

## [54] INTERNAL GRINDER

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[52] U.S. Cl. .... **51/3; 51/165.77**

[51] Int. Cl.<sup>2</sup> .... **B24B 5/06**

[58] Field of Search ..... 51/3.5, 50, 165.77, 165.88, 51/165.93

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## [57] ABSTRACT

A grinding machine having a plurality of relatively movable tables one supporting another which is movable obliquely to the path of travel of the supporting table and mounting a plurality of driven grinders thereon. A second plurality of tables one supporting another and relatively movable. The supported table of the second plurality mounts a work holder for supporting a workpiece. The supporting table of each plurality of tables is movable relative to the base of the machine. Drive apparatus are provided for driving the tables jointly and individually for relatively positioning the workpiece and the individual spindles under control of sensors and detectors that sense and detect positions of the tables to control their positions and relative movements. A dresser for the grinders grinds them accurately under control of a compensating apparatus that controls feed to make certain the dressing takes place only for the proper amount.

**5 Claims, 19 Drawing Figures**

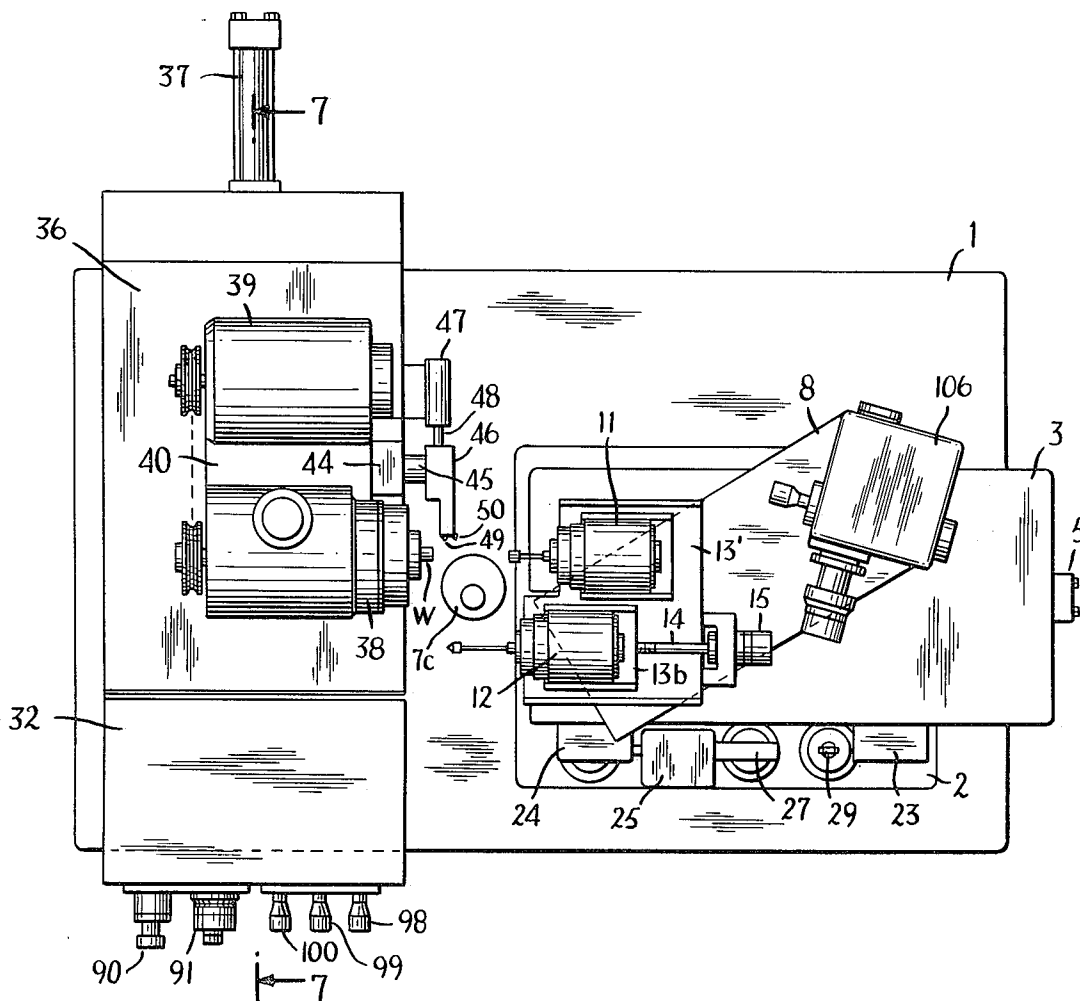


FIG. 1

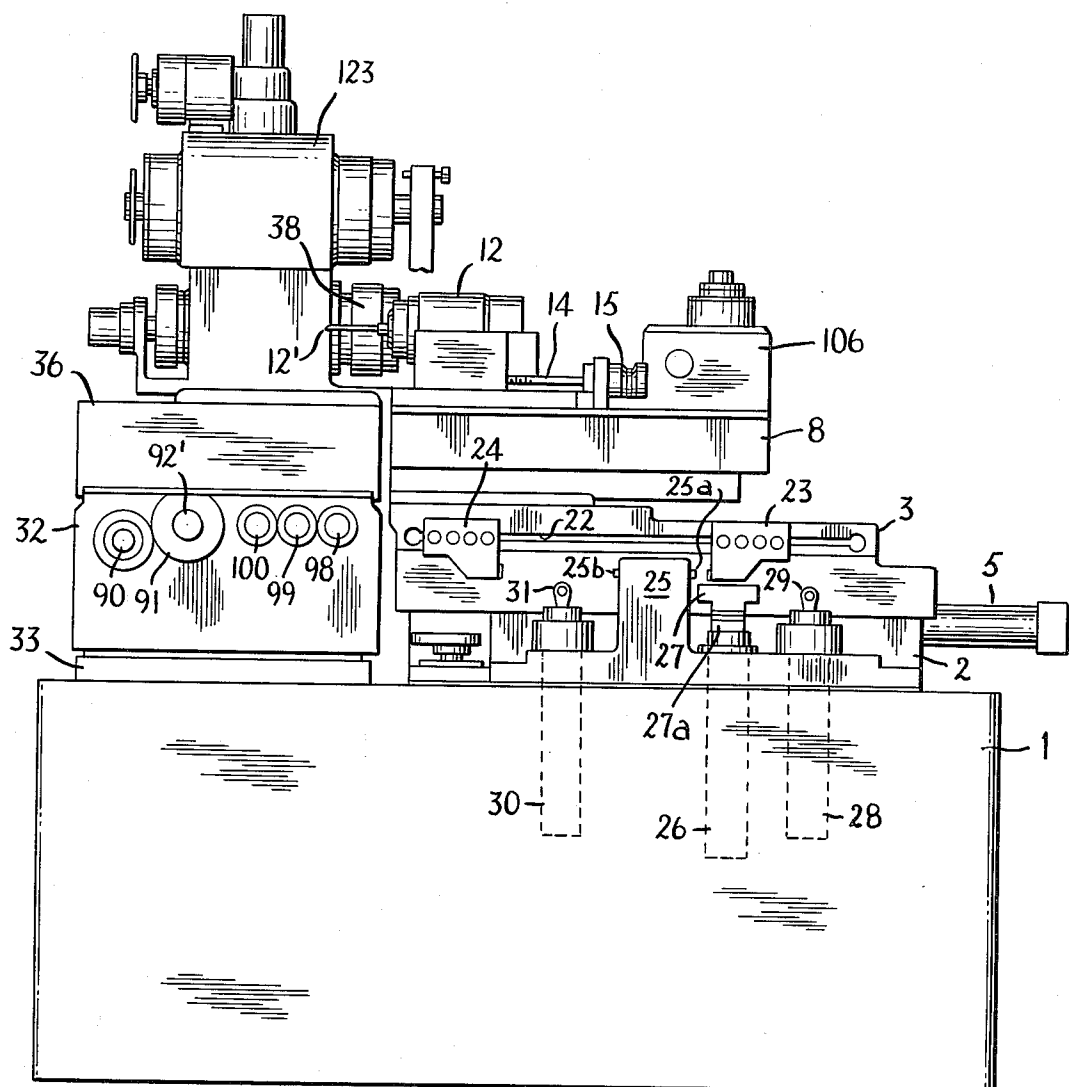


FIG. 2

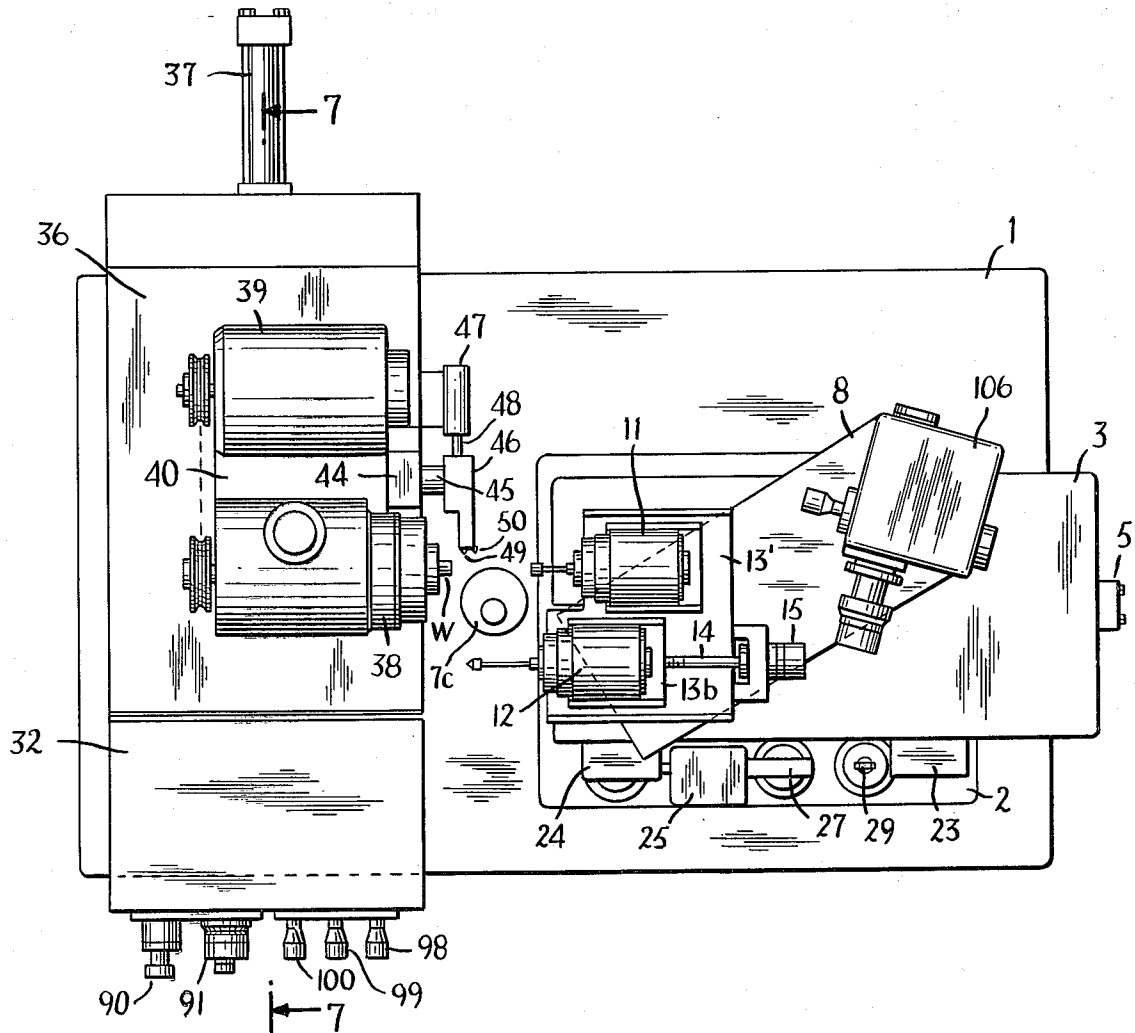


FIG. 3

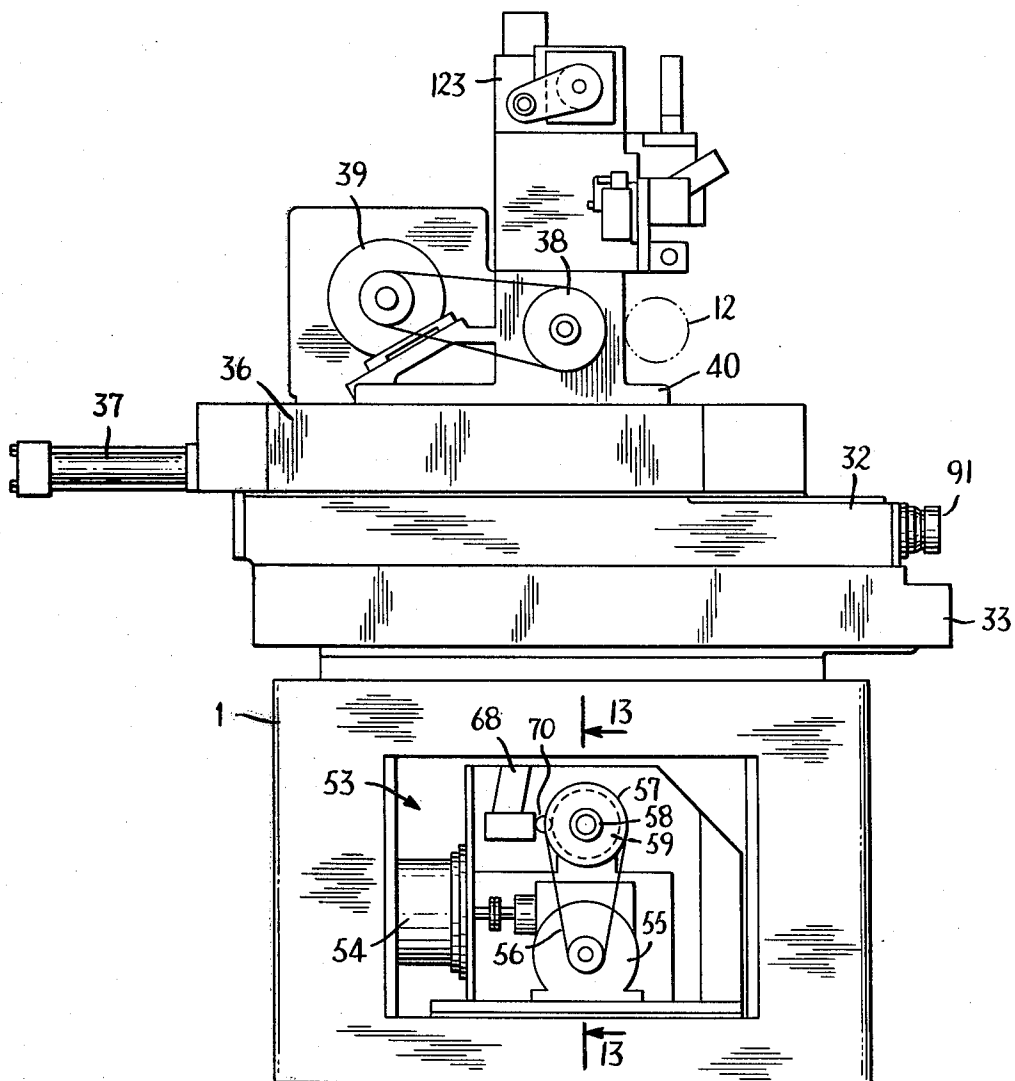


FIG. 4

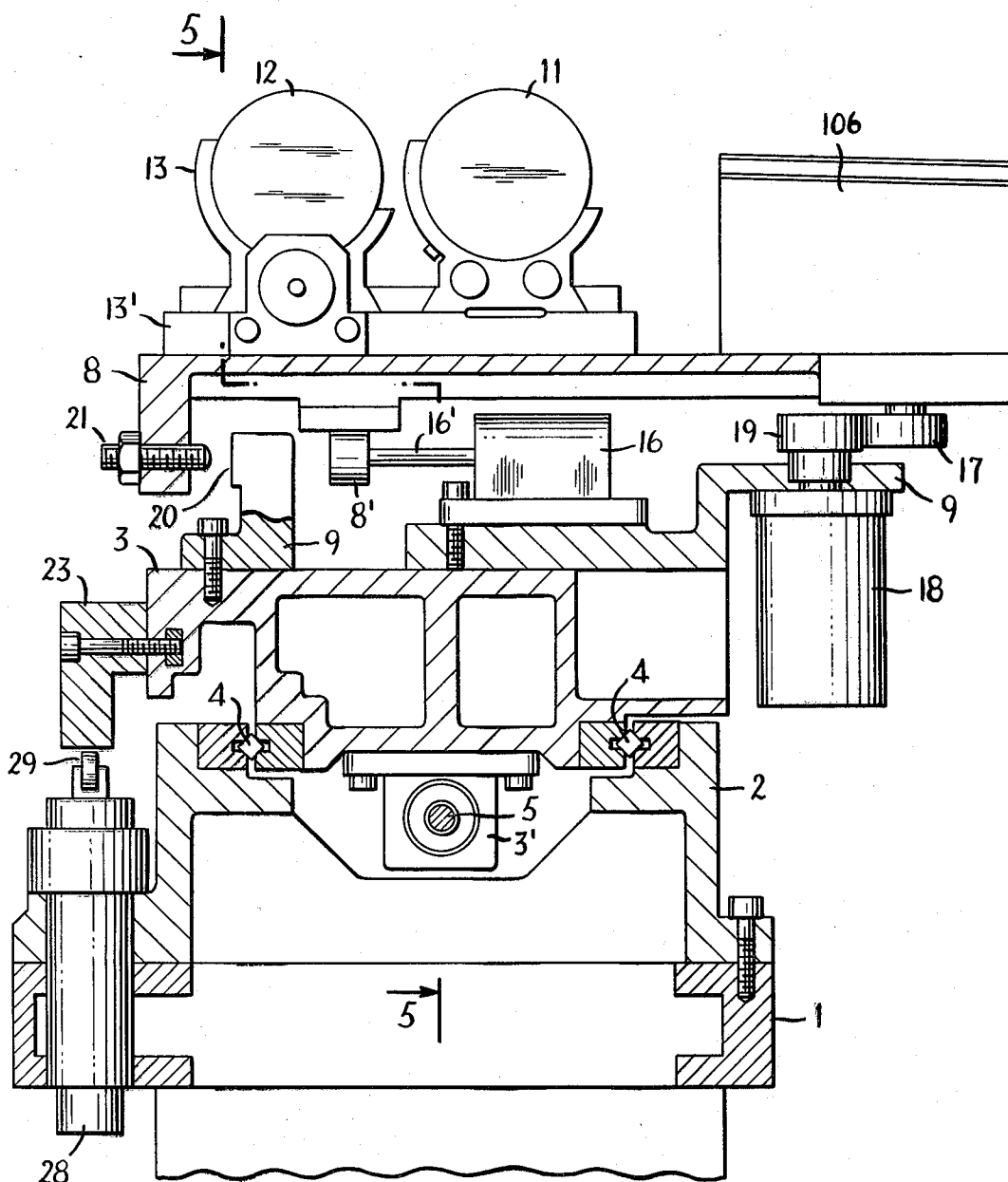
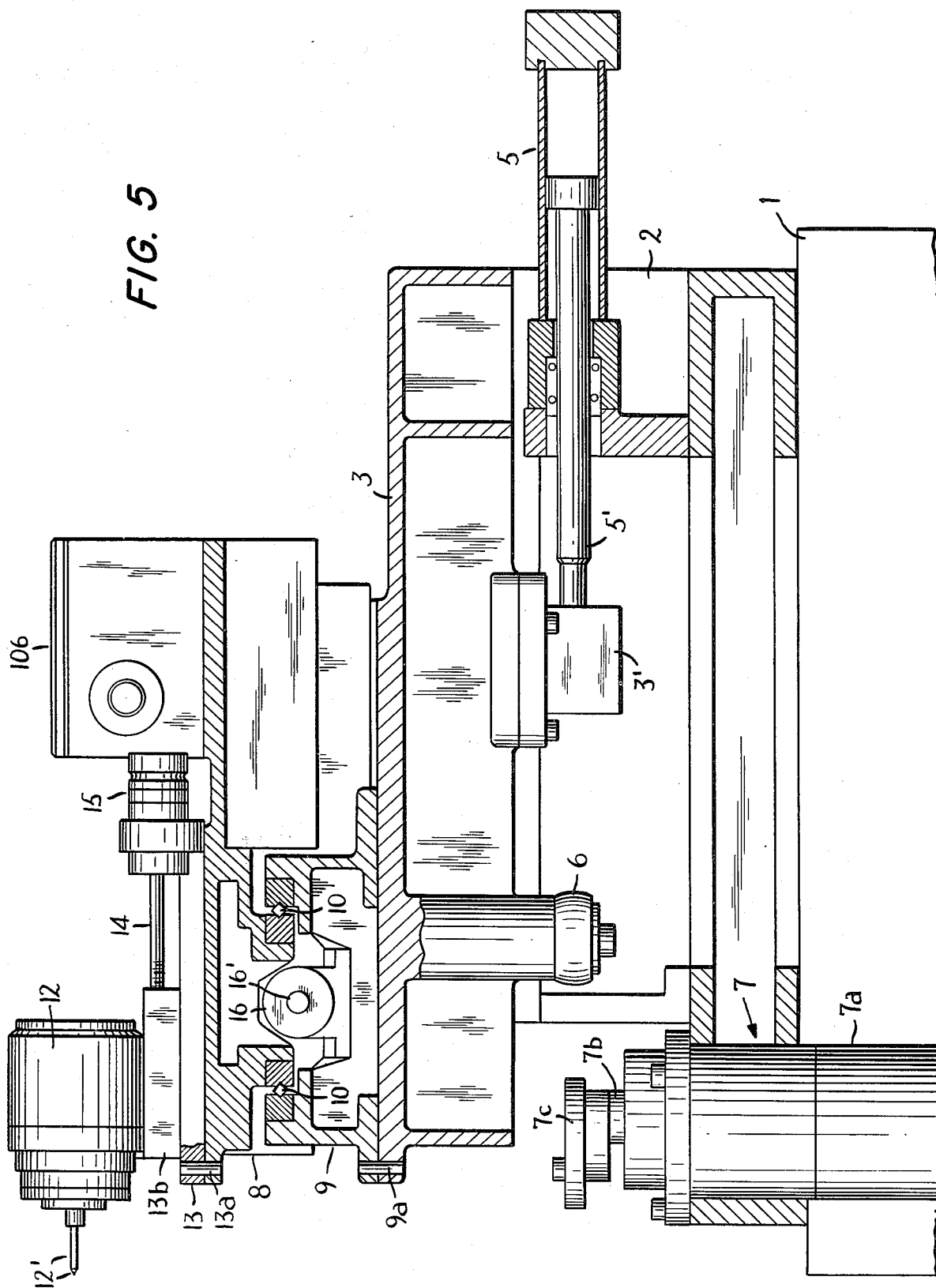
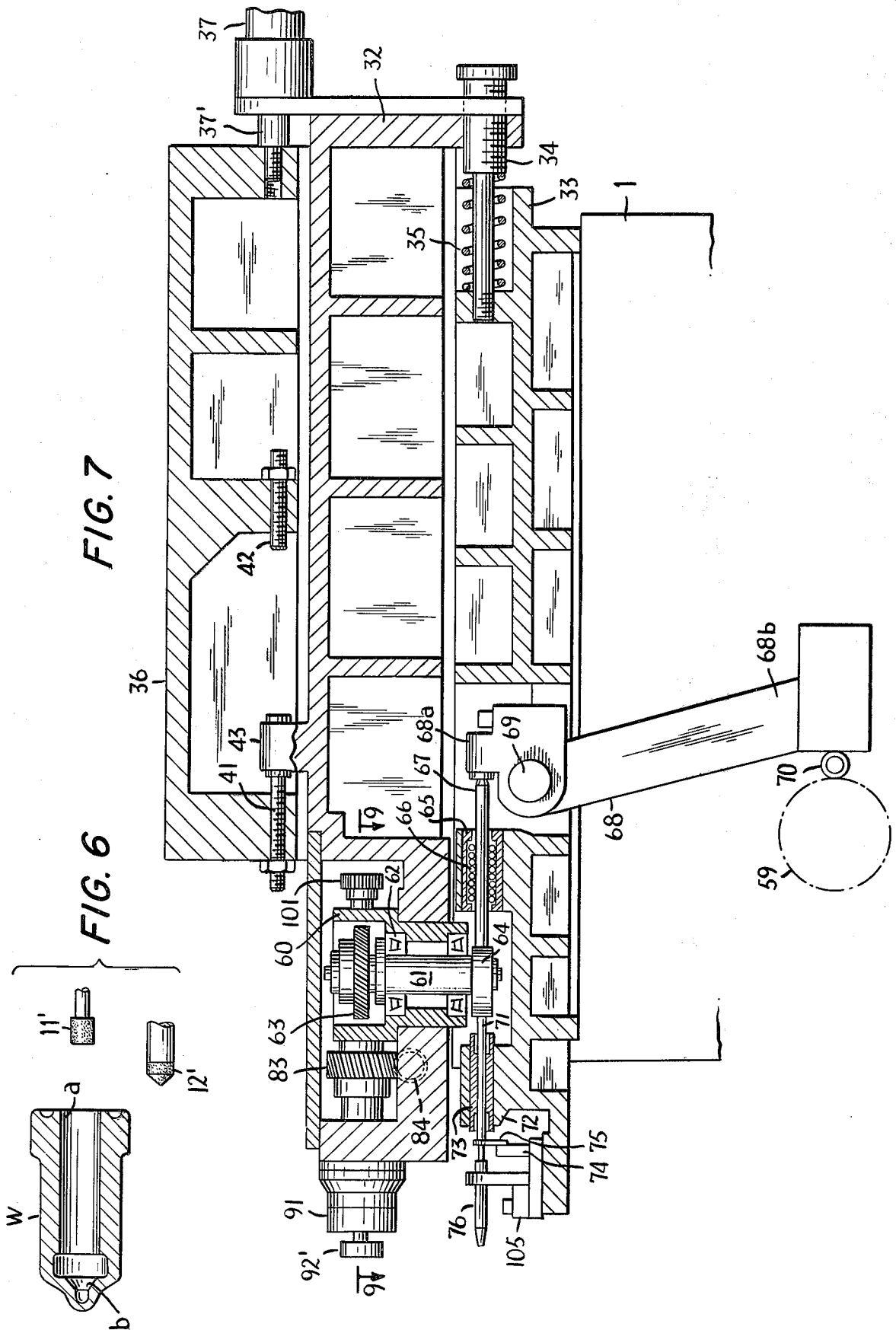
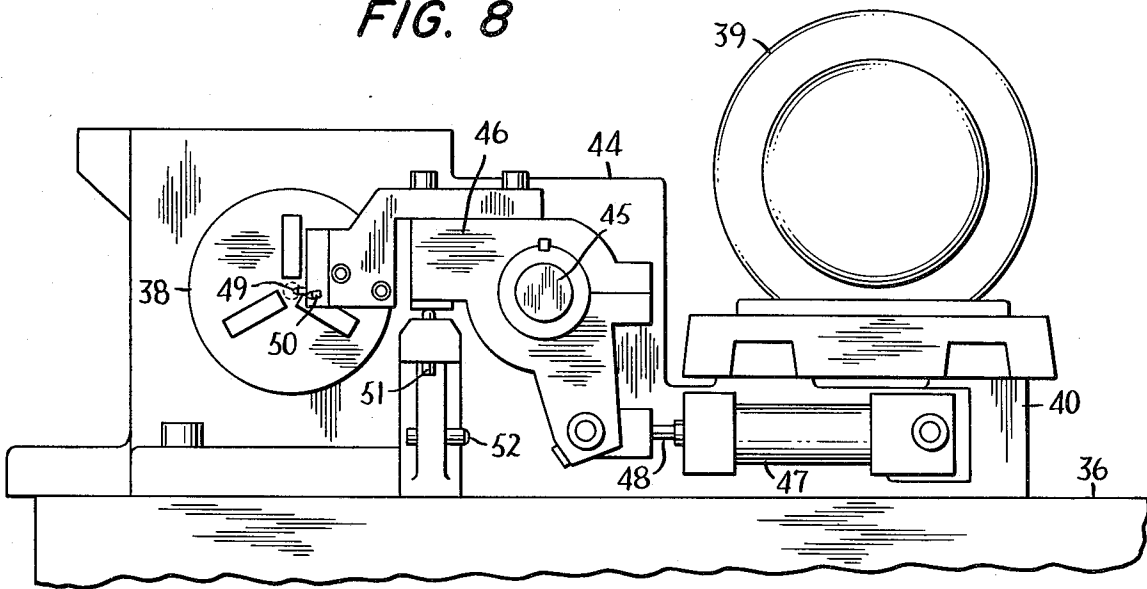


