoted at 66 in a convenient manner to the slider 206 and is pivoted at 68 in a convenient manner, as through a mounting lever 69, to the oscillatable frame structure 62.

In the position shown in FIGURE 6 the entire reciprocation of the slider 216 is transmitted to the pitman 67 and thereby the maximum amplitude of oscillation of the

grinding wheel carrier 62 is obtained. However, with the mounting frame 201 rotated a desired amount through the adjusting knob 204 such as into the position shown in FIGURE 15, it will be apparent that only a component of the reciprocating motion of said slider 206 will be effective to reciprocate said pitman and the amplitude of oscillation of the frame 62 will be diminished. By rotating the mounting frame 201 sufficiently so that the direction of reciprocation of said slider 206 is at right angles to the centerline of the pitman 67, said amplitude of oscillation will be reduced to, or nearly to zero, as desired.

Any convenient means, such as a bolt 72 (FIGURE 5), may be fixed to the upright 59B and extend outwardly through a suitable slot 73 in the casing 70 for tilting the entire hanger 59 as desired about the common axis of the bearings 57 and 58. This will determine the angularity of the axis of the grinder spindle with respect to the horizontal. Suitable reciprocating means, including a cylinder 74, is provided for effecting advancement and retraction of the table 53 in response to suitable input signals for suitable control of the pressure applied to the said cylinder 74. A stop 178 limits the advancement of said table. Such devices are common and need no detailing, a typical one being found for conventional equipment in patent to Bass et al., No. 2,988,858.

A suitable spindle is rotatably received into the bearing structure 63 and is arranged for receiving a grinding wheel G at one end thereof and for receiving the cathode connection of the electrical potential at the other end thereof, such as through brushes of which one is shown at 76. The bearing 63 may also include a motor (not shown except as indicated in FIGURE 10) for effecting rotation of said spindle as set forth in the above-mentioned Patent No. 3,115,454.

Returning now to further details of the sensor 19, attention is called to FIGURES 8 and 9, in which an enlarged elevation thereof is shown, together with a corresponding cross-sectional view thereof. In this embodiment, there is provided a clamp 81 receivable onto a shaft 82 which is supported by suitable bearings 83 in a receptacle 84, the said receptacle being mounted rigidly onto one or the other of the slides 18 and 24 (FIGURE 1) depending upon the direction of rotation of the workpiece.

The clamp 81 supports a tubular housing 86 in which there is slideably arranged a core 87. Said core 87 rigidly supports the finger 22. The lower end of the core 87 is operably in contact with a limit switch 88 and an electrical cable 89 connects through the bottom of the housing 86 to said switch. A further switch 156 schematically indicated in FIGURE 10, is fixedly mounted with respect to the receptacle 84 for opening and closing upon rotation of the shaft 82. In the present arrangement, the switch 156 is normally closed and opens upon counterclockwise (FIGURE 8 or 10) pivoting of the finger 22.

The clamp 81 is adjusted by the screws 81A and 81B to position the housing 86 to locate and lock finger 22 at a height to contact, or "feel" the adjacent surface of a cutter blade located at a level with the horizontal centerline through the cutter body. The upper end of finger 22 is arranged to contact the lower side of a selected tooth, preferably the tooth being ground, when said tooth reaches a position within a few thousandths of an inch of the desired grinding position. Further rotation of the workpiece in a counterclockwise direction (FIGURE 1) then causes the tooth or cutter insert 91 to bear downwardly against the finger 22 which in turn bears down against the switch 88. This signals the operation on the work spindle brake and effects the commencement of a grinding sequence.

Referring now to FIGURE 4, the details of one form of means for mounting the workpiece spindle are shown. Here the workpiece spindle 101 is mounted through suitable bearings 102 and 103 into the upper workpiece spindle support means 11. Said spindle is of uniform

diameter throughout most of its length and is hollow. The portion adjacent the workpiece is interiorly converging as indicated at 104 and is thereafter of uniform diameter as indicated at 106. A rod 107 extends through the portion 106 and has at one end the threaded unit 108 for threadedly engaging the workpiece by means of a tapered mounting arbor 105 and at the other end a hand wheel 109, preferably knurled for rotating same. Rotation of the knurled hand wheel 109 will turn the thread 108 in corresponding threads in the tapered arbor and draw the hub thereof tightly into the tapered opening 104 whereby the said tapered arbor is held firmly in and with respect to the spindle 101. A clutch hub 111 is fixed rigidly onto the spindle 101 as is also a suitable drive gear 112 when engaged by suitable rotation of the nut 110 for automatic indexing. Alternatively, if the workpiece is to be rotated manually, then the gear 112 is declutched by opposite rotation of the nut 110.

