

[54] **END MILL GRINDER**

[75] Inventor: **John Robert Southland**, Arcadia, Calif.

[73] Assignee: **Omark Industries, Inc.**, Portland, Oreg.

[22] Filed: **May 6, 1971**

[21] Appl. No.: **140,972**

Related U.S. Application Data

[63] Continuation of Ser. No. 717,119, March 29, 1968, abandoned.

[52] U.S. Cl.51/96, 51/225, 51/234

[51] Int. Cl.B24b 7/00, B24b 9/00, B24b 3/06

[58] Field of Search.....51/96, 124, 219, 225, 234, 51/216.5, 216.6

[56] **References Cited**

UNITED STATES PATENTS

748,651 1/1904 Reimann51/219

1,052,073	2/1913	Mallory	51/219
1,674,224	6/1928	Rabut	51/219
2,421,358	5/1947	Sneva	51/225
2,494,825	1/1950	Melin	51/96
2,796,703	6/1957	Bushey et al.	51/219 X
3,040,480	6/1962	Winslow et al.	51/219 X
3,209,493	10/1965	Houser	51/219 X

Primary Examiner—Othell M. Simpson

Attorney—Forrest J. Lilly

[57] **ABSTRACT**

A production type machine is designed to grind end mills at a high rate while maintaining rigid standards of accuracy of dimension. Adjustments are quickly and easily made for different profiles of the ground face, the number of flutes on the mill, the size of the end mill, and so on. Operation of the apparatus is fully automatic once the grind cycle is started, after necessary adjustments are made, as only the loading and unloading operations are manually performed.

21 Claims, 31 Drawing Figures

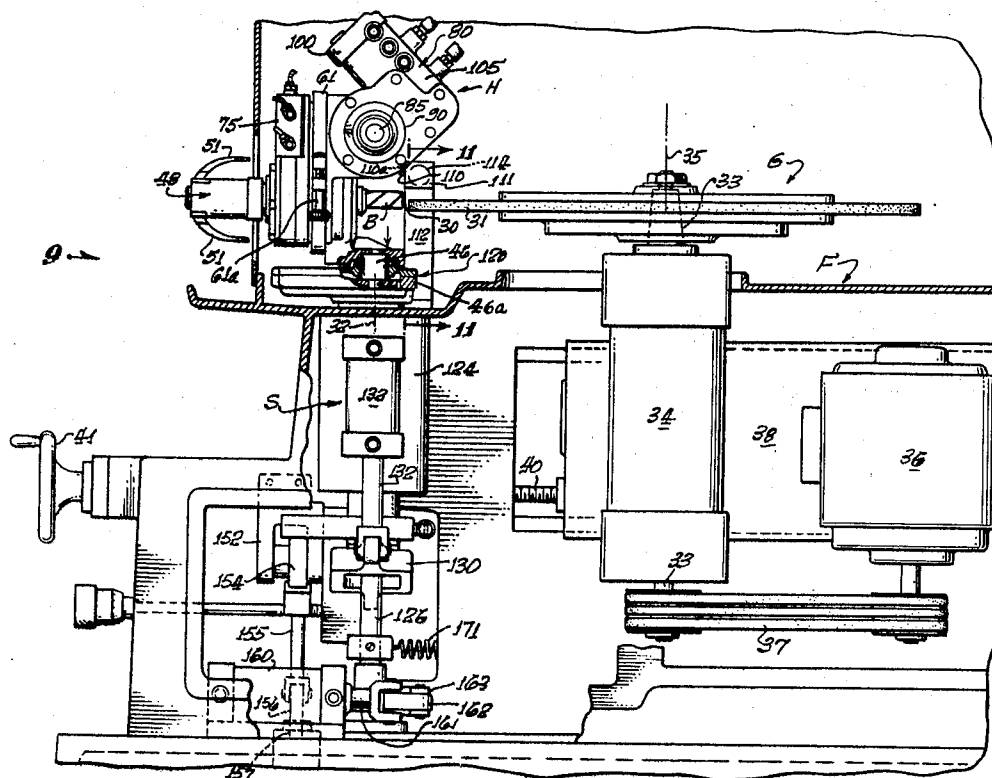


FIG. 1.

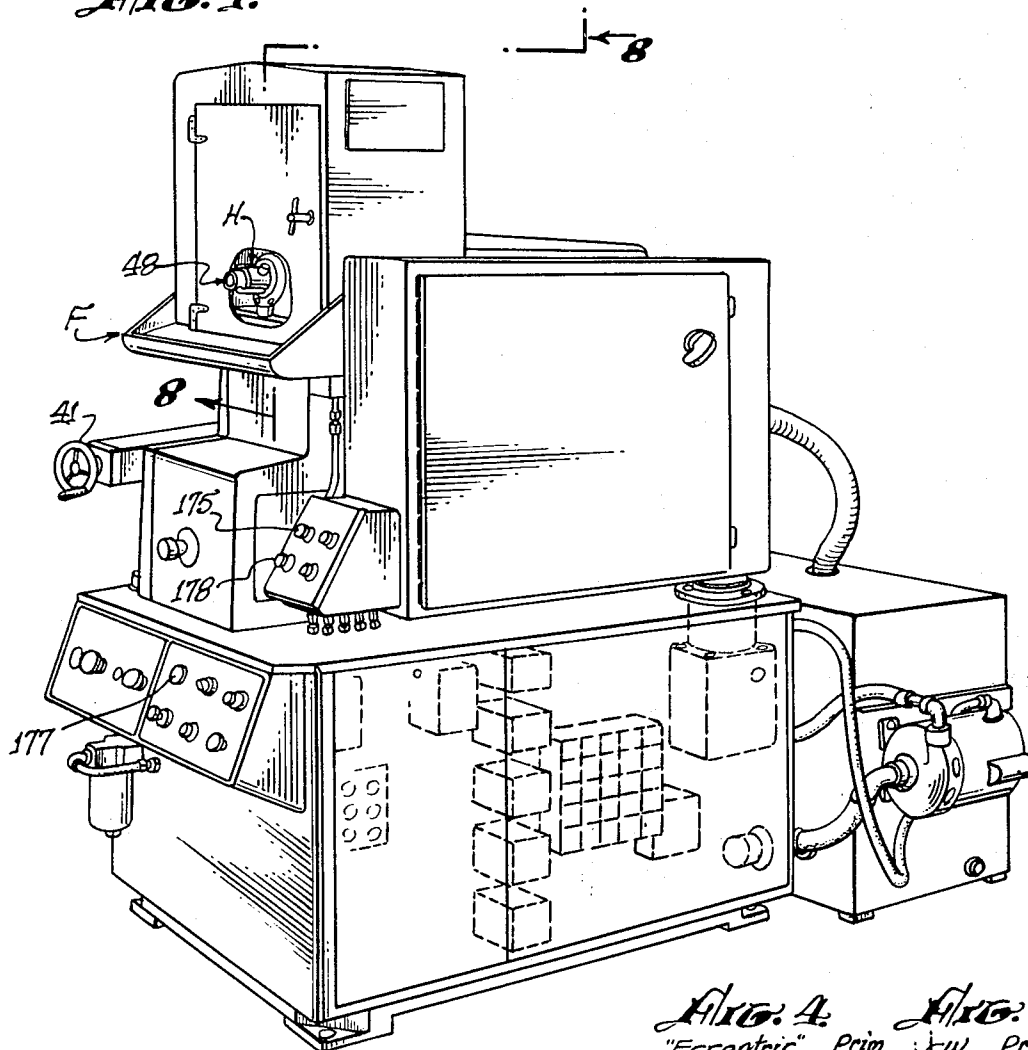


FIG. 2.

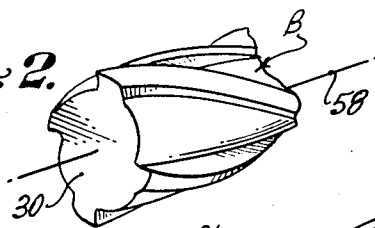


FIG. 3.

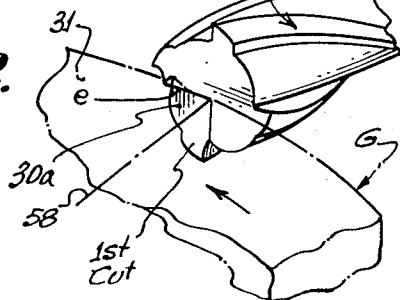


FIG. 4.

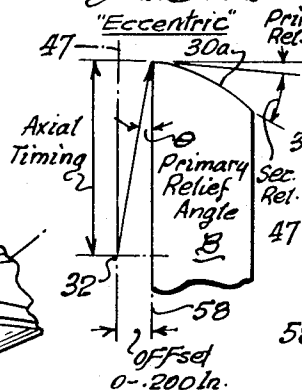
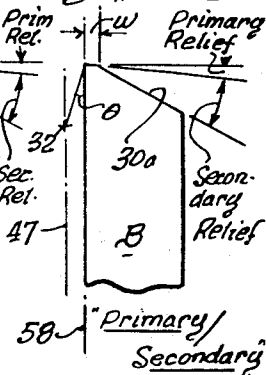


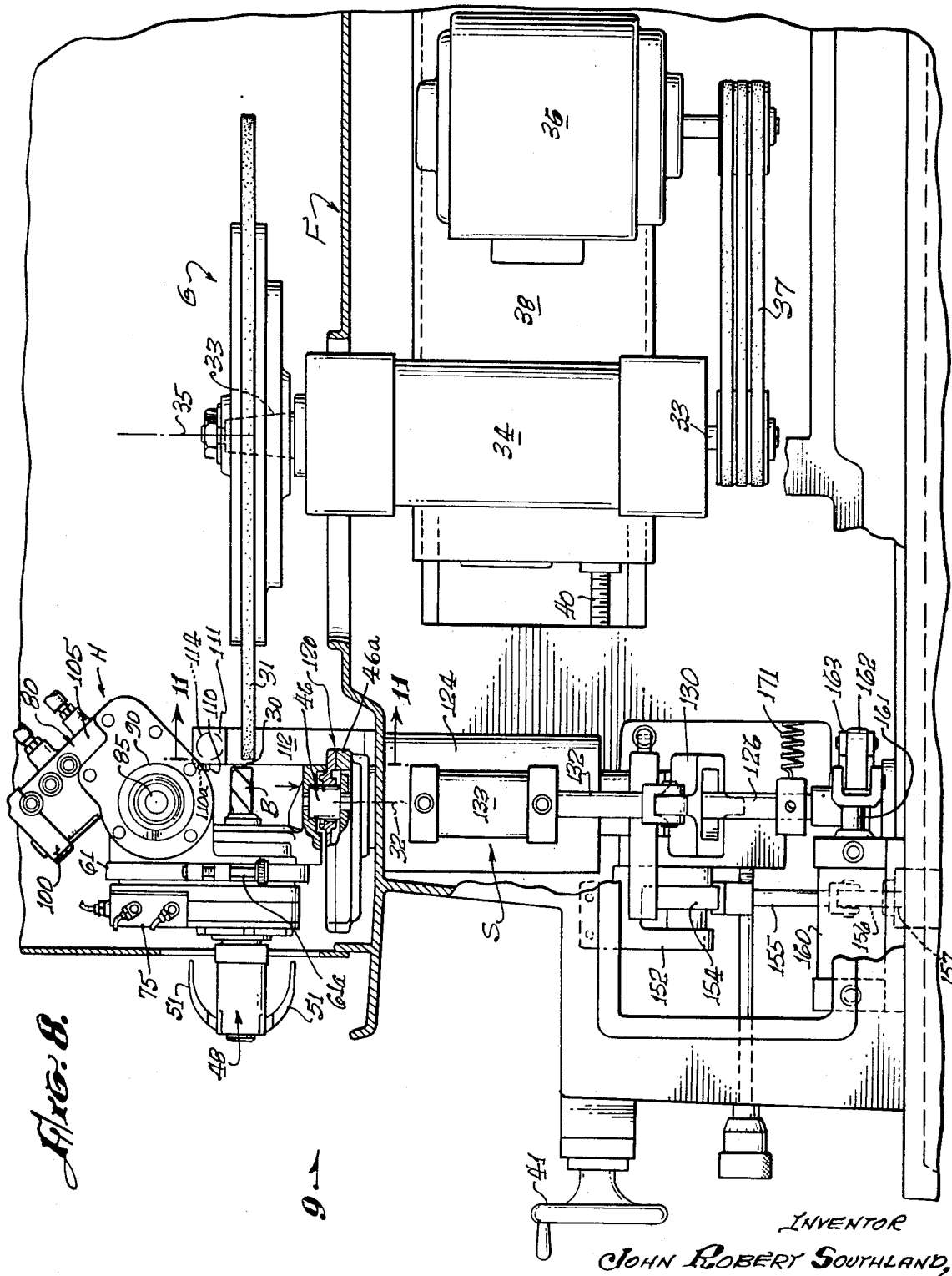
FIG. 5.