FIG. 5





**FIG. 8**



**FIG. 10**

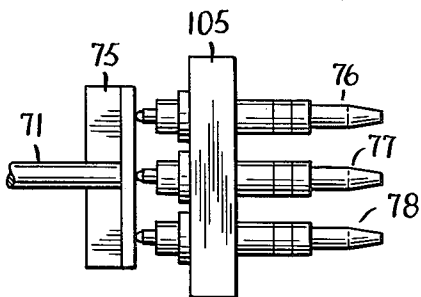


FIG. 11

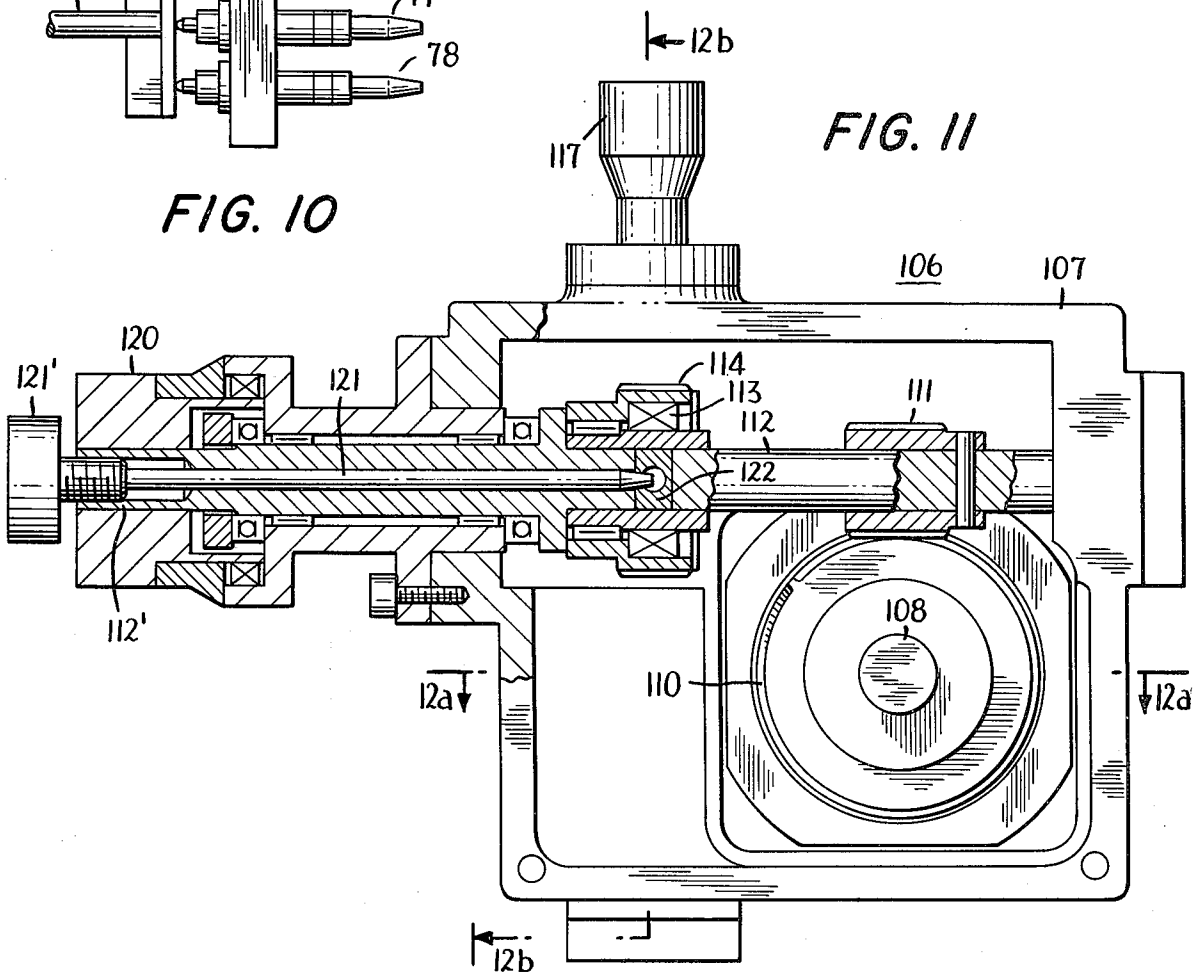


FIG. 9

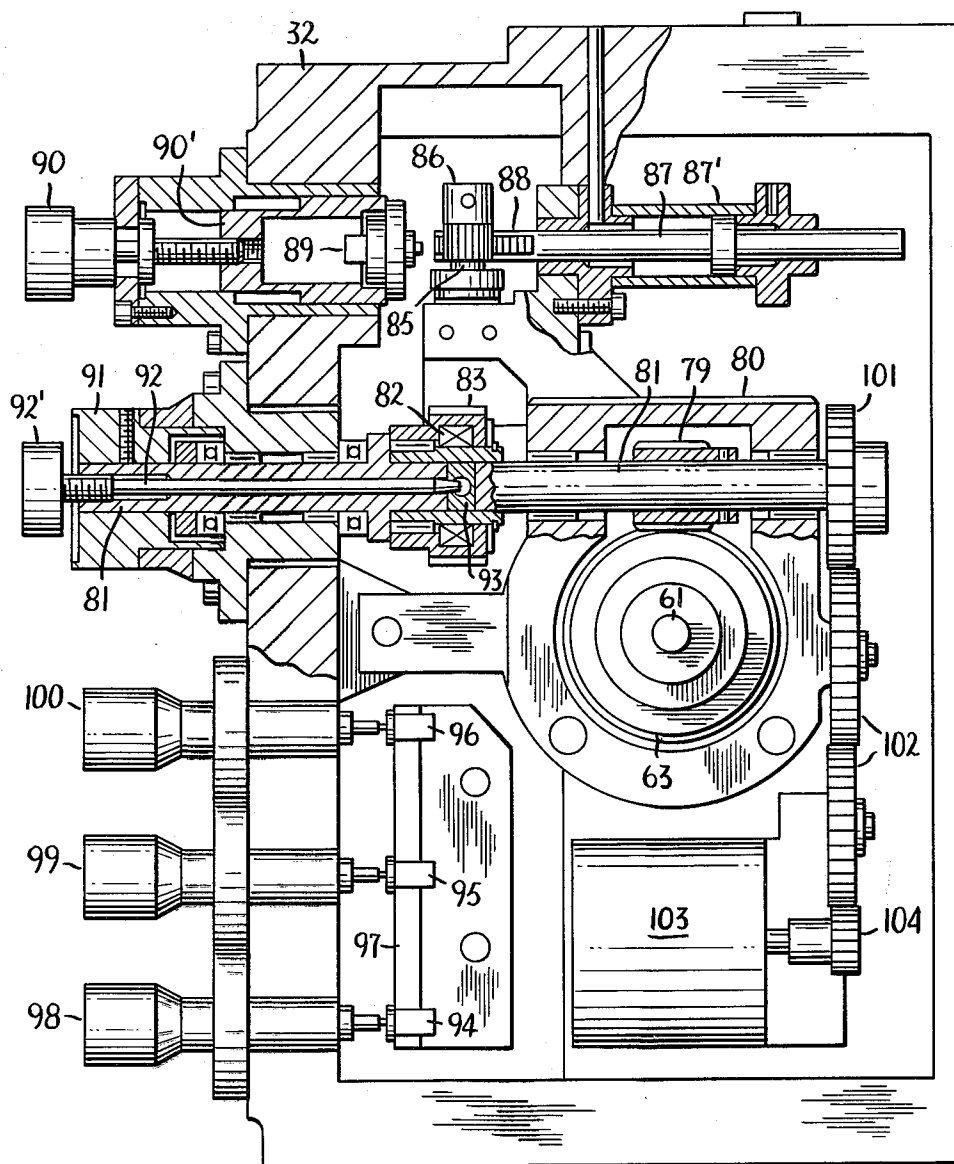


FIG. 12a

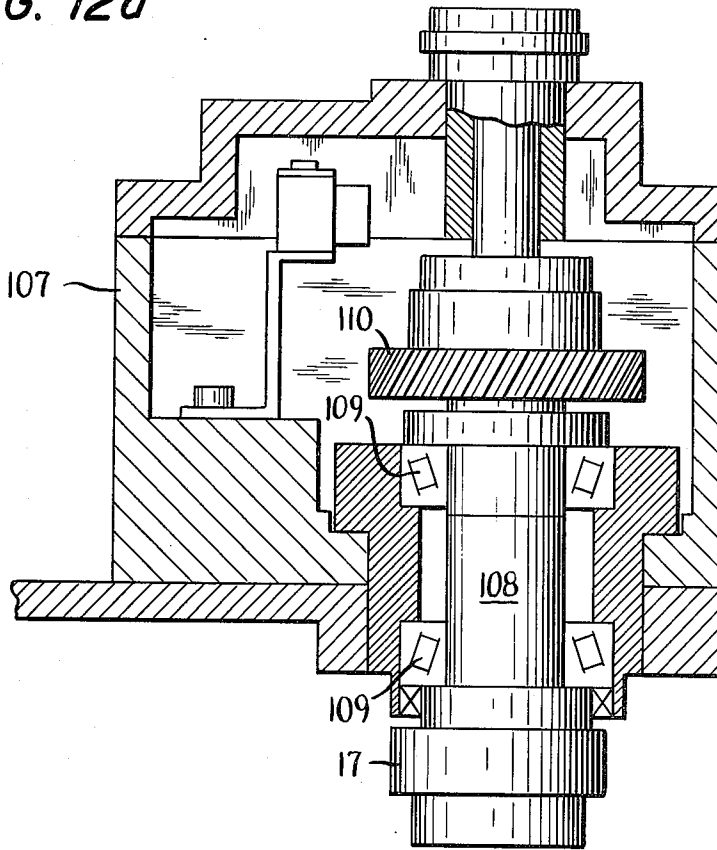


FIG. 12b

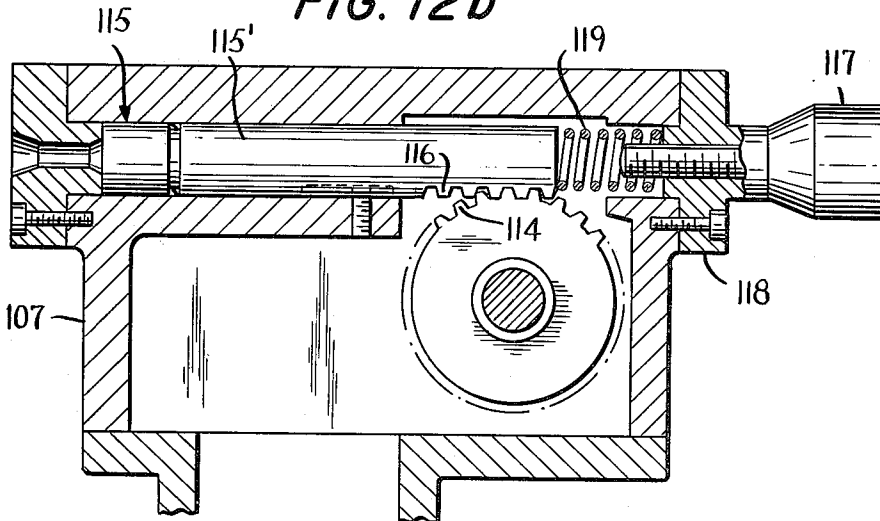


FIG. 13

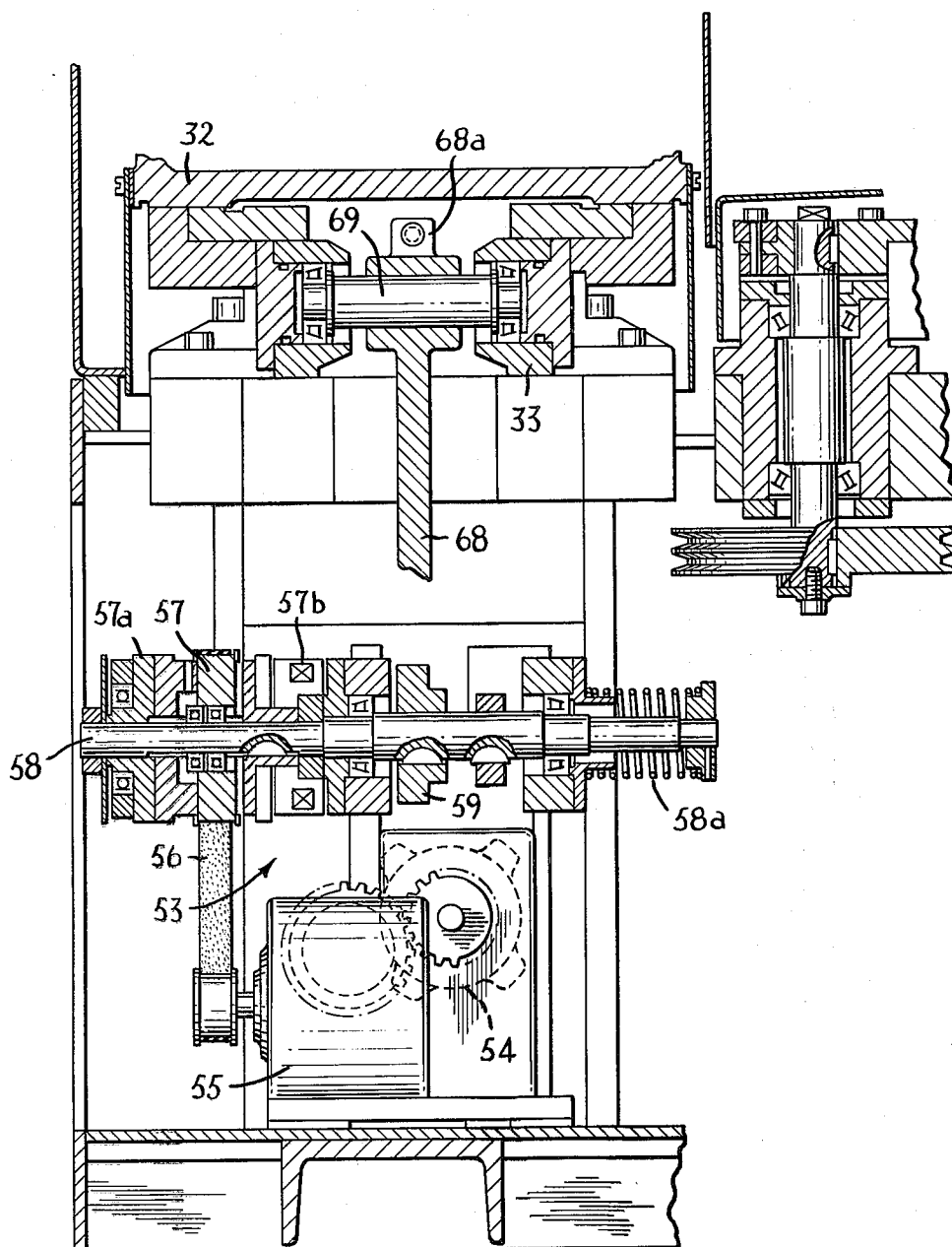


FIG. 14

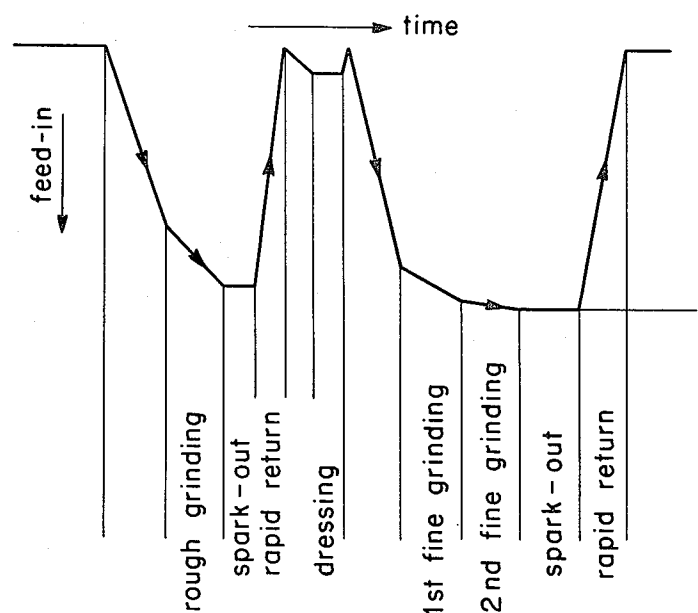


FIG. 15

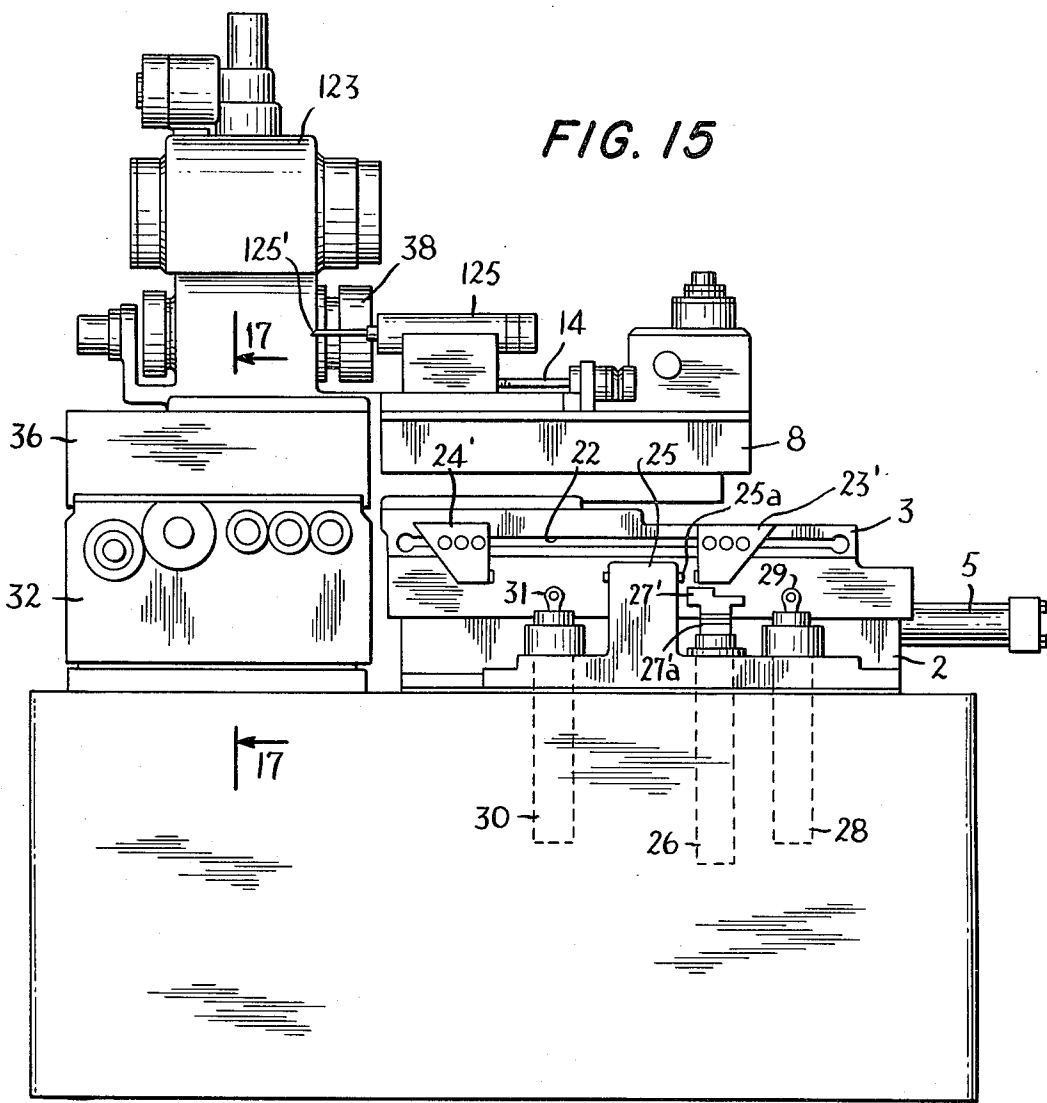
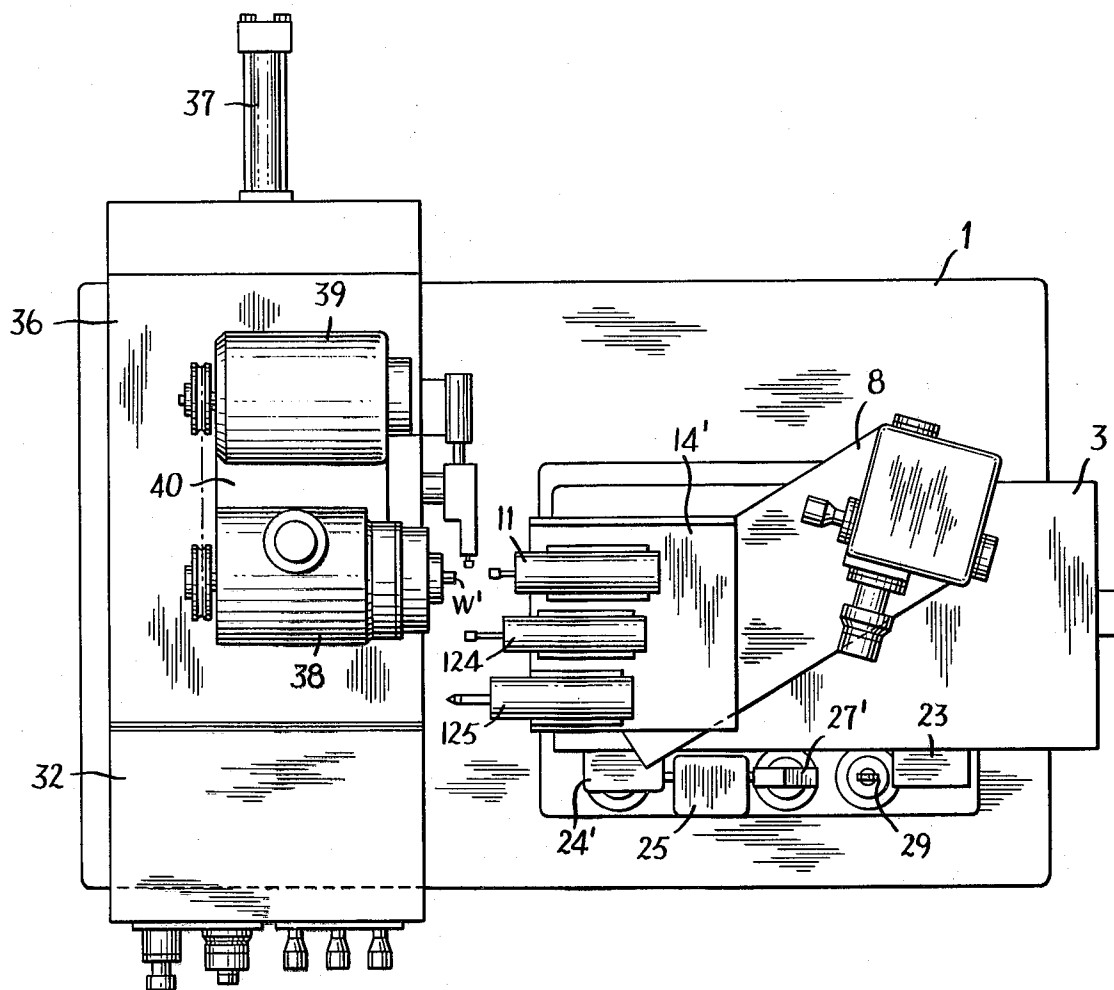
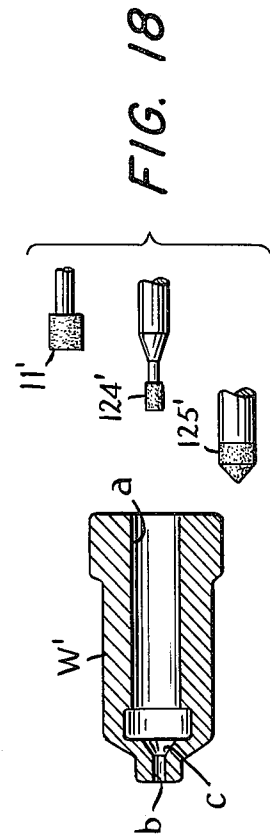
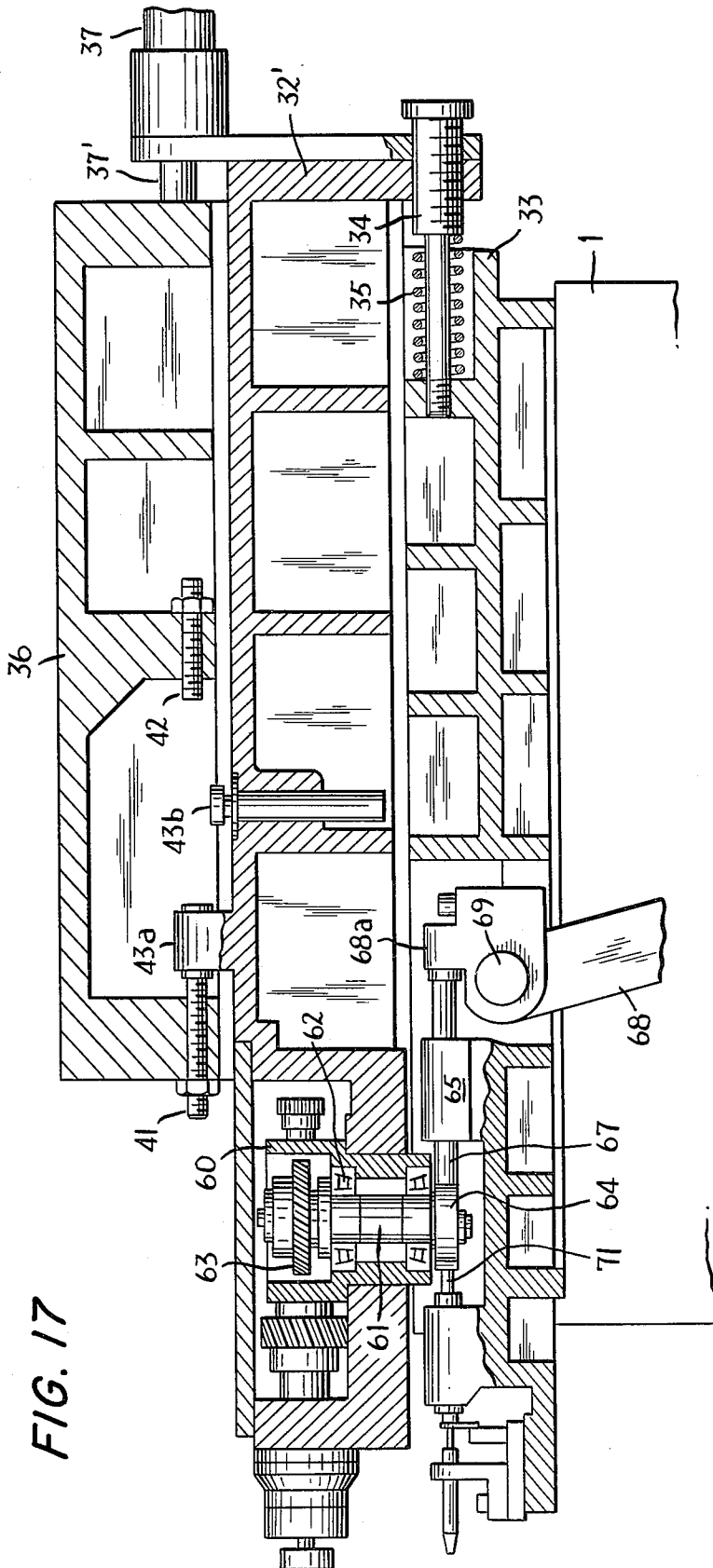


FIG. 16





## INTERNAL GRINDER

## BACKGROUND OF THE INVENTION

This invention relates generally to grinding and more particularly to a new and improved grinder.

The grinding of workpieces ground externally and internally generally presents a problem in that the individual workpieces are transferred to different work stations where the different grinding operations take place. The transfer of the workpiece may require different time-consuming setups and the possibility of inaccurate grinding and accordingly non-uniformity among similar workpieces.

Moreover, where one chucking of a workpiece is effected the grinders are subject to wear and change in dimension because of wear and dressing thereof so that inaccuracies in the grinding may exist if the changes in dimension are not constantly monitored and compensation therefor effected.