Electric power may be applied to spindle 101 in any desired manner. One effective way of so doing is to combine the contact shoe 113 for functioning also as a brake as set forth in the following.

As shown in the drawing (FIGURE 4), a collar 114 is fixed to the spindle 101 by suitable means, such as suitable threading, and locked in place by a set screw 116, and supports on and rotatable therewith, a ring 117, preferably made of conductive material. A toggle arrangement includes the links 121 and 122, the same being pivoted together by actuating yoke 123 (FIGURES 4 and 11). One end of said toggle structure is pivoted at 124 to the ring 117 and is pivoted at its other end 126 to the combined brake and shoe ring 113. Actuation of the actuating yoke 123 of the apparatus in one radial direction will draw the shoe 113 back and away from contact with the exteriorly tapered surface 128, and movement of the actuating yoke 123 in the other radial direction will move the ring 113 solidly against the tapered surface 128 for the twin purposes of effecting a solid electrical contact between and for providing a braking of the spindle 101. Said actuation of the actuating yoke 123 may be carried out automatically or manually as desired. In this embodiment said actuating yoke is operated either manually by the handle 221 or automatically by the piston 222 in the cylinder 223 with return force provided by the spring 224.

In FIGURE 12 there is shown somewhat schematically one form of automatic means for indexing the workpiece. In this apparatus a cylinder 226 is arranged to drive a rack 227 and said rack engages the gear 112 (FIGURES 12 and 4) which is mounted on and for rotation with the spindle 101 (FIGURE 4). Thus, reciprocal movement of said rack 227 in a selected direction will effect corresponding movement in a selected rotative direction of the spindle 101 and the workpiece carried thereon. Cam pins 228 and 229 are arranged on said rack for opening the switch 154 upon movement of the rack 227 a predetermined distance away from its starting position in either direction. The function of this switch will appear hereinafter in the detailed description of operation. A suitable source S of pressure fluid is connected through solenoid valves 182 and 183 to opposite ends of said cylinder 226 for actuation of same in one direction or the other as desired.

OPERATION

The operation of the apparatus of the present invention has been somewhat indicated above, but will be set forth fully to insure a complete understanding of the invention.

The operation will first be summarized with reference to FIGURES 1-12 of the drawings and will then be examined in more detail with respect to the circuit diagram shown in FIGURE 13 of the drawings.

The workpiece, such as the face milling cutter, partially indicated at W in FIGURE 4, is positioned and held on the arbor 105 in any convenient manner. In this embodiment the workpiece is held in place by the cap screws

W-1 and W-2 and centered by the bushing W-3, as shown. The arbor is drawn tightly into the opening 104 by rotation of the hand wheel 109. Next, the grinding wheel is adjusted to provide a grinding operation in the desired plane. In so doing, the grinding wheel carrying means will be swung around the post 33 as desired, or it may be adjusted on the bearings 57 and 58, usually both. The stops 75 and 178 (FIGURES 5 and 10) are fixed and hence need no adjustment, the adjustment governing the relative approach of the workpiece and grinding wheel being found in the adjustment along the slide at 12 by the hand wheel 13 and/or slides 6 and 7 by hand wheel 4. The end 64A (FIGURE 6) of the oscillation means 65 will be located appropriately to select the desired amount of oscillation.

The finger 22 is adjusted horizontally as needed with the adjustment of slide 18 (FIGURE 2) in the slide guide 17 and sleeve 84 (FIGURE 9) through hole in slide 18. Vertical adjustment described hereinabove with respect to clamp 81 may be needed to orient the cutter blade in horizontal alignment with the axis of the work supporting spindle.