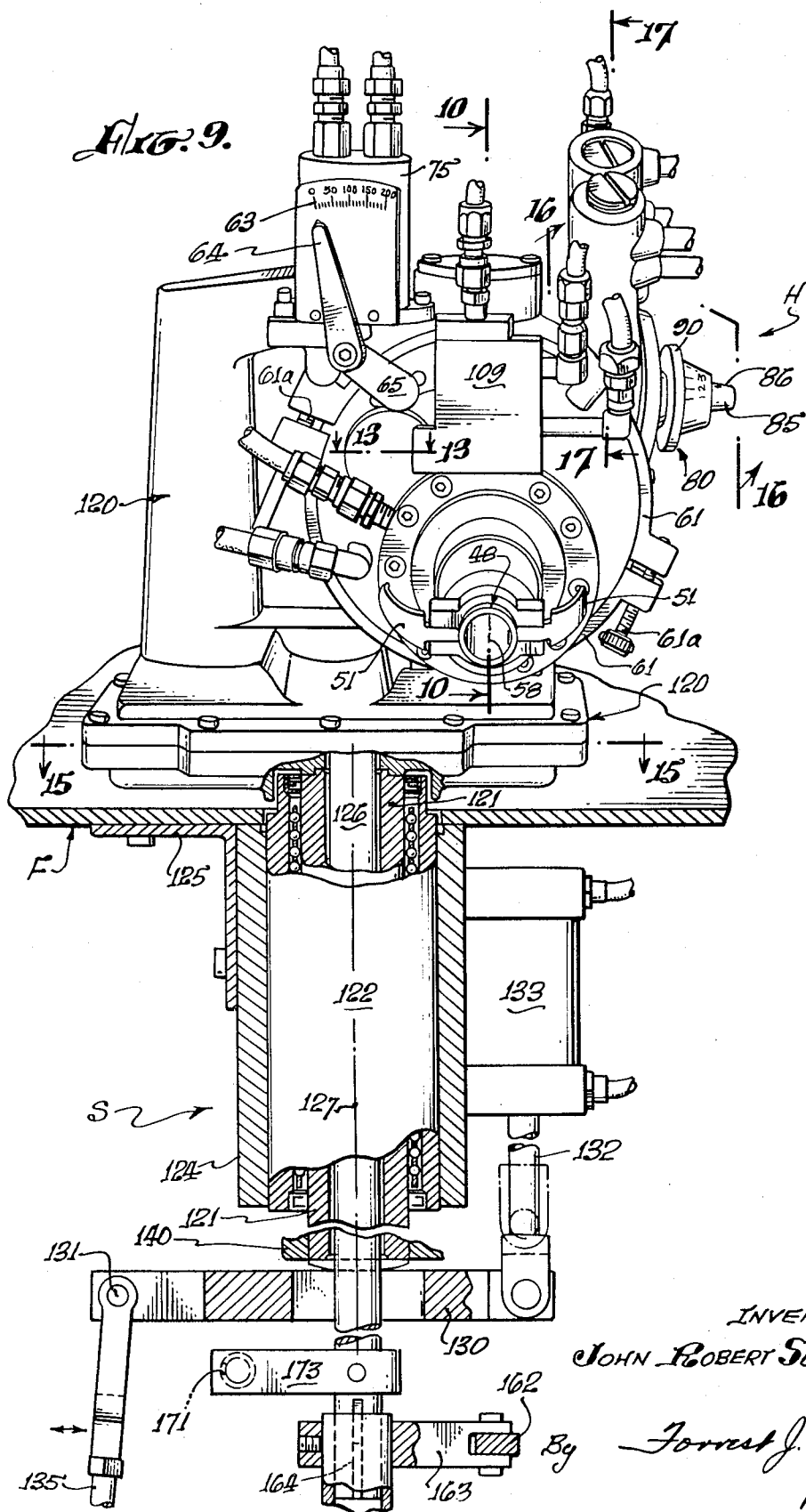


INVENTOR.

JOHN ROBERT SOUTHLAND,

By *Forrest J. Lilly*
ATTORNEY.





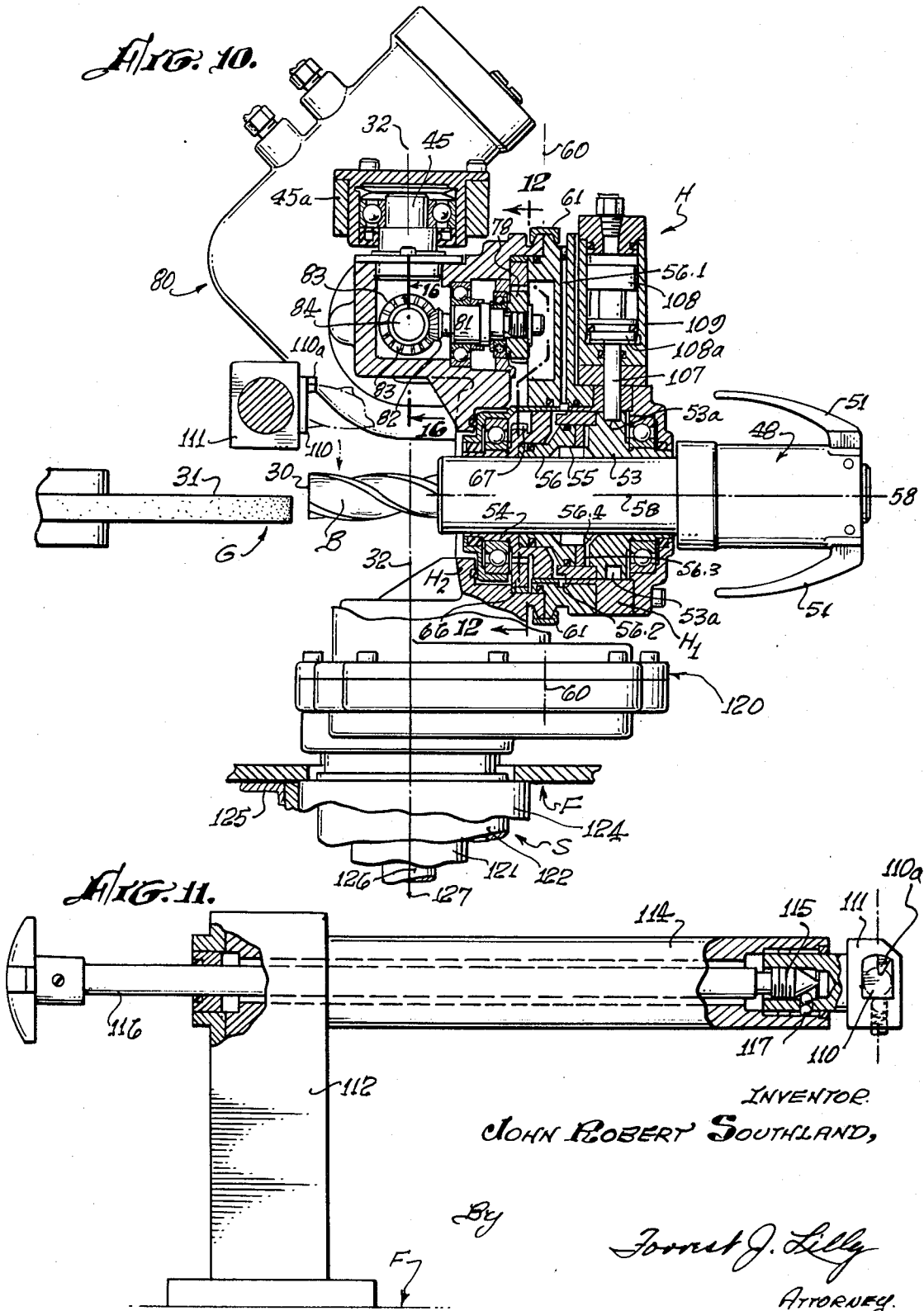


FIG. 10A.

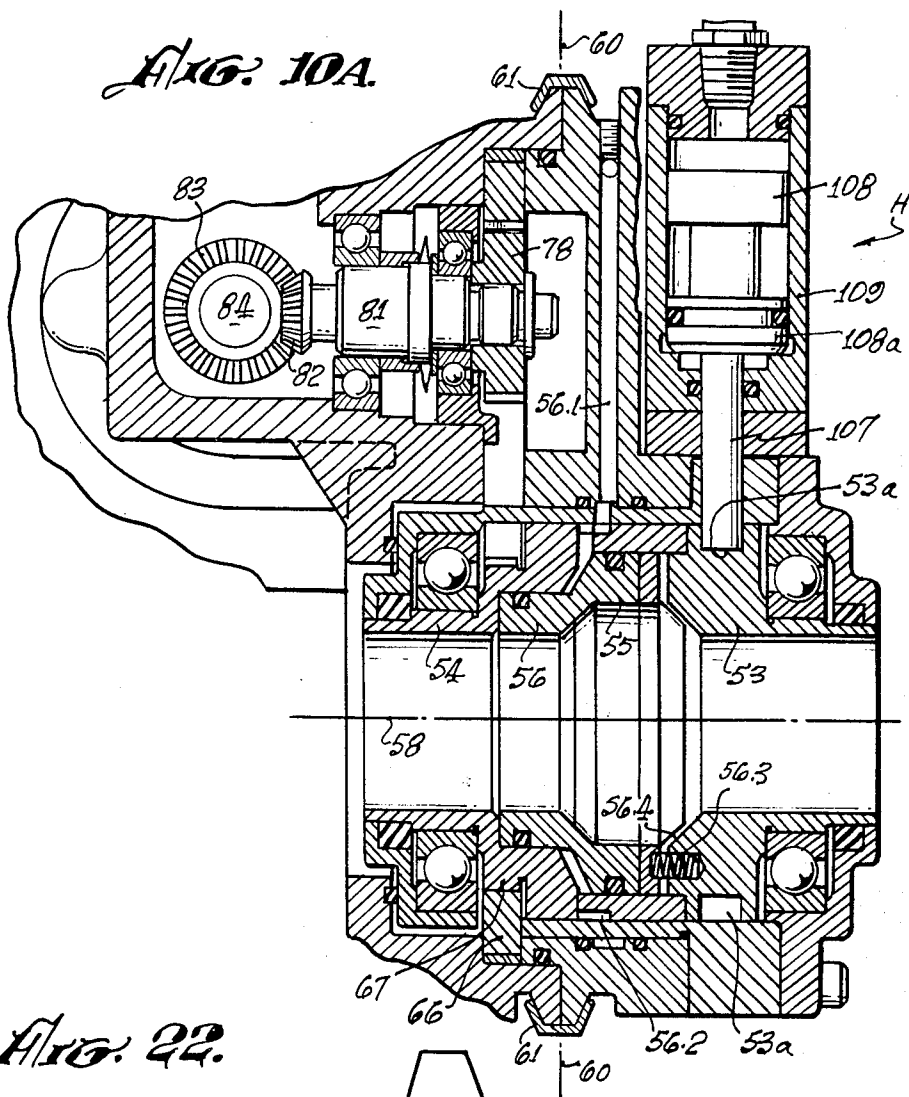
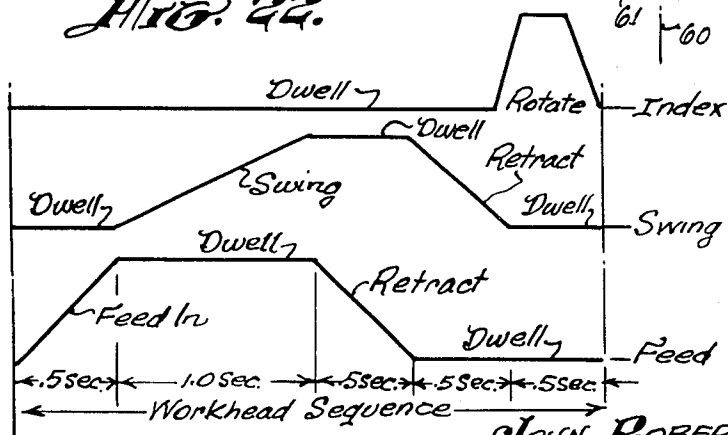


FIG. 22.