## SUMMARY OF THE INVENTION

An object of this invention is to provide an internal grinder, wherein a plurality of wheel spindles is mounted on a reciprocable table and each of the wheel spindles is respectively moved in the direction of the work spindle, so that workpieces with a plurality of inner surfaces are ground with higher accuracy as to a longitudinal dimension.

Another object of the invention is to provide a precise feeding device for machine-tool feed tables, wherein sensors detect the proper feeding positions of the feed table which is advancing the workpiece to a grinding wheel and the outputs of the sensors control the table speed, so that work-pieces are ground with higher accuracy as to a radial dimension, with superior surface finish and with higher grinding speed.

Another object of the invention is to provide a compensating apparatus for grinding wheel dressing, wherein a sensor detects the predetermined table feeding positions for wheel dressing and the output of the sensor controls the table feeding means to feed the table by a dressing depth of the grinding wheel, so that workpieces are ground in a same or uniform size in spite of the decrease of grinding wheel diameter caused by dressing. The internal grinder according to the invention comprises a first wheel head table which is slidable and reciprocable in a work spindle direction. A second wheel head table is mounted on the first wheel head table and is slidable and reciprocable in an oblique direction with respect to that of the first wheel head table. A plurality of grinding wheel spindles are mounted on the second wheel head table. A feed-in table is disposed in front of the first wheel head table and is slidable in a proper direction with the sliding direction of the first wheel head table. A shift table is slidably mounted on the feed-in table whereon a work spindle is mounted, thereby the shift table is shifted so that the work spindle is successively located to positions corresponding to positions for each of the grinding wheel spindles and each portion, such as a cylindrical portion or a tapered portion, of the inner surface of a work-piece is ground by a corresponding grinding wheel, so that, in a single set-up of one work-chucking, work-pieces with a plurality of inner surfaces are ground with higher and more precise concentricity.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevation view of an internal grinder according to the present invention.

FIG. 2 is a plan view of the internal grinder in FIG. 1.

FIG. 3 is a left side elevation view of the internal grinder in FIG. 1.

FIG. 4 is an offset cross section view of the internal grinder in FIG. 1.

FIG. 5 is a cross section view taken along section line 5-5 of FIG. 4.

FIG. 6 is a diagrammatic section view of a workpiece and associated grinders for grinding it.

FIG. 7 is a cross section view taken along section line 7-7 of FIG. 2.

FIG. 8 is a front elevation view of a dressing apparatus of the internal grinder according to the invention.

FIG. 9 is a cross section view taken along section line 9-9 in FIG. 7.

FIG. 10 is a diagrammatic illustration of sensors constituting differential transformers for feed-in table sensing and control.

FIG. 11 is a horizontal cross section view of a compensating mechanism on the internal grinder of FIG. 1.

FIG. 12a is a section view taken along section line 12a in FIG. 11.

FIG. 12b is a section view taken along section line 12b in FIG. 11.

FIG. 13 is a section view taken along section line 13-13 in FIG. 3.

FIG. 14 is a time graph of the operation of a feed-in table on the internal grinder in FIG. 1.

FIG. 15 is a front elevation view of a second embodiment of an internal grinder according to the invention.

FIG. 16 is a plan view of the grinder in FIG. 15.

FIG. 17 is a section view taken along section line 17-17 in FIG. 15.

FIG. 18 is a diagrammatic illustration of a workpiece in section and associated grinders of the grinder for grinding thereof.

Other objects and advantages will appear from the following description of an example of the invention, and the novel features will be particularly pointed out in the appended claims.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the attached drawings in which FIGS. 1 to 3 show the general aspects of an internal grinder according to the present invention, and in which the grinder has a base 1. On one side thereof is provided a table stand 2. A first wheel head table 3 is slidably supported by the stand 2, through roller guide members 4, which are, as shown in FIG. 4, placed in the table stand 2. A hydraulic cylinder 5 is mounted on the table stand 2. As shown in FIG. 5, an end of the cylinder's piston rod 5' is connected with a projecting portion 3' of the table 3 to drive the wheel head table 3. A cam follower 6 is secured under the leading side of the table 3. A table reciprocating apparatus 7 is secured on the base 1 for coaction with the cam follower 6. The reciprocating apparatus 7 consists of a hydraulic motor 7a mounting an eccentric cam 7c on its shaft 7b. The first wheel head table 3 is reciprocated by a camming operation while the cam follower 6 is kept in contact with the rotating cam 7c by the hydraulic cylinder action.

A first swivel table 9 is mounted on the wheel head table 3. The swivel table is swingable to a selected angle by pivoting on a pin 9a as shown in FIG. 5. This swivel table supports a second wheel head table 8 slidable in one direction on a roller guide member 10. A second swivel table 13 is mounted on the second wheel head table 8, and is swingable to a selected angle by pivoting on a pin 13a. A grinding wheel spindle 11 for grinding a bore surface a of a workpiece W, shown in FIG. 6, is secured on the second swivel table 13. The second swivel table 13 is provided with a slidable spindle stand 13b and an adjusting knob 15. Another wheel spindle 12 for grinding a seat surface b of the workpiece W is secured on the upper surface of this spindle stand 13b. The spindle stand 13b is connected with the adjusting knob 15 through a threaded rod 14. Thus, the grinder wheel spindle 12 is adjustable slidably on the spindle stand 13b.

On the first swivel table 9, is mounted a hydraulic cylinder 16 to reciprocate the second table 8. A piston rod 16' of this cylinder 16 is connected with a projection 8' of the second table 8. A cam follower 17 is mounted at the back end of the second table 8. A hydraulic motor 18 with an eccentric cam 19 is mounted on the first swivel table 9. The pressing action of the hydraulic cylinder 16 keeps the eccentric cam 19 in contact with the cam follower 17. A stop 20 is secured on the first wheel head table 3, and an adjustable threaded stop 21 extends through an apron portion of the second wheel head table 8. The adjust stop 21 is brought into contact with the fixed stop 20 to locate the second table 8 at the end of its stroke. When the cylinder 16 moves the second table backwardly, the cam follower 17 is separated from the eccentric cam 19.

As seen in FIG. 1, a dog attaching groove 22 is provided on the front surface of the first wheel head table 3. A pair of dogs 23 and 24 is mounted on this groove 22. Each of the dogs is adjustable along the groove 22. A stop block 25 is fixedly mounted on the base 1. A protruding portion thereof is spaced between the dogs 23 and 24. A stop 25a is fixed on the protruding portion of the block 25 facing the right hand dog 23, while another stop 25b faces the other dog 24. An intermediate stop 27 is disposed adjacently the right hand dog 23 on one side of the projecting portion 25 and is connected with an end of a piston rod of a cylinder 26 through parallel springs 27a. The intermediate stop 27 is actuated upwardly and downwardly by the hydraulic cylinder 26. After the table 3 has withdrawn, the intermediate stop 27 is pushed up between the stop 25a and the right hand dog 23 by the operation of the hydraulic cylinder 26. Even if there is a little clearance between the intermediate stop 27 and the stop 25a, the clearance is eliminated by parallel movement of the intermediate stop 27 caused by the parallel springs 27a when the table 3 moves forward again and the right hand dog 23 pushes the intermediate stop 27.

A clammer 29 is fixed on a piston rod of a hydraulic cylinder 28, which is mounted on the stop block 25. The clammer protrudes from the stop block 25 and is spaced from the intermediate stop 27. The clammer 29 and the intermediate stop 27, which is already fixed upon the stop 25a, hold the right hand dog 23 between them in a releasably locked state, and thus, determine the axial position of the grinding wheel spindle 12 against the workpiece W. A clammer 31 is fixed on the piston rod of a hydraulic cylinder 30, which is mounted on the other side of the stop block 25. When the first

table 3 goes backward, the right hand dog 24 abuts on the stop block 25, and the clammer 31 moves upwardly. The first table 3 is releasably held in a locked state between stop 25b and the clammer 31. Thus, the axial position of the guiding wheel spindle 12 for dressing is determined.

A feed-in table 32 is mounted on the base 1 slidable at an angle, usually at right angles, to the direction of travel of the first table 3, through a tablestand 33, which is fixedly mounted on the base 1. An adjusting screw 34 is threaded in the back wall of this table 32. A spring 35, shown in FIG. 7, is inserted between the adjusting screw 34 and the table stand 33, and biases the feed-in table in a backward direction. A shift table 36 is mounted on this table 32 slidable in the same direction as that of the feed-in table 32 through a roller guide member (not shown). As shown in FIG. 7, a hydraulic cylinder 37 is mounted horizontally on the rear surface of the feed-in table 32. An end of its piston rod 37' is connected with the shift table 36. The hydraulic cylinder 37 shifts the shift table 36. A work spindle 38 and its driving motor 39 are mounted on the shift table 36 through a supporting stand 40 as shown in FIG. 8. On the lower part of the shift table 36 threaded screw stops 41 and 42 are mounted, while a stop 43 is fixedly mounted on the feed-in table 32, having a stop surface corresponding to stop 41 and another stop surface corresponding to stop 42. The workpiece on the work spindle 38 is positioned in operation to be corresponding with one of the grinding wheel spindles 11 when the shift table 36 is moved by the hydraulic cylinder 37 so that the stop 41 comes into contact with the stop 43. The workpiece is positioned to be corresponding with the other grinding wheel spindle 12 at their taper surfaces, when the shift table is shifted so that stop 42 is in contact with the stop 43.

A shaft 45 mounting a dressing arm 46, see FIGS. 2 and 8, is supported rotatably in a supporting block 44 which protrudes from the support stand 40. One end portion of this arm 46 is connected with a piston rod 48 of a hydraulic cylinder 47 which is secured on the supporting stand 40, and the other end portion is provided with diamond dressers 49 and 50. One dresser 49 is for dressing a grinding wheel 11' and the other for dressing a grinding wheel 12'. A stop 51 positions the grinding wheel dressers 49 and 50 for dressing position in height by engaging with the arm 46. A stop 52 restricts the movement of the arm 46 when the dresser is moved away from its dressing position.

As shown in FIG. 3, the feed-in table is driven by a driving apparatus 53 mounted on the base 1 and consists of a D.C. motor 54, a reduction gear box 55 driven by the motor 54, a cam shaft 58 having a pulley 57 with a magnetic clutch. The pulley 57 is rotatable on a shaft 58. A belt 56 engages with pulley 57 and another pulley on the reduction gear box 55. A cam 59 fixedly mounted on the shaft 58, engages with a lever 68 through a cam follower 70 thereon to feed the feed-in table 32.

A bracket 60 is mounted in the fore portion of the feed-in table 32. An upstanding shaft 61 is mounted rotatably on the bracket 60 through roller bearings 62. A worm wheel 63 is fixedly mounted on the upper end of the upstanding shaft 61, and an eccentric disc 64 is fixedly mounted on the lower end as shown in FIG. 7. A feed rod 67 is held slidably in a radial direction of the disc 64, through a supporting case 65 and a ball slide bearing 66 and has an end in contact with the periph-

eral surface of the disc 64. The other end of the feed rod 67 abuts on one end 68a of a feed lever 68. This feed lever 68 for feeding in the feed-in table 32 is rotatably mounted in the table stand 33, through a shaft 69, having a cam follower 70 at its lower end. The cam follower 70 is in contact with the cam 59. According to the grinding amount of the workpiece, the feed-in table 32 is, thus, fed forward through the cam lead.

Upon the opposite peripheral surface of said disc 64, coaxial with the feed rod 67 is disposed a control pin 71 which is slidably inserted in a guide sleeve 73, fixed in a supporting frame 72. The supporting frame is formed as a unit with the table stand 33. On the other end of the control pin 71, a movable plate 75, held by parallel springs 74, which project from the support frame 72, is contacted and the amount of feed-in movement is detected by three differential transformers 76, 77 and 78 hereinafter described.