Regardless of whether the workpiece is manually or automatically indexed, the brake 113 is released by lever 221 (FIGURES 11 and 14) and the workpiece is rotated counterclockwise, when grinding right-hand cutters as seen in FIGURES 1 and 10, to urge the finger 22 downwardly and bear against the limit switch 88. This effects forward feeding of the grinding wheel. At the same time, the cylinder 223 is de-energized to move the yoke 123 appropriately to act through the toggle members 121 and 122 to move the brake cone 113 forwardly by pressure of spring 224 to clamp the spindle 101 against rotation and simultaneously to effect a good electrical connection therewith. The wheel moves forwardly, in response to energizing of cylinder 74, into contact with the surface to be ground and an appropriate grinding operation is carried out. It will be understood that during such grinding operation, suitable power is supplied to the wheel spindle and electrolyte is applied to the grinding area by means, not shown, but all in a manner fully set forth in various prior art patents, such as the U.S. Patent to Keeleric No. 2,826,540 or the U.S. Patent to Bass et al. No. 2,922,258.

When the preset amount of stock has been removed from the cutter element being ground, which may be determined by the closing of the microswitch 164 by the stop 75 (FIGURE 5) upon appropriate advancement of the grinding wheel, the energizing of cylinder 74 is reversed and the grinding wheel is retracted. However, the cylinder 74 is not reversed until a time delay in the circuit hereinafter discussed lets the wheel head advance the stop 178 against stop 179 (FIGURE 5).

The combined brake cone 113 is now released and the spindle 101 is caused to rotate either automatically or manually as desired until the next cutter element indexes to, and engages, the finger 22 and the cycle is ready to be repeated.

Inasmuch as a single operation of the electrolytic grinding means will produce a completely finished operation of the selected surface of a cutting element, one revolution of the milling cutter will effect a complete grinding sequence of the faces of the cutting elements contacted by the grinding wheel during such revolution. After that revolution is completed, the grinding wheel then may be adjusted to contact the second selected surface of the cutting elements and the procedure again repeated for said last-named surface. Subsequent surfaces of the cutter elements, if any, are similarly treated until the cutter is fully ground as desired.

Turning now to FIGURE 13 of the drawings and with continuing reference to the other figures, especially to FIGURE 10, a more detailed examination of the operation of the machine of the present invention will be set forth. The circuitry of FIGURE 13 is, of course, only illustrative of one particular circuitry for carrying out the

operations of the invention and the invention is by no means limited thereto.

The incoming power lines 131, 132 and 133 are connected to the primary winding of a suitable transformer 134 and through appropriate starting circuitry to motors 136 and 137, one of said motors being the motor contained within the bearing housing 63 for driving the grinding wheel G and the other motor being the motor driving the pump effecting circulation of the electrolyte. Said electrolyte is circulated and directed between the grinding wheel and the workpiece in the manner and for the purposes set forth in the patent to Keeleric No. 2,826,540. The secondary winding of the transformer 134 constantly energizes the lines 138 and 139 for purposes appearing hereinafter. Closing of the start switch 141 energizes the winding of relay 142 and effects closing of the contacts 142-C thereof. Closing of a selected one of the grinding wheel switches 143 and 144, depending upon the direction it is desired to have the grinding wheel rotate, will in a conventional manner energize the winding of a relay 146 or 147 connected respectively thereto and thereby energize the appropriate one of lock-in contacts 146-C1 or 147-C1 to effect continuous operation of the grinding wheel in one direction or the other for so long as the master switch 150 is permitted to remain closed. Similarly, manual closing of the electrolyte pump switch 148 energizes the lock in relay winding 149 and thereby closes the contact 149-C1 to lock in said circuit and also the contacts 149-C2 to effect energization of the motor 137. With a selector switch 151, by which the apparatus is conditioned for automatic indexing or hand indexing, turned to its automatic indexing position as shown in the drawing, a typical sequence will now be traced. Assuming that the equipment is positioned with the table 53 in its full retracted position, with the wheel 110 tightened against the gear 112 for clamping same solidly in a proper position on and with respect to the sleeve 111 for driving same and with the workpiece positioned so that a tooth thereof bears against the upper end of the finger 22 with sufficient force to close the switch 88, the apparatus is ready to start. Manual closure of the cycle switch 152 energizes the winding of relay 153 whereby to close the contacts 153-C1, 153-C2 and 153-C3 thereof. Since limit switch 154 is held open momentarily by the appropriate one of the cam pins 228 and 229 (to permit instantaneous stopping of the cycle if desired by merely opening the cycle switch 152) the operator must manually keep the switch 152 closed for a predetermined period of operation, such as one indexing cycle, which gives him an opportunity to check the operation of the system before permitting automatic operation to assume control. As soon as the switch 154 is permitted to close, the locking in of the relay 153 which has already taken place will permit release of the manual switch 152. Closure of the contacts 153-C3 energizes the line 155. Simultaneously so long as the stop 75 is away from the switch 164, the same is in the position shown in FIGURE 10 and current flows therethrough and through the normally closed contact 157-C2 to energize the winding of the relay 160. The energizing of said winding closes the contacts thereof, namely 160-C1 causing the wheel head to feed.