INVENTOR.

JOHN ROBERT SOUTHLAND,

By

Forrest J. Lilly
ATTORNEY.

Fig. 12.

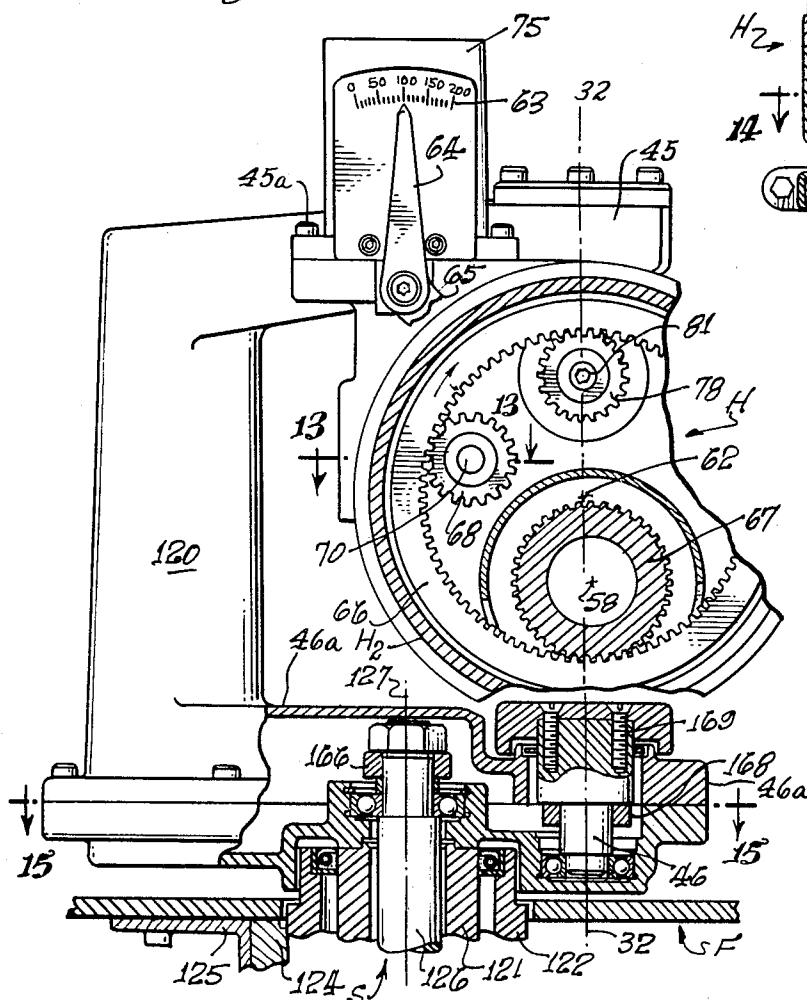


Fig. 13.

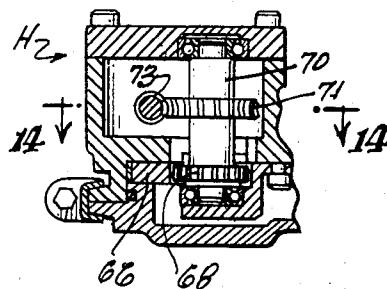


Fig. 14.

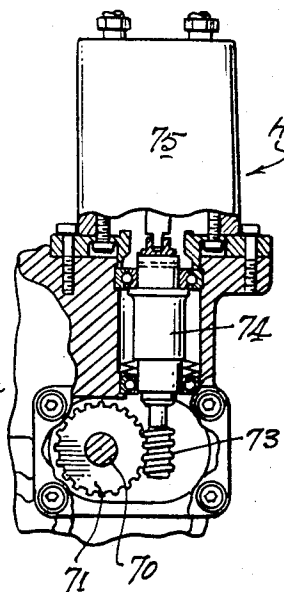
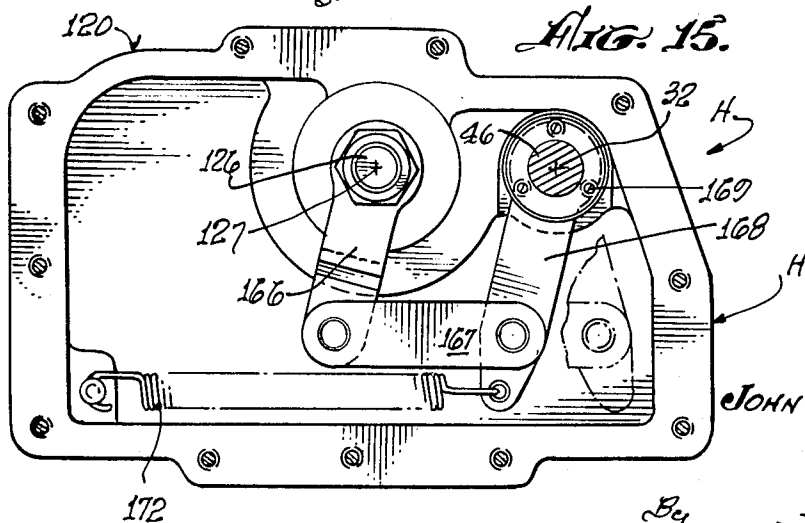
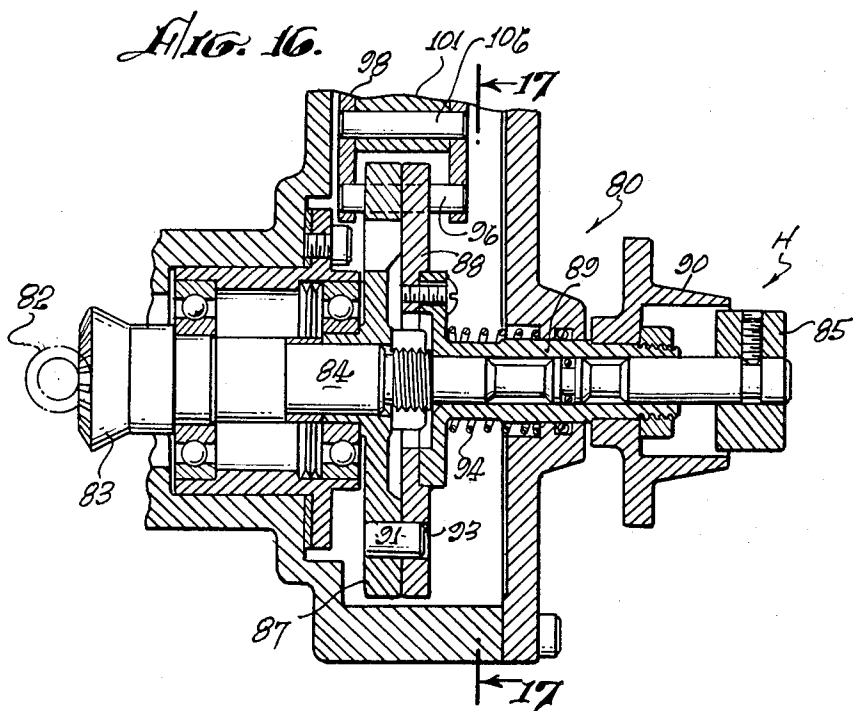
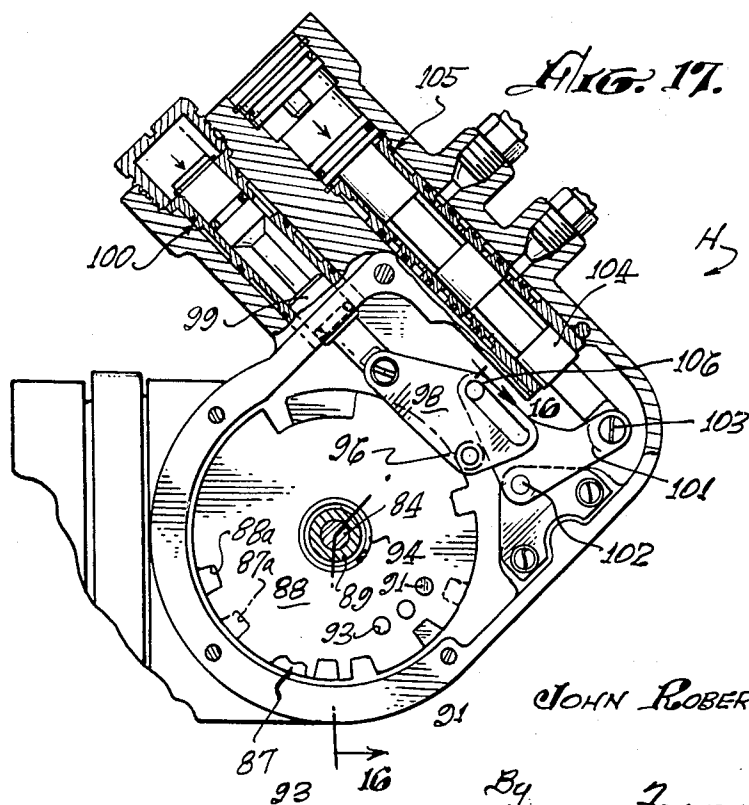


Fig. 15.



INVENTOR.
JOHN ROBERT SOUTHLAND.

By *Forrest J. Lilly*
ATTORNEY.