FIG. 9 shows the feed mechanism, along section line 9-9 of FIG. 7. In dressing of the grinding wheels 11' and 12', this feed mechanism moves the feed-in table 32 forward only the dressing amount feed-in so that the required dressing feed-in is performed on the grinding wheels 11' and 12'. The worm wheel 63 forms a part of this mechanism and meshes with a worm 79 which is securely mounted on a shaft 81. The shaft 81 is rotatably supported on a frame 80 of the feed-in table 32, and set at right angles to the upstanding shaft 61. A worm wheel 83 is mounted in the middle of the shaft 61 through a one-way clutch 82. A rotation transmitting shaft 85, provided with a worm 84 (as shown in FIG. 7) engaging with the worm wheel 83 on its one end, is rotatably mounted on the frame 80. A pinion gear 86 is mounted in the other end of the rotation transmitting shaft. The pinion meshes with a rack 88 formed on a pinion rod 87' of a hydraulic cylinder 87 secured on the frame 80. Reciprocating motion of the rod effected by the hydraulic cylinder 87 causes, step revolutions of the shaft 81 and rotates the disc 64 at some angles and moves in order the feed-in table 32 forward only by the dressing feed-in amount of the grinding wheels 11' and 12'. In addition, a microswitch 89 controls the stroke of the hydraulic cylinder 87 and changes the oil paths or flow of the hydraulic cylinder 87 by means not shown.

Referring now, FIG. 9, to a manual operating mechanism for controlling of dressing feed-in of this feed-in table 32, an end side portion of the shaft 81 extends and protrudes out of an outer end of the feed-in table 32. A dial knob 91 is fixedly mounted on this projecting end. The amount of dressing the grinding wheels effect can be adjusted manually by operating the dial knob 91. Namely, in the axis of the shaft 81 an inner shaft 92 with a knob 92' at one end is inserted and extends from the outer end of the shaft 81 to the one-way clutch 82. The inner shaft 92 is threaded into shaft 81, and an elastic expanding piece 93 is loosely inserted in a hole bored in the outer shaft 81 perpendicularly to its axis and has a tapered split engaging with a tapered end of the inner shaft 92. The rotation of the worm wheel 83 is transmitted to the outer shaft 81 by tightening knob 92' and wedging the inner shaft 92 in the expandable piece 93, accordingly one-way clutch 82 and the shaft 81 operate as a unit, and thus on the one hand, automatic feed-in by the hydraulic cylinder 87 is performed, on the other hand, manual feed-in can be carried out through the dial knob 91 by loosening the knob 92' to withdraw the shaft 92 and to disengage the one-way clutch 82 from the outer shaft 81.

A microswitch 94 is fixed on the table stand 33 for detecting a starting position of the feed-in table 32 to feed-in for dressing new wheels. The starting position is such a position that each dresser 49 or 50 is spaced close to the new wheel. Another microswitch 95 is fixed on the table stand 33 in parallel with the microswitch 94, for detecting a position of the feed-in table 32 that the wheel is dressed up to the maximum size for grinding. A microswitch 96 is fixed on the table stand 33 in parallel with both switches 94 and 95, for detecting a position of feed-in table 32 such that the wheel is dressed up to the minimum size usable for grinding. The protruding end of dial knobs 98, 99 and 100 are provided in the side wall of the feed-in table 32. Each of the dial knobs corresponds with a corresponding one of the microswitches. By the dressing feed-in operation of the feed-in table 32 caused by rotation of the disc 64 each switch 94, 95 or 96 is controlled and the decreasing condition of the grinding wheel dimension can be detected.

A gear 101 is secured on an end of the inner shaft 81 protruding from the frame 80. A driving gear 104 secured on the shaft of an electric motor 103 is coupled with this gear 101 through gear train or drive-transmitting mechanism 102. The worm wheel 63 is rotated by the motor 103 through the gear-train, making the feed-in table 32 move backwardly to the above mentioned starting position.

The differential transformer 76 detects the dressing position of the feed-in table 32. Another differential transformer 77 detects the seat surface grinding position, and a third differential transformer 78 detects the cylindrical surface grinding position. Each of the differential transformers is mounted on the table stand 33 through a supporting frame 105 as shown in FIG. 10. When the feed-in table 32 moves forward by the action of the feed-in driving apparatus 53 in feeding step, each of the differential transformers is sequentially operated, and so, the feed-in table positions for the dressing grinding wheels, for the wheel 11' to finish the inner cylindrical surface of the workpiece and for the wheel 12' to finish the seat surface, are detected. These detection signals are used to control the feed-in driving apparatus 53.

As the feed-in table 32 shifts forwardly a little at every dressing, the relative axial position between the work-piece on the feed-in table 32 and the grinding wheel 12' on the table 8 varies, so that the seat surface of the workpiece to be ground varies in spacing from the conical surface of the grinding wheel 12'. FIGS. 11, 12a and 12b show a feed mechanism 106 to move the second table 8 forward a little in a direction to compensate the above-mentioned phenomenon. A vertical rotating shaft 108 on the second table 8 is rotatably mounted on a frame yoke 107 of this mechanism 106 through roller bearings 109. The cam follower 17 to reciprocate the second wheel head table 8 is secured eccentrically on the lower end of the rotatable shaft 108. A worm wheel 110 is mounted on an upper end portion of the rotating shaft 108. The worm wheel 110 meshes with a worm 111. This worm 111 is secured on a shaft 112 which is rotatably supported on the frame yoke 107 at right angles to the shaft 108. A pinion gear 114 is secured in the middle portion of the shaft 112 through a one-way clutch 113. A rack 116 formed on a plunger 115' of a hydraulic cylinder 115, which is mounted on the frame yoke 107, meshes with the pinion gear 114 and so, the shaft 112 is intermittently ro-

tated by reciprocating plunger 115 through the one-way clutch 113. Thus the worm wheel 110 is rotated and the circular center of the cam follower 17 is gradually moved around the axis of the upstanding shaft 108. And the second table 8 is shifted forward by a needed amount for dressing compensation through the eccentric cam follower 17, when the table 8 is in such a state as to be reciprocated by the hydraulic motor 18. A screw stop 117 of the dial type for adjusting the plunger stroke is threaded in a flange 118 at a side of the frame yoke 107 coaxial with the axis of the plunger 115'. A spring 119 is inserted between the stop and the plunger 115'.

Referring to the manual compensation mechanism of the second table 8, on an end portion of the shaft 112 which extends and protrudes out of the frame yoke 107, a dial type knob 120 is secured, and the dressing compensation of the grinding wheel 12' is obtained by manually operating this knob 120. That is, in the axis of the shaft 112, an inner shaft 121 having a knob 121' is inserted and extends from its protruding end portion to a one-way clutch 113. The inner shaft 121 is threaded into the outer shaft 112. An elastic expandable piece 112 is loosely inserted in a hole bored in the outer shaft 112 perpendicularly to its axis and has a tapered split engaging with a taper end of the inner shaft 121. The above-mentioned automatic shift by the hydraulic cylinder 115 is performable, when the inner shaft 121 is tightened and wedged into the expandable piece 122 and the one-way clutch 113 and shaft 112 become one unit. By loosening the knob 121', the combination of the one-way clutch 113 and the inner shaft 112 is disconnected and a manually feed-in is performed by the dial knob 120. An automatic loading device 123 for the workpieces is mounted on the work spindle 38.

#### OPERATION

Next, the operation of the present invention will be described. In case a traverse grinding for the cylindrical and seat surfaces of workpiece W as shown in FIG. 6 is performed, the first swivel table 9 is swiveled, so that the sliding direction of travel of the second table 8 is set to coincide with a line crossing the seat surface of work-piece W and the horizontal diametral plane. The grinding wheel spindles 11 and 12 are set in parallel with the work spindle 38 after swiveling of the second swivel table 13. The swivel table 13 is secured on the second table 8, then, the wheel spindles 11 and 12 are first dressed. That is, the shift table 36 is shifted through the hydraulic cylinder 37 until the stop 41 abuts on the stop 43 as shown in FIG. 7. The work spindle 38 and spindle 11 for grinding the cylindrical surface are in opposed positions and the dresser arm 46 is swiveled counterclockwise through the cylinder 47 shown in FIG. 8 and abuts on the stop 51, and the dresser 49 approaches the extension area of the grinding wheel 11'.

Next, after the first table 3 is rapidly moved forward through the hydraulic cylinder 5, it is controlled by microswitches mounted on the table stand 2 and a dog secured on the table 3 (not shown). The grinding wheel 11' is reciprocated to an opposite position to the dresser 49 through the hydraulic cylinder 5. On the other hand, as the hydraulic cylinder 87 shown in FIG. 9 is reciprocated, the eccentric disc 64 shown in FIG. 7 performs intermittent rotation from its original position, the feed-in table 32 is moved forwardly and the first dressing is performed. In this time interval, the sec-

ond table 8 is returned and kept backward through the hydraulic cylinder 16 until the stop 21 abuts on the stop 20. After dressing grinding wheel 11', the dressing arm 46 is swung clockwise by means of the operation of hydraulic cylinder 47 by operating the microswitch 95 through a pointed end of the dial knob 99, and the disc 64 returns to its original position. The first table 3 moves backward through the hydraulic cylinder 5, the dog 24 abuts on the stop 25b, then, the hydraulic cylinder 30 raises the clasper 31, and the first table 3 is clamped. The dog 24 is securely held between the block 25 and clasper 31. Simultaneously, the shift table 36 is shifted to the position in which the screw stop 42 abuts the stop 43. The dressing arm 46 is abutted on the stopper 51 again with a swiveling motion, and the dresser 50 approaches the extension area of grinding wheel 12'. After the second table 8 is rapidly moved forward through the hydraulic cylinder 16 it is controlled by microswitches (not illustrated) mounted on the swivel table 9 and a dog (not illustrated) mounted on table 8. The grinding wheel 12' is reciprocated to a position opposite to the dresser 50 through the hydraulic cylinder 16, and the feed-in table performs the dressing feed-in as in the dressing of the grinding wheel 11'.

After the dressing, the microswitch 95 operates and the dressing arm 46 withdraws. The shift table 36 is shifted again, so that the work spindle 38 is opposed to the spindle 11 for grinding of the cylindrical surface. The clasper 31 drops down to release the clamp of the first table 3. The second table 8 is fixed, stop 20 abuts on the stop 21, after returning back through action of the hydraulic cylinder 16. The cam follower 6 engages with the eccentric cam 7c by a rapid forwarding of the table 3 through the hydraulic cylinder 5, and the table 3 and the grinding wheel 11' begin reciprocating motion by driven of the reciprocating apparatus 7. The driving apparatus 53 begins to operate, the feed-in table 32 is imparted a feed-in motion through the feed lever 68, feed rod 67 and disc 64 moving in correspondence to the cam 59, and the traverse grinding of the cylindrical surface is performed with the above-mentioned reciprocating motion of grinding wheel 11'.

As shown in the diagram in FIG. 14, the movement of the feed-in table 32 is set such that, rapid forwarding, rough grinding feed-in, spark-out, rapid return, dressing feed-in, rapid forwarding, the first fine grinding, the second fine grinding, spark-out and rapid return are carried out. To begin with, the feed-in table 32 is moved at high speed by means of the high-rotation speed of DC motor 54 in the driving apparatus 53 through the cam 59 and the feed lever 68. And, when the grinding wheel 11' comes in contact with a cylindrical surface *a* of the workpiece, the differential transformer 78 detects a feed-in speed change point and makes the DC motor 54 rotate with a lower speed, the feed rate of the feed-in table 32 falls in appropriate velocity for rough grinding. At this feed rate, a cylindrical surface of the workpiece is rough-ground with the reciprocating motion of the grinding wheel 11'.