With the finger 22 in the position shown in FIGURE 8 the switch 156 is closed and accordingly potential from the line 155 passes through the normally closed contacts 157-C1 to energize the winding of the relay 158. Energizing of the relay 158 closes the contacts 158-C1 to energize the winding of solenoid 183 whereby to energize cylinder 226 in a direction to urge the workpiece W to rotate in a counterclockwise (FIGURES 8 and 10) direction whereby to hold the tooth being ground solidly against the finger 22. This holds the switch 88 closed. Thus, current flows from the junction point 159 through the switch 88 (mechanically closed as above mentioned) and the closed contacts 160-C1 to energize the windings of the relay 161 and the timing relays 162 and 163. Ener-

gizing relay 163 opens switch 163-C1 and de-energizes the brake cylinder 223. This permits the spring 224 to again apply said brake and back the spindle 101 against turning. Energizing of the relay 161 closes the contacts thereof 161-C1 which conducts current to the juncture point 166 and thence through the normally closed limit switch 167 to energize the winding of the solenoid 168. Said solenoid 168 operates an on-off valve 175 supplying a hydraulic pressure fluid to the cylinder 74 and when same is energized as aforesaid the supply of such fluid to said cylinder advances the table 53 toward the workpiece. Simultaneously energy flows from the junction point 166 to the solenoid 169 which supplies further fluid in the same direction to the cylinder 74. This effects a rapid feed to a point close to the working position. At a suitable predetermined distance from the workpiece, the limit switch 167 (FIGURES 5 and 10) is actuated by the cam 170 and the solenoid 168 is de-activated and the supply of pressure fluid from the cylinder 74 is thereby diminished sufficiently to effect a slow final feed of the grinding wheel to the workpiece, this being manually adjustable by a flow control valve (not shown).

As the grinding operation proceeds and the table 53 advances under pressure of the cylinder 74, the actuator 75 contacts the limit switch 164 to move same against the contact 164A (FIGURE 13) and thereby causes the energization of the relay 157 and the timed relay 172 and the de-energization of relay 160 expecting that relay 160 is held energized for a few seconds by the contacts 172-C1 of the timed relay 172. Thus, pressure is held on the feed cylinder for a few seconds further while the positive stop 178 moves against the abutment 179 to provide a definite limit to the forward movement of the grinding wheel. This permits the grinding operation to be completed and any pressure between the wheel and the work due to the resilience of the mechanical equipment to be dissipated.

When the relay 172 times out, the de-energized winding of relay 160 causes contacts 160-C1 to open which de-energizes the coils of the relay 161 and the timed relays 162 and 163. The opening of contact 161-C1 de-energizes the solenoid 169 in valve 175 and causes the retraction of the wheel head including table 53. The retracting of table 53 closes switch 164 to energize the coil of relay 160 to close contacts 160-C1 so that when switch 88 closes relays 161, 162 and 163 will be again energized. When the relay 163 times out, contact 163-C1 will close energizing solenoid 171 which causes the air cylinder 223 to retract the yoke 123 away from the spindle 101 thus releasing clutch contact 113. Subsequently thereto, the relay 162 times out causing contact 162-C1 to close thus energizing coil 181, which causes the contact 181-C1 to close to energize the solenoid 182 which results in oil being supplied under pressure to the proper end of the cylinder 226 to revolve the workpiece blade 91 clockwise away from the finger 22 and open switch 88. The next following blade 91A then causes rotation of shaft 82 which in turn operates limit switch 156 to close contacts 156A to energize the coil of relay 184. The energization of relay 184 causes the contacts 184-C1 to open. This de-energizes relay 157 which results in the closing of contacts 157-C1. As the next workpiece blade 91A following in rotation clears the finger 22, the finger 22 will react to a small spring therein and return to the neutral position thus closing the contact 156-B. This energizes the coil of relay 158 which results in the closing of contacts 158-C1 to cause the energization of solenoid 183 to cause oil to be supplied under pressure to the other end of the cylinder 226 to reverse the rotational direction of the workpieces (counterclockwise) to press the workpiece blade 91A against the finger 22 and again close switch 88. The cycle will now repeat.