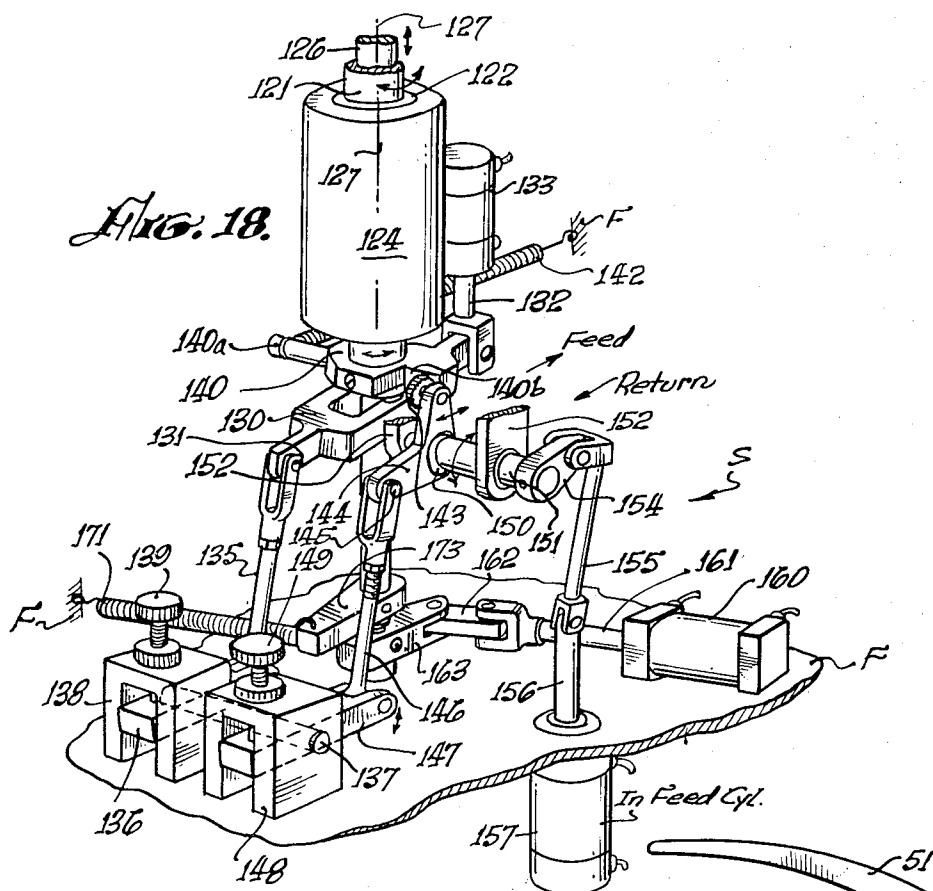
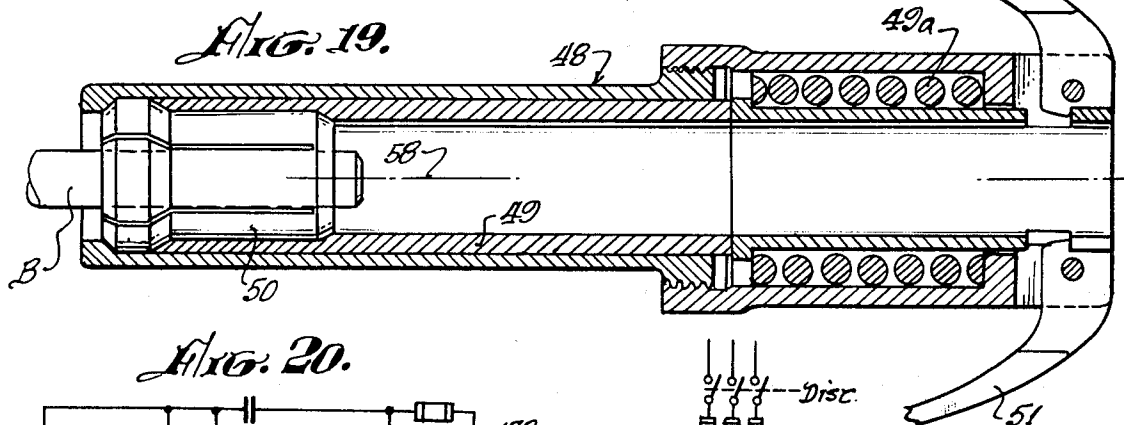
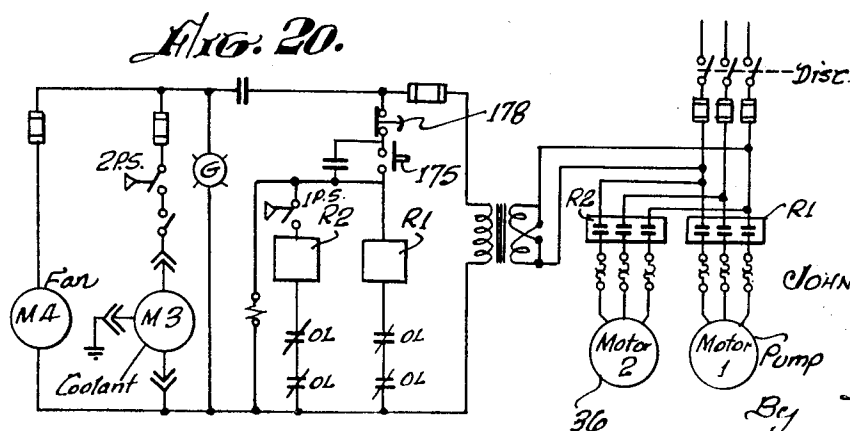


INVENTOR.

JOHN ROBERT SOUTHLAND,

By

Forrest J. Lilly
ATTORNEY.



INVENTOR.
JOHN ROBERT SOUTHLAND,

Forrest J. Lilly
ATTORNEY.

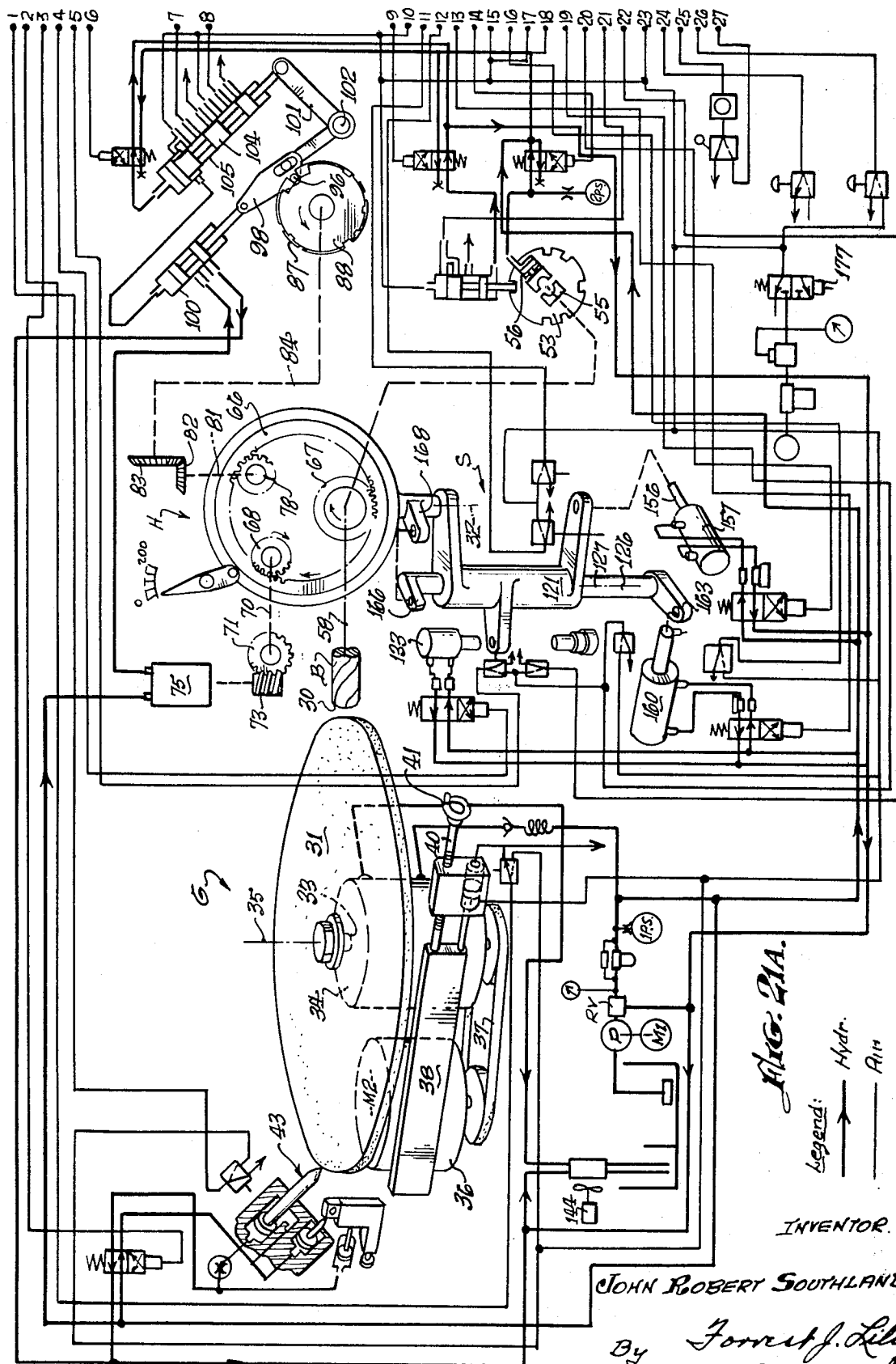
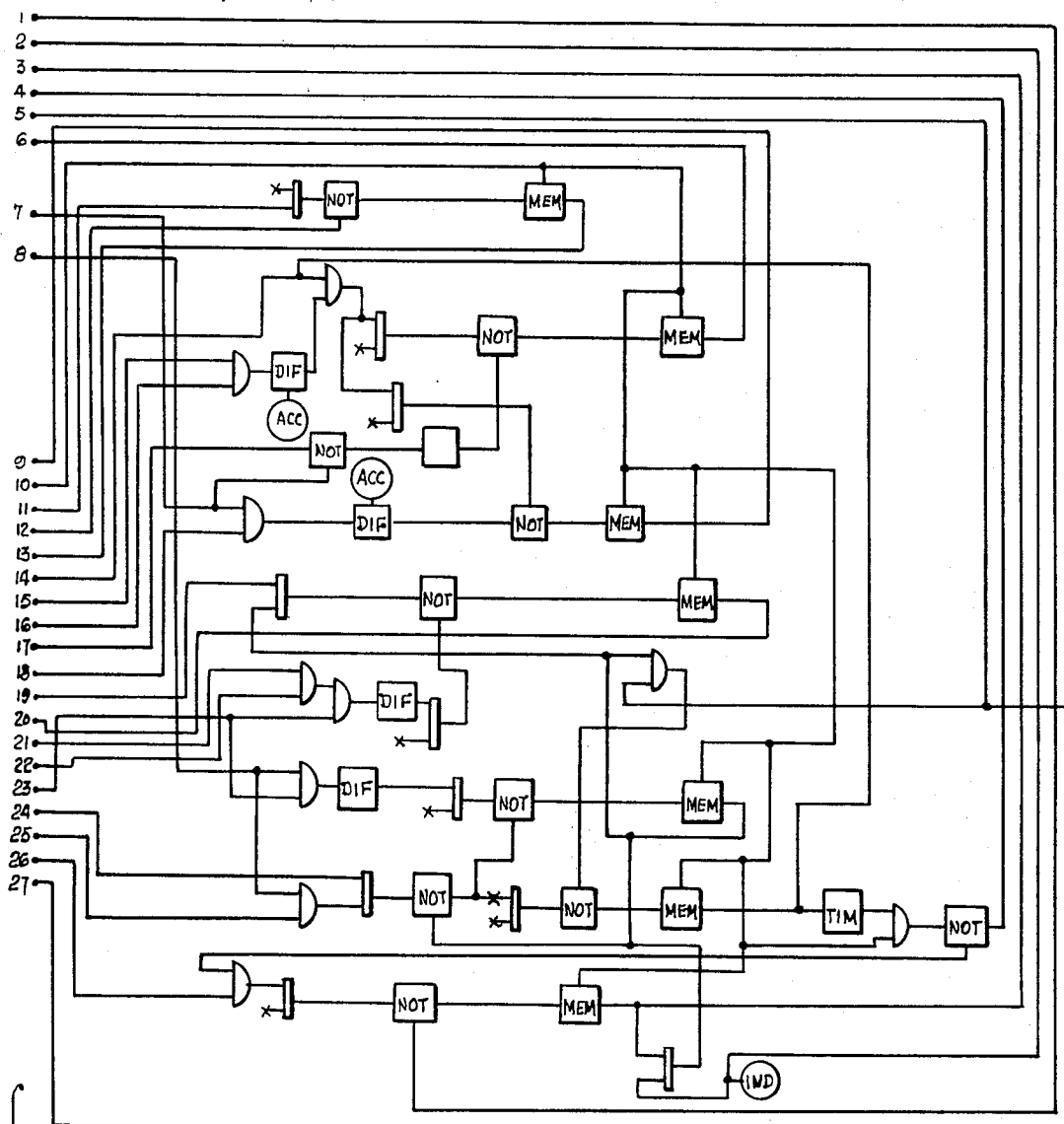
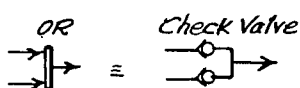
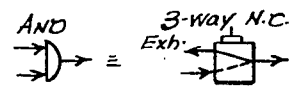
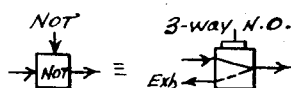


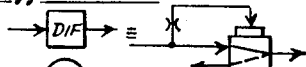
FIG. 218.