When the required rough grinding is performed for a given grinding of the workpiece, the differential transformer 78 detects another change point. The clutch 57a in FIG. 13 puts out and the cam shaft 58 is held by putting on the brake 57b. That is, the infeed table 32 is stopped in this position, the spark-out of the rough grinding is performed. Next, when the brake 57b puts out by a signal of the spark-out timer for rough grind-

ing, the cam shaft 58 reverses rapidly through a torsion bar spring 58a secured in the end of the cam shaft, the feed-in table 32 is moved backwardly rapidly through the spring 35.

The first table 3 is moved backward to the starting position of the required dressing and the surface of the grinding wheel 11' which effected the rough grinding is dressed. The feed-in table 32 is moved backward only the needed amount for dressing feed-in of the grinding wheel 11' to reciprocate the hydraulic cylinder 87 of the dressing feed-in and to rotate the disc 64 by the worm wheel 83, the shaft 81 and the worm wheel 63.

Next, the feed-in table 32 is moved forward a little by the driving apparatus 53 and the dressing position is detected by the differential transformer 76. The driving apparatus of the feed-in table 32 is stopped at its position. The hydraulic cylinder 87 for dressing feed-in performs one reciprocation. The disc 64 is rotated a little by the worm wheel 83, shaft 81 and the worm wheel 63, the dressing apparatus and the first wheel table 3 are operated in the same way as the above mentioned first dressing, and dressing for fine grinding is performed. With the finish of the fine dressing, the first wheel table 3 is moved forward and performs reciprocating motion. At the same time the feed-in table 32 is rapidly moved forward by the driving apparatus 53 and performs the feed for fine grinding from the position detected by the differential transformer 78.

The first grinding wheel table is reciprocated through its reciprocating device, the cylindrical surface *a* of the workpiece *W* has performed thereon a fine grinding as far as the feed-in table travels and reaches the position where the output of the differential transformer 78 is reduced to zero. When the output of the differential transformer 78 is reduced to zero, after the fine grinding spark-out at a constant-time set in advance by a timer, not shown, in the same time as the rough grinding is performed. And the clutch 57a of the driving apparatus for feed-in is declutched; the cylindrical surface grinding of workpiece *W* is finished. The cam 59 is rotated in an opposite direction through the torsion bar spring 58a and the feed-in table 32 is returned in the original position through spring 35.

When the cylindrical surface grinding is finished, the first wheel table 3 moves backward until the dog 24 engages with the stop 25b. Next when the intermediate stop 27 ascends, again the table 3 moves forward and the dog 23 is engaged with the intermediate stop 27. The clamber 29 is raised by the hydraulic cylinder 28 and the dog 23 is held between the intermediate stop 27 and the clamber 29, table 3 is securely held in a fixed condition.

Simultaneously, the shift table 36 is moved forward by operation of the hydraulic cylinder 37 until the stop 42 engages with the stop 43, for positioning the wheel spindle 12. Next, the second wheel table 8 is moved forward by the hydraulic cylinder 16, the cam follower 17 is engaged with eccentric cam 19 of the hydraulic motor 18 and the table 8 is reciprocated by the hydraulic motor 18. The grinding wheel 12' is inserted in the seat surface *b* of the workpiece. When the feed-in table 32 is moved forward to feed-in the seat surface of the workpiece is ground by the driving apparatus 53 the same as in the cylindrical surface grinding. When the feed-in table 32 is fed by the driving apparatus, it is similar to the cylindrical surface grinding in that the differential transformer 77 performs the changing of feed-in rates, detects the position of spark-out and controls the

driving apparatus 53. And the dressing before fine grinding is performed with the above-mentioned method. In this mode, the second table 8 is compensated in its movement forward, the eccentric cam follower 17 is rotated by the hydraulic cylinder 115, through rack 116, pinion 114, one-way clutch 113, shaft 112, worm 111 and worm wheel 110, to cancel any lack of correspondence between seat surface of workpiece *W* and the cone surface of the grinding wheel 12 caused by a dressing feed-in of the feed-in table 32. Upon completion of this seat surface grinding, the first table 3 moves backward sufficiently for the ground workpiece to be discharged from the work spindle 38, and a new workpiece is fed to the work spindle 38 by the automatic loading apparatus 123, the shift table 36 completes moving backward.

The above-mentioned operation is performed as one cycle, and a series of the cycles are carried out. When the grinding wheel 11' for grinding the cylindrical surface is worn out and no longer is usable because it has reached a minimum diameter, the microswitch 96 operates and an exchange indication for changing of the guiding wheel 11' is indicated. The indicating graduations on dial knob 120 show the exchanging needs and thereby when the time comes for exchanging the grinding wheel 12' for grinding the cylindrical surface.

## SECOND EMBODIMENT

FIGS. 15 and 16 show general views of another embodiment of this invention. The parts having the same reference numerals as those heretofore described correspond thereto. A wheel spindle 11 with a grinding wheel 11', to grind a cylindrical surface *a* of workpiece *W* shown in FIG. 18, a wheel spindle 124 with a grinding wheel 124' to grind another cylindrical surface *b* and a wheel spindle 125 with a grinding wheel 125' to grind a seat surface *c* are mounted on the table 8.

A pair of dogs 23' and 24' are mounted on a groove 22 prepared on the front wall of the first wheel head table 3. An intermediate stop 27', which is provided with two of engageable end faces with the dog 23', is spaced close to a stop block 25. This intermediate stop 27' is connected with the top of a piston rod of a cylinder 26 through parallel flat springs 27', and 27'a which correspond to the springs 27 and 27a of the first embodiment. A clamber 29 and said intermediate stopper 27' clamp and set the position of the first table 3 for a grinding wheel 124' to grind the cylindrical surface *b* and the position for the grinding wheel 125' to traverse-grind the taper surface *c*. When the first table 3 moves backward and the dog 24 abuts on the block 25, the first table 3 is held in a locked state for grinding wheel 125' to be dressed, the clamber 31 having been moved upward.

As shown in FIG. 17, screw stops 41 and 42 set feed-in table positions for a work spindle 38 to be located in positions corresponding with a wheel spindle 11, 124, or 125. Stop 41 abuts on a stop receiver 43a, which is fixedly mounted on the feed-in table 32, to position the work spindle 38 corresponding to wheel spindle 11. Stop 42 abuts on the stop 43a, and positions work spindle 38 corresponding to a wheel spindle 125, and stop 42 abuts on an intermediate stop 43b, which is slidably supported on feed-in table 32 and is engageable with the stop 42 at its upper position, to position work spindle 38 corresponding to a wheel spindle 124. Each of other numerals in this embodiment of FIGS. 15 to 18 correspond to that in the first embodiment of FIGS. 1

to 13.

## OPERATION OF SECOND EMBODIMENT

The operation of this embodiment is mentioned below. In case the cylindrical surface *a* of the workpiece *W'* shown in FIG. 18 is to be ground the shift table 36 is moved by the hydraulic cylinder 37 until the stop 41 abuts on a stop receiver 43a, and so, the work spindle 38 is against the grinding wheel spindle 11. Then the cylindrical surface *a* of the work-piece on work spindle 38 is traverse-ground in the same way as in the first embodiment.

In finish grinding of the cylindrical surface *a* the first table 3 and the feed-in table 32 move backward respectively, and then, the first table 3 is moved forward and stop 23' abuts on the middle and recessed engageable face of the intermediate stop 27', which is held at a middle position, after the shift table 36 moves forward and is located in order that the work spindle 38 is in position corresponding to the grinding wheel spindle 124, the intermediate stop 43b is spaced at an upper position and blocking stop 42. The grinding wheel spindle 124 is preset in this position so that the grinding wheel 124' may sufficiently grind the cylindrical surface *C* of the workpiece *W*. The surface *C* is ground with the feed-in movement of feed-in table 32. Then, the first table 3 is moved backward, the intermediate stop 27' is moved to its upper position so that the stop 23' abuts on the outside engageable face of the stop 27' afterwards the first table is moved forward again.

The shift table 36 is moved backward and intermediate stopper 43b is lowered after disengaging from the stop 42. Then the shift table 36 is moved forward again and the stop 42 abuts on the stopper receiver 43a. Thus the work spindle 38 corresponds with the wheel spindle 125, and the seat surface *b* of workpiece *W'* is ground in a way similar to that of the first embodiment.

Other features and structure of the second embodiment in FIGS. 15 to 18 are similar to those of the first embodiment. However, in case more than three wheel spindles grind respectively one or more cylindrical surfaces, or one or more tapered surfaces, it is preferable to provide some differential transformers in addition, corresponding to the number of wheel spindles. It is obvious that differential transformers as mentioned above in the embodiments are exchangeable with such other precise sensors as electro-magnetic sensors, pneumatic sensors on photo-electric sensors.

In the present invention, as described above, a plurality of wheel spindles is mounted on a second wheel head table. The second wheel head table is slidably mounted on a first wheel head table which is slidable in an oblique direction relative to the second wheel head table sliding direction. A work spindle is to be located corresponding to each of the wheel spindles on a shift table which is mounted on a feed-in table, and the workpiece held in the work spindle is successively ground at one chucking at each portions of a plurality of inner surfaces with traverse or feed-in motion, so that the internal grinding of excellent concentricity among inner surfaces, especially between a cylindrical

surface and a taper surface, is obtained with high efficiency.

Moreover, a feed-in driving apparatus is controlled by precise sensors, for example differential transformers, which detect feed-in table positions, so that suitable feed-in motion for any workpiece is easily obtained. Each detecting point is independently shiftable. The feed-in table is provided with dressers and a dressing feed apparatus, and the apparatus is controlled with a sensor which detects the feed-in table position for dressing away from other feed-in sensors' detecting positions so that uniformly sized work-pieces are obtained in spite of the decrease of the wheel diameter caused by the dressing, without longer loss time in the dresser approaching a grinding wheel, and the dressing depth is easily adjustable to the workpiece.

Those skilled in the art will understand that the electrical circuitry and hydraulic circuitry, not shown, necessary to effect the sequence of movements of the various components as described above, can be constructed in a suitable configuration.

We claim:

1. A grinding machine comprising, support means, a first grinding wheel head table mounted movably on said support means, a second grinding wheel head table transported on said first grinding wheel table and mounted for oblique movement relative to a direction of travel of the first grinding wheel head table, means mounting a plurality of driven grinding wheel spindles for driving a plurality of grinders for grinding a workpiece, a feed-in table mounted movably on said support means for movement relative to said first grinding wheel head table to feed in operation a workpiece to the grinders individually, a shift table mounted on said feed-in table for movement therewith and relative thereto, means mounting a workpiece-holding means for supporting a workpiece thereon, and means for moving said tables individually and including means moving them jointly for relatively positioning a workpiece on said shift table accurately relatively with said grinders individually in registry with said workpiece for grinding thereon and means to relatively feed at a progressively decreasing rate the grinders and workpiece for executing accurate and controlled grinding of the workpiece.

2. A grinding machine according to claim 1, including locating means for locating operative positions of said tables individually.

3. A grinding machine according to claim 1, in which said workpiece-holding means comprises a work-holding spindle.

4. A guiding machine according to claim 1, in which said means to relatively feed at a progressively decreasing rate the grinders comprises means to automatically move the feed-in table at decreasing rates.

5. A grinding machine according to claim 4, including means to automatically rapidly return the feed-in table to a position in readiness for dressing of the grinders, and subsequently feed said feed-in table to others of said grinders automatically at a progressively decreasing rate and then automatically rapidly return said feed-in table to said position.

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