Although particular preferred embodiments of the invention have been disclosed above in detail for illustrative purposes, it will be recognized that variations or modi-

fications of such disclosure, which come within the scope of the appended claims are fully contemplated.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An electrolytic grinding device intended primarily for grinding a plurality of successive presented surfaces spaced around a circumference, comprising:

a work supporting spindle and first supporting means for rotatively supporting same for stepwise rotation around a first axis lying in a first plane;

a grinding wheel spindle and second supporting means for supporting same for rotation, said second means being supported with respect to said first means for pivoting around a second axis lying in a second plane which is perpendicular to said first plane, whereby to adjust the axis of said grinding wheel spindle angularly to the axis of the work supporting spindle;

electrical potential means for applying an electrical potential between said spindles;

feeding means effecting relative movement between said spindles whereby the workpiece on said workpiece spindle and the grinding wheel on said grinding spindle will approach each other in a work performing relationship;

control means responsive to and coordinated with the rotative position of said workpiece for actuating said feeding means.

2. The device defined in claim 1 wherein said feeding means effects movement of said grinding wheel spindle toward and away from the workpiece spindle.

3. The device defined in claim 1 wherein said workpiece spindle supporting means comprises a base and a reciprocal carriage mounted thereon together with means effecting reciprocation of said carriage toward and away from the grinding spindle.

4. The device defined in claim 1 including means for additionally moving the axis of said grinding spindle within a plane parallel to said second axis.

5. The device defined in claim 1 including also a sensing device comprising a mechanical finger positioned for engagement by a predetermined portion of the workpiece and operative in response to pressure by said workpiece thereon for initiating a grinding operation.

6. The device of claim 1 wherein said first plane is horizontal and said second plane is vertical.

7. The device defined in claim 1 wherein said second plane is positioned vertically and wherein said workpiece spindle is supported at one end thereof and has a free end for the reception and support of said workpiece and wherein said free end terminates in a plane parallel to said second plane and which is substantially coincident with the corresponding side of said base, whereby the workpieces may be installed onto and removed from the workpiece spindle without the necessity of lifting same appreciably inwardly of said side of the base.

8. The device defined in claim 1 wherein said sensing device consists of a finger positioned substantially parallel with said second plane and located to engage the one face of a cutting element which is to be ground, and wherein the means to support the sensing element includes a limit switch, said limit switch being adjusted for closing the contacts in response to a relatively light pressure applied thereto by rotation of said workpiece against said sensing unit, whereby the operator is assured that grinding action will commence only when a tooth to be ground is seated solidly against said sensing unit.

9. The device defined in claim 1 wherein said electrical potential means includes a brake shoe arranged for engaging said workpiece spindle in braking relationship therewith and arranged for simultaneously conducting electrical current to said workpiece spindle.

10. A device defined in claim 1 wherein said sensing device consists of a finger positioned substantially paral-

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1. A grinding device comprising:
 a workpiece spindle and first support means for rotatively supporting same for stepwise rotation around a first axis lying in a first plane;
 a grinding wheel spindle and a second support means for supporting same for rotation, the second support means being supported with respect to the first support means for pivoting around a second axis lying in a second plane which is perpendicular to the first plane whereby to adjust the axis of the grinding wheel spindle angularly to the axis of the workpiece spindle;

11. The device of claim 1 wherein said feeding means includes reciprocating means effecting reciprocation of said grinding spindle toward and away from said work performing relationship and a positive stop or said reciprocating means positively locating a position representing the maximum advance of said spindle during said work performing relationship, position sensing means sensing the approach of said spindle into said last-named position and causing reversal of movement thereof out of said position, said workpiece being held fixedly in a given position with respect to said work location throughout the entirety of a grinding sequence.