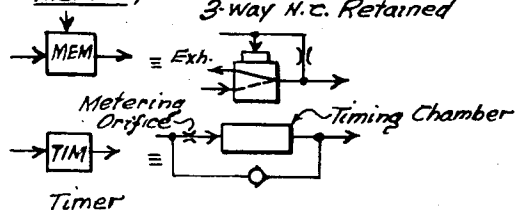
LEGEND



Differentiators



Memory



INVENTOR.

JOHN ROBERT SOUTHLAND,

By *Forrest J. Lilly*

ATTORNEY

END MILL GRINDER

RELATED APPLICATION

This application is a continuation of my prior application Serial No. 717,119 filed March 29, 1968, and entitled END MILL GRINDER, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates generally to grinding apparatus, but more especially is concerned with apparatus for grinding the end faces of the cutters of end mills with improved efficiency and accuracy.

Heretofore, the operation of grinding or sharpening an end mill has been basically a manual operation, aided by some jigs and fixtures. The operation has been characterized by dependency upon the manual dexterity and skill of the operator for both production rate and accuracy of grind. As a consequence, the cost of performing these operations has been relatively high because of the labor involved and the comparatively low rate of production as compared with rates possible with machines. Also, the accuracy or repeatability of a particular grind does not always reach desirable standards.

Consequently, it is a general object of the present invention to provide a fully automatic machine for effecting the grinding or sharpening of end mills, all operations being performed and controlled by the machine itself.

It is also an object of the present invention to provide a machine which has the capability of improving the production rate and increasing the accuracy of the grind of end mills.

A further object of the invention is to provide a machine for grinding end mills of the character described which provides all the adjustments necessary to achieve the high accuracy and other advantages proposed.

SUMMARY OF THE INVENTION

The above objects and advantages of the present invention are achieved in an apparatus for grinding an end mill which comprises a frame on which there is mounted a rotating grinding wheel, means on the frame for holding an end mill during a grinding operation, such means being referred to generally herein as a work head, a locator orienting the end mill in the work head at a predetermined position relative to the grinding wheel, (both axially, and rotably in relation to the end mill flutes) and means for moving the work head with the end mill in it to bring the end mill into engagement with the grinding wheel. The last mentioned means includes means for moving the end mill over a predetermined path relative to the wheel which includes, in sequence, advancing or feeding the end mill toward the grinding wheel, swinging the end mill relative to the grinding wheel to obtain the desired shape for the end surfaces of the cutters, retracting the end mill, and finally swinging the end mill back to the initial position and then indexing the end mill to bring another cutter end face into position, after which the same operations are repeated at each of the remaining cutters on the end mill.

The work head is pivotally mounted to swing about an axis parallel to the axis of rotation of the grinding

wheel and preferably laterally offset from the longitudinal axis of the end mill being ground, the extent of lateral offset being adjustable to vary the shape of the ground surface on the end mill.

The work head also includes indexing means which turns the end mill through the predetermined angle about its longitudinal axis in order to position the end mill with reference to each of the flutes of the end mill for a grind on the end face. The flute selector means comprises a pair of coaxial discs each with a plurality of peripheral notches, different combinations of notches being brought into registration by manual rotation of one of the discs relative to the other, means being provided responsive to presence of notches in registration with each other to operate the indexing means, thereby adapting the indexing means according to different numbers of flutes on different mills.

BRIEF DESCRIPTION OF THE DRAWING

How the above objects and advantages of the present invention, as well as others not specifically mentioned herein, are attained will be more readily understood by reference to the following description and to the annexed drawing, in which:

FIG. 1 is a front and side perspective view of an end mill grinder embodying the present invention;

FIG. 2 is a fragmentary perspective of the end of an end mill blank;

FIG. 3 is a fragmentary perspective showing the relative position of the blank and the grinding wheel during start of the first face grind on the blank;

FIGS. 4 and 5 are diagrammatic views showing different shapes of surfaces which might be ground on an end mill, only one longitudinal half of the end mill being shown;

FIGS. 6A to 6F are a series of six diagrammatic views showing the relative movement of the end mill during the cycle of operations for grinding at one flute;

FIGS. 7A, 7B, and 7C are three side elevations of the discs comprising the flute selector means illustrating different relative positions of the two discs, according to the number of flutes on the end mill being ground;

FIG. 8 is a fragmentary vertical longitudinal section approximately on line 8—8 of FIG. 1 showing in side elevation the work head for holding an end mill, the section passing through both the swing axis for the work head and the grinding wheel axis;

FIG. 9 is a front and top perspective, with enclosure removed, of the work head and mounting means therefor viewed from the left in FIG. 8, the lower portion being in section;

FIG. 10 is a vertical median section through the work head on line 10—10 of FIG. 9;

FIG. 10a is an enlarged fragment of FIG. 10 with the tool holder removed;

FIG. 11 is a fragmentary combined elevation and section showing the mounting means for the end mill locator;

FIG. 12 is a vertical transverse section taken substantially on line 12—12 of FIG. 10;

FIG. 13 is a fragmentary horizontal section on line 13—13 of FIG. 12 showing the drive from the hydraulic motor to the ring gear of the work head;

FIG. 14 is a fragmentary vertical section substantially on line 14—14 of FIG. 13 showing the output shaft from the hydraulic motor for the work head;

FIG. 15 is a fragmentary horizontal section through the mounting means for the work head taken substantially on line 15—15 of FIG. 9 or FIG. 12;

FIG. 16 is a fragmentary vertical section through the flute indexing mechanism taken substantially on line 16—16 of FIG. 9, FIG. 10 or FIG. 17;

FIG. 17 is a fragmentary vertical section taken on line 17—17 of FIG. 9 or FIG. 16;

FIG. 18 is a fragmentary perspective of the means for moving the work head;

FIG. 19 is a longitudinal median section through the tool holder;

FIG. 20 is a schematic of the electric circuit;

FIGS. 21A and 21B are a schematic in two parts, showing the air-hydraulic control system and the component parts operated and controlled thereby, the pneumatic logic units being shown symbolically according to the legend on the figures; and

FIG. 22 is an operating diagram showing the movements of the various parts during a sub-cycle grinding of a single face on the end mill.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawing, there is shown in elevation an end mill grinder embodying the present invention. Viewing the machine in its entirety, it may be considered for purposes of description as comprising four main groups of parts grouped according to the general functions of these parts. These parts are all mounted in any suitable manner on a frame or supporting structure which may have any design or configuration adapted to the purpose. This frame is generally designated at F in the drawing but is not described in detail since it is subject to change. On this frame is mounted a grinding wheel assembly and dressing tool, indicated generally at G and illustrated particularly in FIGS. 8 and 21A.

A work head H is provided in which the tool to be ground is placed. The work head, in cooperation with other elements, properly locates or positions the end mill and moves it over a predetermined path. In order to effect the desired movement of the work head and the tool therein, support and actuating means for the work head are provided, as generally designated at S. This support and actuating means is enclosed in a suitable housing on the completed machine shown in FIG. 1, the parts thereof being shown in greater detail in FIGS. 8, 9, and 18. To effect automatic control of the duration and sequence of the various motions of the machine required to grind a cutter face on the tool for each flute in succession on an end mill, there is provided an air-hydraulic system which includes pneumatic logic units. This system is shown schematically in FIGS. 21A and 21B.

GENERAL OPERATION

Before setting forth in detail the construction and operation of the parts of the machine, the general operation performed on an end mill will be described as an introduction to the more detailed description of the machine itself.

In FIG. 2, there is shown a fragment of an end mill blank B which has an end face 30 to be sharpened or ground. Grinding is accomplished by bringing face 30 on the end mill into contact with the periphery of a grinding wheel 31 normally thereto, and with its lon-

gitudinal axis 58 substantially in the plane of the top surface of the grinding wheel, so that the peripheral grinding surface will be tangent to only the lower half of the end of the blank B, as shown in FIG. 3. The ground surface provided on the end face 30 for each pass of the blank with respect to grinding wheel 31 produces a cutting lip or edge *e*, extending generally radially of the end mill, and, in back of which is a cutter face 30 α formed with axial "clearance" as later more fully described, there being one such lip *e* and face 30 α for each flute on the end mill. The shape in profile of the ground face 30 α (to provide clearance) may be more or less smoothly curved, as shown in FIG. 4, which is defined as an eccentric grind; or the face grind may have, adjacent the lip or edge *e* a central, more or less flat, primary relief area, in back of which there is a second more or less flat area disposed at an angle to the first area. These two areas are shown in FIG. 5, and a grind of this type is designated as primary/secondary. Improvements for producing the grind of FIG. 5 are disclosed and claimed in a copending application of ERNST BORCHERT III, filed June 29, 1972, Ser. No. 267,437. The sequence of movements for making the grind of FIG. 4 is indicated in schematic form in the successive positions in FIG. 6A through FIG. 6F.

First, the end mill blank B is hand loaded into the work head and properly positioned, as shown schematically in FIG. 6A. Next, the end mill feeds in endwise toward the grinding wheel to engage the wheel as shown in FIG. 6B after which one face grind forming a cutting lip is applied by swinging the end mill as shown in position C about an axis 32 which is hereinafter referred to as the swing axis. The swing axis 32 is vertical and parallel to the axis 35 about which grinding wheel 31 rotates. It is also offset laterally from end mill axis 58, in a vertical plane 47, parallel with axis 58 and through grinding wheel axis 35. It is also offset laterally from axis 58, in a vertical plane 47 through grinding wheel axis 35.

After the grinding pass, the end mill is retracted as indicated in FIG. 6D and then it swings back about the swing axis to its position at FIG. 6E, following which the end mill blank is indexed at FIG. 6F by rotating it around its longitudinal axis to bring it into position for grinding another lip on the end face 30. The grind sub-cycle shown in FIG. 22 for the various positions of FIGS. 6A to 6F is then repeated according to the number of flutes on the mill with an indexing rotation taking place between each two grinding sub-cycles, except that after the last grind, the grind cycle is terminated automatically.

GRINDING WHEEL ASSEMBLY

The grinding wheel assembly is shown in FIG. 8 and comprises a grinding wheel 31 rotatably mounted on the frame by spindle 33 journaled in bearing housing 34. Spindle 33 mounts the grinding wheel to turn about a vertical axis 35 and is driven from motor 36 by one or more belts 37 which pass from the output shaft of the motor to a drive pulley mounted on an extension of spindle 33. Spindle housing 34 and motor 36 are mounted on block 38 which in turn is mounted in any suitable manner for horizontal movement relative to frame F. This movement is controlled by lead screw 40 attached to hand wheel 41 so that the operator by

rotating hand wheel 41 can move the grinding wheel assembly toward and away from the workpiece as required by change of the diameter of the wheel.

The grind wheel assembly also includes a wheel dressing tool which is shown schematically and generally at 43 in FIG. 21A. Dressing tools of this character are well known in the grinding art, and the tool may be of any suitable design and construction, its purpose being to redress the grinding face of the wheel as may be necessary.

WORK HEAD

Work head H has a trunnion type mounting comprising upper and lower trunnions shown at 45 in FIG. 10 and 46 in FIG. 8, respectively. These two trunnion pivots establish the vertical swing axis 32 about which the work head and the end mill swing. Axis 32 is parallel to grind wheel axis 35 and the two axes may be considered as lying in a common plane indicated at 47 in FIGS. 4 and 5. These trunnions are mounted in the upper and lower arms 45a and 46a of a work head carriage in the form of a yoke 120 (FIG. 2).

Work head H is basically means for holding, positioning, and moving the end mill in a programmed manner; but to adapt it to end mills of different dimensions, the end mill blank is placed in a removable tool holder 48 illustrated in detail in FIG. 19. The external housing of the tool holder remains constant in size in order that the holder may be held firmly in the work head, but the holder has an internal sleeve 49 which engages collet 50 that is replaceable in order to provide a collet of the proper size, to hold end mills of different diameters and lengths. The inner sleeve 49 is spring-biased by a spring 49a to urge collet 50 to the left in FIG. 19 and into a closed or gripping position, but the end mill can be released by grasping handles 51 and manually bringing them together to relieve the pressure of spring 49a and sleeve 49 on collet 50.

Tool holder 48 is held within the work head by a chuck comprising a pair of spaced bearing sleeves 53 and 54 which receive the tool holder with a snug-sliding fit. Between sleeves 53 and 54 is collet 55 which can be closed by movement of an hydraulically actuated piston 56 (to the right in FIG. 10) to firmly grip the exterior of tool holder 48.

As may be seen better in FIG. 10A, hydraulic fluid under pressure is admitted to the lefthand face of piston 56 through fluid passage 56.1 in the head and an annular distribution passage 56.2 in the periphery of sleeve 54. The force exerted by the fluid moves piston 56 to the right against spring 56.3 which normally urges the piston to the position of FIG. 10 in which the collet is open. Movement of the collet to the right closes the collet, by engagement with inclined surface 56.4, to grip tool holder 48.

When collet 55 is released, the tool holder is free to move axially or rotationally about longitudinal axis 58, which is also the longitudinal axis of blank B when mounted in holder 48. Work head H establishes axis 58 at a known position with respect to grind wheel 31.

The location of longitudinal axis 58 is indicated in FIGS. 4 and 5 from which it will be noticed that this axis is laterally offset from and is parallel to plane 47 which passes through swing axis 32 and wheel axis 35. The spacing between plane 47 and axis 58 is referred to

as the "offset" and is variable by means to be described. The magnitude of this offset is one of the factors controlling the shape of the ground surface 30a on end face 30 of the end mill and consequently is closely controlled. Typically, but not necessarily limitatively, the magnitude of the offset varies between 0 and 0.200 inches.

The work head is divided into front and rear halves H_1 and H_2 more or less along a vertical transverse plane 60 illustrated in FIG. 10. The two halves are firmly clamped together by an annular band or clamping ring 61 which is provided with screw 61a by which the clamp ring can be tightened to firmly hold the two halves of the head in adjusted positions. It will be seen by reference to FIG. 12 that the geometric center 62 of the two halves of work head H is above axis 58, that is, it is eccentric with respect to axis 58. Consequently, when the front half, H_1 or face plate, in which the tool holder 48 is held, is rotated about the geometric center 62 with respect to the rear half H_2 of the work head, the tool holder 48 moves in a short horizontal arc and thereby the longitudinal axis 58 of the tool can be moved toward or away from plane 47 in order to establish the desired magnitude of the offset between plane 47 and axis 58.

In order to indicate the amount of this offset, there is provided on the front of the work head scale 63 (FIG. 9) which is shown graduated in thousandths of an inch. Cooperating with this scale to indicate the amount of actual offset is pivoted index arm 64 which is actuated by link 65 connected to the arm and to the front half of the work head. Adjustment of the magnitude of the offset is accomplished with clamping ring 61 released by backing off screw 61a. After the desired offset is obtained, screw 61a is tightened and the two halves of the work head are then held firmly in adjusted position by clamping ring 61.

The rear half H_2 of the work head carries trunnion pivots 45 and 46 and consequently is fixed relative to the trunnion support yoke 120, except for rotation about vertical axis 32.

Recessed and rotatable in the forward face of the rear half of work head H is ring gear 66, seen particularly in FIGS. 10 and 12. The periphery of the ring gear is smooth and provides a bearing surface for the gear as it turns. It is provided with internal teeth which, as shown in FIG. 12, mesh with three spur gears 67, 68 and 78. The lower one of these spur gears 67 comprises teeth cut on the periphery of bearing sleeve 54 whereby rotation of the ring gear turns bearing sleeve 54 and tool holder 48 when collet 55 is tightened since the collet frictionally locks the tool holder to the front bearing sleeve 53 and the two sleeves 53 and 54 are connected by pins (not shown) to transmit torque from one sleeve to the other.

Ring gear 66 is rotated by a second spur gear 68 on a short horizontally extending shaft 70 mounted in suitable bearings in the rear half of head H. Shaft 70, shown in FIG. 13, also carries a second gear 71 which meshes with worm gear 73 driven by shaft 74 from the output shaft of hydraulic motor 75. Hydraulic motor 75 is not shown in detail since it may be of any suitable design, a gear or lobe type positive displacement motor having a rotary output member being preferred.

FIG. 12 shows the work head substantially as it would appear if the front half of the head were removed. From this view, it is apparent that as ring gear 66 rotates, for example in a clockwise direction, gear 67 likewise rotates clockwise about axis 58. This rotates tool holder 48 with the blank B to index the blank by the angle between successive flutes. The sequence and control of this movement will be discussed later.

As illustrated in both FIGS. 10 and 12, there also meshes with ring gear 66 a third spur gear 78 which is driven by movement of the ring gear. This gear is an input to the flute selector mechanism which is adjusted manually by the machine operator in order to index automatically the tool as required according to the number of flutes on the blank being ground. The flute selector mechanism is generally indicated at 80 and is shown in detail in FIGS. 16 and 17.

Spur gear 78 is attached to shaft 81 (FIG. 10) which is rotatably mounted in the rear half of work head H and which carries at its rear end bevel gear 82. Bevel gear 82 meshes with a second bevel gear 83 mounted on shaft 84. Shaft 84 is mounted in suitable bearings, as shown in FIG. 16, in a housing constituting part of the work head structure. Shaft 84 extends forwardly beyond the housing and carries at the outer exposed end knob 85 which is preferably provided with an index mark 86 as shown in FIG. 9.

Mounted on shaft 84 to rotate therewith is a first selector disc 87. Adjacent disc 87 is a second selector disc 88 mounted coaxially of disc 87 on a hub 89 which surrounds the extension of shaft 84 and carries on its outer free end knob 90. Knob 90 carries indicia which cooperate with index 86 to indicate to the machine operator the relative positions of the two discs 87 and 88.

One of the discs, typically disc 87, carries a fixed pin 91 which can be located in a selected one of a plurality of openings 93 in disc 88. In order to locate pin 91 in a selected opening 93, disc 88 is mounted for axial sliding movement on shaft 84; but it is biased by spring 94 to the position shown in engagement with disc 87, thereby keeping pin 91 in a selected opening 93. To change the location of the hole in which pin 91 is placed, the operator can grasp knob 90, pull it outwardly on shaft 84 thereby compressing spring 94 and freeing disc 88, and turning the knob to bring another hole into registration with pin 91. Release of knob 90 then allows the pin to enter the newly selected hole under the biasing action of spring 94.

The relationship to each other of the two discs 87 and 88 of the flute selector mechanism is shown schematically FIGS. 7A to 7C which illustrate three different positions of the discs.

Since end mills are normally provided with two, three, or four flutes, provision has been made in the preferred embodiment for only these numbers of flutes; but it will be understood that in the broad sense the invention is not so specifically limited. Referring now to FIGS. 7A to 7C, it will be noticed that disc 87 has around its periphery a plurality of notches 87a. Likewise, disc 88 has around its periphery a series of notches 88a. These notches in the peripheries of the two discs are so located that various combinations of the notches are brought into registration with each

other by relative rotation of the discs with respect to each other. Two notches in registration form a "gate," the purpose of which will become apparent.

For example, in FIG. 7A, two pairs of notches 87a and 88a, spaced 180° apart around the discs, are brought into registration when pin 91 is in the center one of the three holes 93 in disc 88. This is the condition existing when it is desired to index the tool for two flutes, it being necessary to rotate the tool 180° between contacts with the grinding wheel.

When the tool has three flutes, disc 88 is shifted to the position of FIG. 7B in which three pairs of notches 87a and 88a spaced 120° apart around the periphery of the discs are in registration, as shown.

In the case of a four-flute mill, the two discs can be rotated to the position in FIG. 7C in which four pairs of notches are in registration, as shown. The relative positions of the two discs are displayed to the operator by the cooperation of index 86 and markings on knob 90 which are shown schematically in FIGS. 7A, 7B, and 7C.

The object of this arrangement of the two selector discs is to present to control pin 96 a number of gates in the form of peripheral indentations, equal to the number of end mill flutes and equally spaced around the periphery of the combined discs. Entry of the control pin into the peripheral gate results in delivery of a signal for the control system which automatically controls operation of the machine.

In general, the signal produced by the entry of control pin 96 into a peripheral indentation or gate provided by a pair of notches 87a and 88a in mutual registration conveys the information to the control system that the tool has now been rotated to a new position and now the machine is ready to perform again the grind sub-cycle of operations illustrated in FIGS. 6A to 6F. However, in order to terminate the grinding operation after one complete revolution of discs 87 and 88, representing a complete revolution of tool B, one pair of notches is made radially deeper than all others. For example, the pair of notches at the upper right portion of FIG. 7A. Upon entry into these deeper notches, the greater radial inward movement of the control pin 96 conveys the additional information that all flutes have been ground so that the particular blank in the machine has now been finished.

Control pin 96 is mounted on swinging link 98 which is pivotally connected to one end of spool 99 in hydraulic valve 100. Also connected to link 98 is bell crank 101 which is pivoted at 102 to a fixed portion of the frame. One arm is pivoted at 103 to spool 104 of pneumatic control valve 105 while the other arm of bell crank 101 is coupled by pin 106 sliding in a slot in link 98 allowing relative movement between the pin and the link 98. Movement of pin 96 radially of selector discs 87 and 88 causes bell crank 101 to swing about its fixed pivot 102 and thereby shifts spool 104 longitudinally of valve 105.

When indexing an end mill blank, shaft 84 and the selector discs 87 and 88 turn in a counterclockwise direction viewed in FIG. 17. During this movement, control pin 96 rides against the circumference of one or both discs 87 and 88. Normally, both discs are of equal, or nearly equal, diameter as shown in FIG. 16. The showing of them as being different in diameter in FIG.

7 is for illustrative purposes; but this difference in diameter may be incorporated into the machine if desired.

When one of the gates formed by registration of two notches 87a and 88a passes under control pin 96, the control pin enters the gate and moves a short distance with the discs and as a result, link 98 is moved toward the upper left in FIG. 17, thus shifting upward spool 99 of valve 100. This valve is a two-position valve and is in series with the supply of hydraulic fluid to motor 75. In the lower position, the valve freely passes hydraulic fluid to the motor. In the upper position, the valve reduces that fluid supply and decelerates motor 75 but does not shut off hydraulic fluid supply entirely.

The motion of pin 96 is transferred by link 98 to pin 106 which in turn acts through bell crank 101 to shift spool 104 of valve 103 between three positions to regulate flow of air in the control system, shown in FIG. 21. When pin 96 is out of a gate and is riding on the periphery of discs 87 and 88, as shown in FIG. 17, spool 104 is shifted to the extreme lower right position. In this position, it conditions the pneumatic elements of the control system to index the end mill. This is accomplished, as explained above, by the supply of hydraulic fluid under pressure to motor 75.

When the end mill has been rotated through the desired angle, thus completing the indexing movement, pin 96 drops into one of the gates of normal depth and the pin is advanced a short distance with the discs. In this position of pin 96, spool 104 is shifted to the mid-position. In this position, the spool conditions the pneumatic elements of the control system to initiate and proceed through a complete grinding sub-cycle, as illustrated in FIGS. 6A to 6F and 22. After the end mill has been rotated one complete revolution, pin 96 drops into a gate which is deeper than the other gates (FIGS. 7A to 7C) and consequently the pin moves radially inwardly of the discs a greater distance than at the other gates. This shifts spool 104 to the extreme upper left. In this position, valve 105 signals the pneumatic elements of the control system that the full grinding cycle has been completed and consequently further indexing of the end mill is stopped.

The final position of the end mill B after each indexing movement is determined by lock plunger 107 which is reciprocated toward and away from bearing sleeve 53 by pressure of air or hydraulic fluid on one of pistons 108 and 108a, respectively, moving within cylinder 109 on the work head. Sleeve 53 has around its periphery a plurality of notches 53a any one of which may be entered by plunger 107 when it is in the lowered or advanced position of FIG. 10. When plunger 107 is in the raised or retracted position, it is out of the notches 53a and sleeve 53 is free to turn under torque imparted to it from ring gear 66.

Notches 53a correspond in number and location to the gates provided by discs 87 and 88. Consequently, when control pin 96 is out of a gate and spool 104 is in the lowermost of the three positions, valve 105 signals the control system to index the drill bank. In the proper position in the angular movement of the chuck, plunger 107 is urged toward bearing sleeve 53 by air pressure applied to piston 108 and enters the appropriate notch 53a in the sleeve.