12. The device defined in claim 11 including also means for adjusting the workpiece with respect to said spindle prior to the commencement of a grinding sequence whereby to govern the depth of cut to be effected by a given work performing operation.

13. The device defined in claim 1 wherein said position sensing means is positioned for activation prior to contact of the positive stop means by said reciprocating means together with means holding said reciprocating means energized in a feeding direction for a period of time slightly after the energizing of said position sensing means, whereby the grinding wheel feeding means will be held against said positive stop and the grinding operation continues until all resilience in said grinding device has been dissipated.

14. The device defined in claim 1 wherein said sensing device consists of a finger positioned substantially parallel with said second plane and locatable in a first position in the path of the cutting elements to be ground, said finger being movable upon engagement therewith of a cutting element upon rotation of said workpiece to a second position and a switch operated by said finger to first and second positions by movement of said finger respectively to its first and second positions and circuitry coordinated with said control means and responsive to said first position of said switch for permitting a grinding cycle to take place including advancement of said workpiece and responsive to the second position of said switch for terminating an advancing movement of said workpiece, causing the urging of said cutting element against said finger and the initiating of a new grinding cycle.

15. An electrochemical grinding device intended primarily for grinding a plurality of successively presented surfaces spaced around a circumference of a workpiece, such as a milling cutter, comprising:

- a workpiece spindle and first support means for rotatively supporting same for stepwise rotation around a first axis lying in a first plane;
- a grinding wheel spindle and a second support means for supporting same for rotation, the second support means being supported with respect to the first support means for pivoting around a second axis lying in a second plane which is perpendicular to the first plane whereby to adjust the axis of the grinding wheel spindle angularly to the axis of the workpiece spindle;

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electrical potential means for applying an electrical potential between the spindles;

feeding means effecting reciprocating movement of the grinding wheel spindle toward and away from the workpiece spindle for causing the axial end face of the grinding wheel to approach and engage the workpiece in a work performing relationship;

means for supplying electrolyte to the end face of the grinding wheel for permitting electrochemical grinding of the workpiece; and

control means responsive to and coordinated with the rotative position of the workpiece for actuating the feeding means.

16. A grinding device according to claim 15, wherein the feeding means effects reciprocating movement of the grinding wheel spindle in a direction parallel to a third plane containing the rotational axis of the grinding wheel whereby the end face of the grinding wheel moves toward and away from the workpiece.

17. A grinding device according to claim 16, wherein the feeding means includes reciprocating means effecting reciprocation of the grinding spindle toward and away from the work performing relationship and a positive stop for positively locating a position representing the maximum advance of the grinding spindle during the work performing relationship and position sensing means sensing the approach of the grinding spindle into the last-named position and causing reversal of movement thereof out of the position, the workpiece being held fixedly in a given position with respect to the work location throughout the entirety of a grinding sequence.

18. A grinding device according to claim 17, wherein the position sensing means is positioned for activation prior to contact of the positive stop means by the reciprocating means together with means holding the reciprocating means energized in a feeding direction for a period of time slightly after the energizing of the position sensing means, whereby the grinding wheel feeding means will be held against the positive stop and the grinding operation continues until all resilience in the grinding device has been dissipated.

19. A grinding device according to claim 15, wherein the electrical potential means includes a brake shoe arranged for engaging the workpiece spindle in braking relationship therewith and arranged for simultaneously conducting electrical current to the workpiece spindle.

20. A grinding device according to claim 16, further including adjustment means for permitting the rotational axis of the grinding wheel spindle to be angularly adjusted in a plane substantially transverse to a horizontal diameter of the grinding wheel.

21. A grinding device according to claim 15, further including drive means for effecting angular oscillation of the grinding wheel within a plane substantially transverse to the rotational axis thereof, the drive means further including a control mechanism for permitting adjustment of the amplitude of oscillation of the grinding wheel.

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