After plunger 107 enters into a notch 53a, it stops the work head from turning. Fluid supply to hydraulic motor 75 is reduced but not entirely shut off so that the motor urges the chuck against plunger 107 thus eliminating any backlash or play in the system and bringing the end mill blank accurately to the desired grind position.

At the end of the grind sub-cycle, the return swing of the work head to the position of FIG. 6E conditions the control system to initiate the next indexing motion. As a part of the operation, hydraulic fluid is admitted to cylinder 109 under piston 108a, forcing plunger 107 upwardly and releasing bearing sleeve 53 so that it can turn under the torque imparted to the work head chuck by hydraulic motor 75. At the proper time in the next angular motion of the chuck, plunger 107 is again urged forwardly to complete the indexing movement and accurately position the mill, as already described.

Although not an integral part of the work head, locator 110 cooperates therewith to position blank B. As shown in particularly in FIG. 10, locator 110 is mounted on holder 111 above the rim of grinding wheel 31 at a position to be engaged by the end of the blank. Work head H has a vertical movement provided by means later described which raises the work head initially to a position such that axis 58 passes through locator 110 and blank B occupies the dotted line position of FIG. 10. When the blank is placed in the work head, it is advanced axially until the end face 30 engages the locator, after which holder 48 and the blank are rotated around axis 58 until one of the lands between flutes engages projection 110a on the locator. At this time, the blank has now been positioned both longitudinally and rotatably with respect to the work head and the grinding wheel to produce the desired configuration of the ground surfaces.

End mill locator 110 is mounted on frame F by a stationary bracket 112 having a horizontally projecting arm 114. Locator 110 can be attached to arm 114 in any suitable manner, but as typical of such means, it is removably mounted in holder 111 which in turn is adjustably mounted on the free end of arm 114 by screw-threaded lock 115 having a conical tip. The lock member can be advanced by rotating handle 116 to bring the conical tip into engagement with balls 117 which are wedged against the exterior housing to lock holder 111 and the locator in position. Once holder 111 is properly positioned, different locators 110 can be quickly placed in the head for different sizes or types of end mill blanks.

SUPPORT AND ACTUATION OF WORK HEAD

The means S for supporting and moving the work head, and ultimately the end mill held by the work head, over a predetermined path is disclosed in detail particularly in FIGS. 8, 9, and 18. The support means S produces a compound movement of the work head which has three major components. In the order in which they are described below, these are, first, a vertical lift of the head and support means as a whole; second, an angular movement of the head and support means about a vertical feed axis 127 which causes the approach of the end mill blank to the grinding wheel and return, referred to as the feed and retract motions; and, third, an angular movement of the head only with

respect to its support mechanism about vertical swing axis 32 while the tool is being ground, referred to as the swing of the head.

Work head H is supported directly in a U-shaped yoke 120 having two vertically spaced, horizontally extending arms which contain the bearings for the trunnions 45 and 46 which establish the swing axis 32. As seen best in FIG. 12, yoke 120 is supported on and connected to the upper end of inner sleeve 121 which is mounted for vertical reciprocation and angular oscillation in external bearing sleeve 122. Bearing sleeve 122 contains a series of straight rows of ball bearings between the inner and outer sleeves. Bearing sleeve 122 is mounted within collar 124 which is attached in any suitable manner to the frame F of the machine, as by an angle bracket 125.

Within and concentric of inner sleeve 121 is vertically extending shaft 126 of which the longitudinal axis 127 is parallel to but laterally offset from axis 32 of the trunnions of the work head. Shaft 126 extends above and below inner sleeve 121; and the inner sleeve in turn extends below the bearing sleeve.

The lower end of inner sleeve 121 rests upon yoke 130 which surrounds shaft 126. At one end, yoke 130 is pivoted at 131 to what may be regarded as an anchor or relatively fixed pivot point. The other end of yoke 130 is connected to piston rod 132 projecting down from hydraulic cylinder 133 which is mounted on collar 134 or any other element of the machine frame F. The lifting motion of the work head and support structure is accomplished by introducing hydraulic fluid under pressure into cylinder 133 and raising the piston therein to raise rod 132, thereby swinging yoke 130 about pivot 131 to raise it from the full line position of FIG. 9 to the dotted line position of that figure. This is the vertical movement which shifts the blank B between the lower grinding position in FIG. 10 and the upper dotted line position in which it engages locator 110. Cylinder 123 is double-acting so that reversing hydraulic flow through the cylinder lowers the blank to the grinding position.

Pivot point 131 may be considered as being fixed; but in order to obtain precision grinding and to compensate for wear, tolerances in manufacturing, and other necessary accommodations, means are provided for adjusting pivot point 131 vertically by a limited amount. Such means are shown in FIG. 18. Pivot pin 131 is connected to a clevis on the end of rod 135, the other end of rod 135 being pin-connected to the righthand end of lever 136 which rocks about a fulcrum established by rod 137. Rod 137 passes through the two depending legs of the U-shaped bracket 138 and establishes a horizontal axis about which lever 136 can rock. The position of the lever is closely controlled by thumb screw 139 and a lock nut thereon. By turning thumb screw 139, the forward end of lever 136 and hence the precise position of pin 131 can be adjusted up or down, as desired.

The second component of the compound movement of the work head is the angular movement of the work head and its support about vertical axis 127, which is established by shaft 126, in order to feed the end mill blank toward and retract it from the grinding wheel. Near the lower end of inner sleeve 121 is fastened collar 140 which is shown in FIG. 18 as having two op-

positely extending arms, 140a and 140b. Arm 140a has connected to it one end of helical spring 142, the other end of the spring being attached to a suitable stationary point, as a portion of frame F. The pull of spring 142 on arm 140a biases collar 140 and inner sleeve 121 to move in a clockwise direction, viewed from above. As will become more apparent, this is the direction of retract movement which moves the workpiece away from the grinding wheel.

Mechanism for rotating the collar and the work head in the opposite direction to feed the workpiece toward the grinding wheel engages the opposite arm 140b to effect rotation of the sleeve with the work head in the opposite or counterclockwise direction, viewed from above. This latter mechanism includes roller 143 which bears against arm 140b and is mounted on one arm of bell crank 144. The other outwardly extending arm of this bell crank is pin-connected at 145 to a clevis on the upper end of rod 146. Rod 146 is designed to permit adjustment of the level of pivot pin 145, in the same way as described previously in connection with pin 131. For this purpose, rod 146 is pin-connected at its forward end to lever 147 which rocks about fulcrum rod 137 which passes through the depending legs of bracket 148. The position of lever 147 is established by adjusting screw 149 which is provided with a lock nut and is threaded into bracket 148. By turning thumb screw 149, lever 147 can be rocked to raise or lower the forward end and thereby establish pin 145 at the desired level.

Bell crank 144 is pivotally mounted on eccentric 150 on rock shaft 151. Rock shaft 151 is rotatably mounted in suitable bearings in brackets 152 which are attached to suitable portions of the frame F. Rock shaft 151 has non-rotatably attached to it arm 154, the outer end of the arm being attached by linkage 155 to the upper end of vertically moving piston rod 156. Piston rod 156 is attached to a piston moving within double-acting hydraulic cylinder 157, this cylinder being referred to as the in-feed cylinder, since introduction of hydraulic fluid under pressure into the upper end of the cylinder lowers the piston within the cylinder, thereby dropping piston rod 156 and rotating rock shaft 151 in a clockwise direction, viewed from the right-hand end thereof in FIG. 18. Such rotation of rock shaft 151 about its longitudinal axis rotates eccentric 150 and pushes bell crank 144 against collar arm 140b. The movement of the bell crank is essentially one of translation since pin 145 moves only in a short arc that is approximately horizontal. This motion of arm 140b is transmitted through inner sleeve 121 to the yoke 120 supporting the head which in turn moves head H toward the grinding wheel.

When flow of hydraulic fluid is reversed through cylinder 157, reverse movement of yoke 120 in the grinding head to retract the workpiece from the grinding wheel is effected.

The third component of the compound movement of the work head is a swinging movement of work head H about axis 32 established by trunnions 45 and 46. This swinging movement of the work head is initiated by supplying hydraulic fluid under pressure to double-acting cylinder 160, the fluid moving piston rod 161 out of the cylinder. This motion of the piston rod is conveyed through link 162 to arm 163 which is non-rotatably at-

tached to inner shaft 126, as may be seen in FIGS. 9 and 18. The connection between arm 162 and shaft 126 preferably includes a spline or key 164 (FIG. 9) in order to permit shaft 126 to move vertically relative to arm 163, as already described.

Referring to FIG. 15, it will be seen that at the top of shaft 126 there is attached to the shaft in a suitable non-rotatable manner arm 166. The outer end of arm 166 is pin-connected to link 167, the other end of the link being pin-connected to an arm 168 non-rotatably attached by screw 169 to trunnion 46. Arms 166 and 168 are preferably parallel to each other, and the linkage is such that the work head swings through an arc equal to the angular movement of shaft 126.

The return swinging movement of the work head is accomplished by reversing hydraulic fluid flow through swing cylinder 160, thereby allowing the work head to return to its initial position. Spring 171 is attached at one end to arm 173 non-rotatably attached to shaft 26 in the vicinity of arm 163, while spring 172 is attached at one end to the outer end of arm 168. Both of the return springs are attached at their other ends to a fixed abutment, such as a suitable element of frame F. The springs are provided to eliminate backlash in the system.

OPERATING CYCLE

Having described the structure of the end mill grinder embodying the present invention, added description of the operation of the machine will now be supplied.

Initial operations can be grouped under the general heading of the set-up which is designed to ready the machine to place a particular grind on a particular size of end mill. The initial step is to dress grinding wheel 31 to the desired shape and profile, using wheel dresser 43. This operation is well known in the art and need not be described in detail here.

Next, there is selected the proper tool holder 48 to accommodate the end mill to be ground, the collet 55 in the tool holder being selected according to the diameter and length of the mill B to be held in the holder.

Next, the operator installs and properly positions locator 110. This is selected to accommodate the end mill blank to provide correct radial and axial timing and is positioned with reference to the grinding surface of wheel 31 to produce the desired grind. Next, work head H is adjusted for the correct offset. The offset, indicated in FIG. 4, is adjusted by rotating the front half of the work head with respect to the rear half, the amount of offset being shown by indicator 64 against scale 63. The spacing of the end surface 30 of the end mill blank beyond swing axis 32 is determined by selection of the locator, this distance being referred to as axial timing and is so designated in FIG. 4.

Next, the flute selector is set by means of knob 90 to agree with the number of flutes on the mill to be ground. The blank shown in FIG. 2 has four flutes and so the two discs 87 and 88 are set, as shown in FIG. 7C, to provide four matching pairs of recesses or gates adapted to receive control pin 96.

With all of these adjustments made, the machine is now placed on standby condition by pressing start button 175 (FIGS. 1 and 20) on the control panel. This

results in energizing the electrical circuit shown in FIG. 20 and places in operation the motor M1 which drives the pump P (FIG. 21A) to provide hydraulic fluid under pressure for the control system. As soon as hydraulic pressure reaches a safe value, pressure switch 1PS closes and spindle drive motor 36 (M2) starts. No movement of the parts takes place on standby but power is supplied to various electric or hydraulic motors. At this time, the work head is in the raised position. Now, the machine may be loaded by placing tool holder 48 into the work head, advancing the tool holder through bearing sleeves 53 and 54 and collet 55 until the end face 30 of the blank comes into contact with locator 110 as shown in dotted lines in FIG. 10. Next, the tool holder is rotated to bring one lip of the blank into contact with locator projection 110e, thus orienting the blank both axially and angularly to produce the desired movement of the blank relative to grinding wheel 31.

Next, the operator presses cycle start button 177 which initiates the automatic operations by supplying air to the control system shown in FIGS. 21A and 21B and causing it to take over control and perform automatically a programmed sequence of operations. First, hydraulic fluid is applied to the upper end of cylinder 133, thereby dropping the work head to the grind position in which blank B is in the solid line position shown in FIG. 10. When this grind position is reached, then hydraulic fluid under pressure is supplied to cylinder 157 to feed the blank in toward the grind wheel as indicated in FIG. 6B. After proper movement of the blank, hydraulic fluid under pressure is supplied to swing cylinder 160, causing the work head to swing about axis 32, moving the blank B with respect to grinding wheel 31 as shown in FIG. 6C.

Now, the flow of fluid through feed cylinder 157 is reversed. Being a double-acting cylinder, the hydraulic fluid now causes the cylinder to retract the work head, the movement of the tool being as indicated in FIG. 6D, essentially in the reverse direction of the feed movement. After the retraction or reverse feed movement is completed, the flow of hydraulic fluid through swing cylinder 160 is reversed. This cylinder being a double-acting cylinder, the head and end mill blank B now swing in the reverse direction around swing axis 32 as shown in FIG. 6E.

Upon return to this position, a signal is supplied to the control system; and upon receipt of this information, hydraulic motor 75 is fully energized thereby rotating ring gear 66 and through collet 55 rotating the tool holder and blank B about its longitudinal axis 58. To permit this angular movement for indexing, control pin 96 is lifted out of a gate in the periphery of the selector discs and lock plunger 107 is retracted. The end of the correct angular movement of the tool holder is signaled by pin 96 dropping into another gate in the periphery of the selector flutes, thereby moving spool 99 in valve 100 to reduce supply of hydraulic fluid to motor 75 to decelerate the motor and the chuck. At the proper time, a signal to the control system advances lock plunger 107 into a recess 53a to hold the chuck with the end mill during the grind sub-cycle and the sequence of operations illustrated in FIG. 6.

This same sub-cycle is automatically repeated for each flute on a blank B. The control system is pro-

grammed by the flute selector to automatically grind an end face 30a with reference to each flute in exactly the same manner and in sequence. After the last grind set by the flute selector, pin 96 drops into the gate in the periphery of the selector discs which is deeper than the other gates, thereby producing an additional travel of valve spool 104 which signals the end of the grinding of the end mill. When all faces are ground on blank B, the work head raises to the high position and releases the hydraulic pressure on collet 55 so that the tool holder can be manually removed and the machine unloaded. The ground blank is then removed by hand from the tool holder 48, a new blank inserted in the tool holder, and the tool holder again loaded into the work head to repeat the cycle of operations just described when cycle start button 177 is again depressed to energize the central system. A stop button 178 in the electric circuit (FIG. 20) is depressed to de-energize the pump and spindle motors M1 and M2.

CONTROL SYSTEM

The various movements of the work head required to grind each of the faces on the end of an end mill B could, of course, be carried out by hand, after making certain necessary minor modifications in the machine. However, it is an objective of the present invention and one of its advantages that the automatic sequence of the various operations, as described above, is carried out by a control system with greater speed, accuracy, and uniformity of product, than is possible by manual operation. To control the various operations, there has been provided a control system which may be characterized as being an air-hydraulic system and is shown in some detail in FIGS. 21A and 21B.

Generally speaking, power is delivered in the control system and work performed by the hydraulic part of the system since the hydraulic fluid delivered from the pump is particularly adapted to this function. The hydraulic lines are shown as heavier lines in FIGS. 21A and 21B. The control functions are carried out by the air portion of the control system, the lines for this purpose being shown as light lines in FIGS. 21A and 21B.

The major control functions are carried out by a series of pneumatic logic elements, shown particularly in FIG. 21B. These logic elements are shown symbolically in the figure according to their function; but physically they are valves with the character shown in the legend attached to FIG. 21. In addition to the elements shown in the legend, there are a number of position sensors which are basically limit valves or switches actuated by the movement of parts of the work head of the supporting structure therefor. These sensors are generally two-position valves, as shown diagrammatically in FIG. 21A where these sensors are shown as unnumbered elements associated with the component parts of the machine which actuate the sensors. The purpose of such sensors is to signal the completion of certain movements of the machine, thereby causing the control system to complete certain movements or to initiate other movements, as will be well understood by those skilled in the art.

The construction of the control system is not described in greater detail than is disclosed by the figure since other control systems may be used and it is considered that one skilled in the art can construct and

install a control system necessary to perform the sequence of operations described in detail from the information provided in FIGS. 21A and 21B.

At the same time, it will be realized that the disclosure of an air-hydraulic control system is not limitative upon the invention since other types of systems may be utilized for this purpose.

From the foregoing description, it will be understood that various changes in the detailed construction and arrangement of the parts constituting the end mill grinder of the present invention may occur to those skilled in the art without departing from the spirit and scope of the present invention. Accordingly, it is to be understood that the foregoing description is considered to be illustrative of, rather than limitative upon, the invention as defined by the appended claims.

I claim:

1. In an end mill grinding machine for grinding cutter end faces on a cutter end of an end mill that has a longitudinal axis, the combination of:
 - a frame;
 - a grinding wheel rotatably mounted on said frame;
 - a work head including a rotatably mounted collet in which the end mill is clamped;
 - means mounting the work head on the frame for movement relative to the grinding wheel, including means supporting and guiding said work head for feed movement toward a position of engagement of the cutter end of said end mill with said grinding wheel, and for swing movement about a rock axis perpendicular to the longitudinal end mill axis to bring different portions of said cutter end of said end mill to bear against the grinding wheel; and
 - coordinated motor means for motivating said feed and swing movements to occur in predetermined sequence.
2. The machine of claim 1, wherein said rock axis is perpendicular to but laterally offset from the longitudinal end mill axis.
3. The machine of claim 2, wherein said feed movement is a swing movement about a feed axis, said feed axis being spaced from the end mill face to be ground by a distance which is large relative to the radial distance from said rock axis to said end mill face.
4. The machine of claim 2, wherein said feed movement is a swing movement about a feed axis parallel to said rock axis.
5. The machine according to claim 4 that also includes means for rotating the collet in the work head to present successive end faces on the end mill to the grinding wheel.
6. The machine according to claim 3, which also includes motor means for moving said work head along said feed axis.
7. In a machine for grinding faces on an end mill, the combination that comprises:
 - a frame;
 - a grinding wheel rotatably mounted on the frame;
 - a work head including a rotatably mounted collet in which the end mill is clamped;
 - mounting means for the work head on the frame establishing two spaced parallel axes about which the work head can turn; and
 - separate independently operable motor means, one corresponding to each of said axes, for moving the

work head about said axes to bring the end mill into engagement with the grinding wheel.

8. The machine according to claim 7 that also comprises independently operable motor means for moving the work head along one of said two axes.

9. The machine according to claim 7 that also comprises motor means for rotating the collet in the work head to present successive faces on the end mill to the grinding wheel.

10. The machine according to claim 9 that also includes manually adjustable means controlling the angular extent of each rotational movement of the collet.

11. The machine according to claim 7 that also comprises separate and independently operable motor means for moving the work head along one of said two axes and for rotating the collet in the work head; and
a control system for actuating automatically all of said motor means in a predetermined sequence and for predetermined periods of time.

12. Apparatus for grinding an end mill having a longitudinal axis, comprising:

- a frame;
- a grinding wheel rotatably mounted on the frame; and
- a work head supported in the frame for holding an end mill during a grinding operation, including a work head body;
- a collet rotatably mounted in the body and in which the end mill is clamped to turn the end mill about the longitudinal axis of the end mill;
- trunnion means on the body establishing a second axis about which the work head can turn, said second axis being perpendicular to said first mentioned axis, and
- separate independently operable motor means for moving the collet alone about the first mentioned axis, and the work head body with the collet about said second axis.

13. Apparatus for grinding an end mill of the type having a fluted shank having a longitudinal axis and whose end has a plurality of end cutters symmetrically disposed about the longitudinal axis of the shank, each cutter having a cutting edge disposed generally radially of said axis, and having a cutter end face in back of said cutting edge formed with axial clearance relative to a plane normal to said longitudinal axis, comprising:

- a frame;
- a grinding wheel with a side face bounded by a peripheral grinding surface rotatably mounted on said frame;
- means mounted on the frame for holding an end mill during a grinding operation;
- feed means for moving the holding means with the end mill therein so that the end mill feeds in toward the peripheral grinding surface endwise, with its longitudinal axis substantially in the plane of the side face of the grinding wheel, and with substantially half the end thereof overlapping said peripheral grinding surface, and the remainder beyond the plane of said side face of said grinding wheel; and
- swing means operable on said holding means after the end mill has been so moved into predetermined proximity with said peripheral grinding surface for swinging the end mill against and longitu-

dinally along said peripheral grinding wheel surface.

14. The apparatus of claim 13 wherein said holding means feeds in said end mill with the longitudinal axis thereof offset laterally a predetermined distance from a plane parallel thereto and passing through the grinding wheel axis; and means included in said end mill swinging means comprising a pivot means therefor having a pivot axis parallel to the axis of said grinding wheel and located in said plane through said axis of said grinding wheel.

15. Apparatus according to claim 14 in which said feed and swing means include means for sequentially advancing the end mill toward the grinding wheel, swinging the end mill relative to the grinding wheel, retracting the end mill away from the grinding wheel, and finally swinging the end mill back to the initial position.

16. Apparatus according to claim 13 which includes indexing means turning the end mill in the holding means to grind successive end faces of the end mill, and also includes flute selector means adjustable to operate the indexing means with reference to the number of flutes on the end mill.

17. Apparatus for grinding an end mill of the type having a fluted shank having a longitudinal axis and whose end has a plurality of end cutters symmetrically disposed about the longitudinal axis of the shank, each cutter having a cutting edge disposed generally radially of said axis, and having cutter end face surface in back of said cutting edge formed with axial clearance relative to a plane normal to said longitudinal axis, comprising:

- a frame;
- a grinding wheel with a peripheral grinding surface terminating in a curved peripheral edge rotatably mounted on said frame; and
- holding and operating means mounted on the frame for holding an end mill and for moving it to be ground by said grinding wheel;
- said holding and operating means including feed means for substantially bodily feeding the end mill toward said peripheral grinding surface with the cutter end portion to be ground presented toward said grinding surface, and with the longitudinal axis of the end mill substantially intersecting said curved peripheral grinding wheel edge, on approach of said end mill face to proximity with said grinding wheel surface, so that substantially half the end of the end mill overlaps said grinding wheel surface, and the remainder is beyond said curved peripheral grinding wheel edge;
- said holding and operating means including also swing means for moving said end mill about a swing axis perpendicular to the longitudinal axis of the end mill; and
- indexing means for periodically rotating said end mill on its longitudinal axis through a predetermined angle to present successive end mill cutter faces to said peripheral grinding surface.

18. The apparatus of claim 17, wherein said swing axis is laterally offset from said grinding wheel axis.

19. The apparatus of claim 17, wherein said parallel axes are both perpendicular to and laterally offset from the longitudinal end mill axis, with the offset of one of

19

said axes greater than the other, and with the one of said axes which is least offset substantially passing through the grinding wheel axis.

20. The apparatus of claim 19, including means in said work head rotatably adjustable about the longitudinal axis of the end mill held therein for adjusting the distance between said least offset axis and said longitudinal end mill axis.

21. In an end mill grinding machine for grinding cutter end faces on a cutter end of an end mill that has a longitudinal axis, the combination of:

- a frame;
- a grinding wheel rotatably mounted on said frame;
- a work head including a rotatably mounted collet in which the end mill is clamped;
- carriage means mounting the work head on the frame for pivotal feed and retract movements rela-

20

tive to the grinding wheel;

means pivotally mounting the work head on said carriage means for swing movements relative to said carriage means about a rock fixed relative to said carriage means, said rock axis being substantially parallel to the axis of said pivotal feed and retract movements, and perpendicular to the longitudinal end mill axis and laterally offset therefrom, to successively bring different end face portions of the cutter end of the end mill to bear against the grinding wheel; and

motor means for motivating said carriage means to undergo its pivotal feed and retract movements, and said work head to undergo its pivotal swing movements relative to said carriage means, in a predetermined coordinated sequence.

* * * * *

20

25

30

35

40

45

50

55

60

65