June 6, 1961 J. C. WILSON 2,986,852

GRINDING MACHINES

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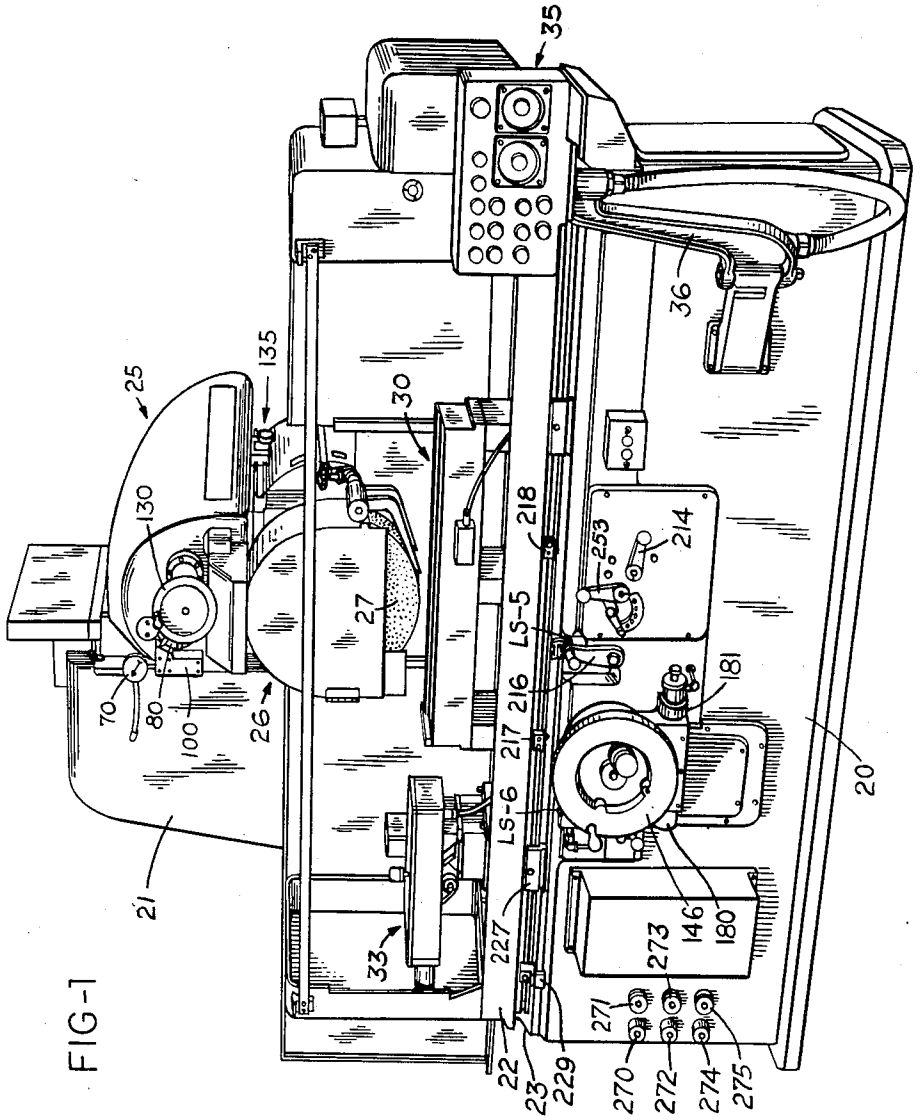


FIG-1

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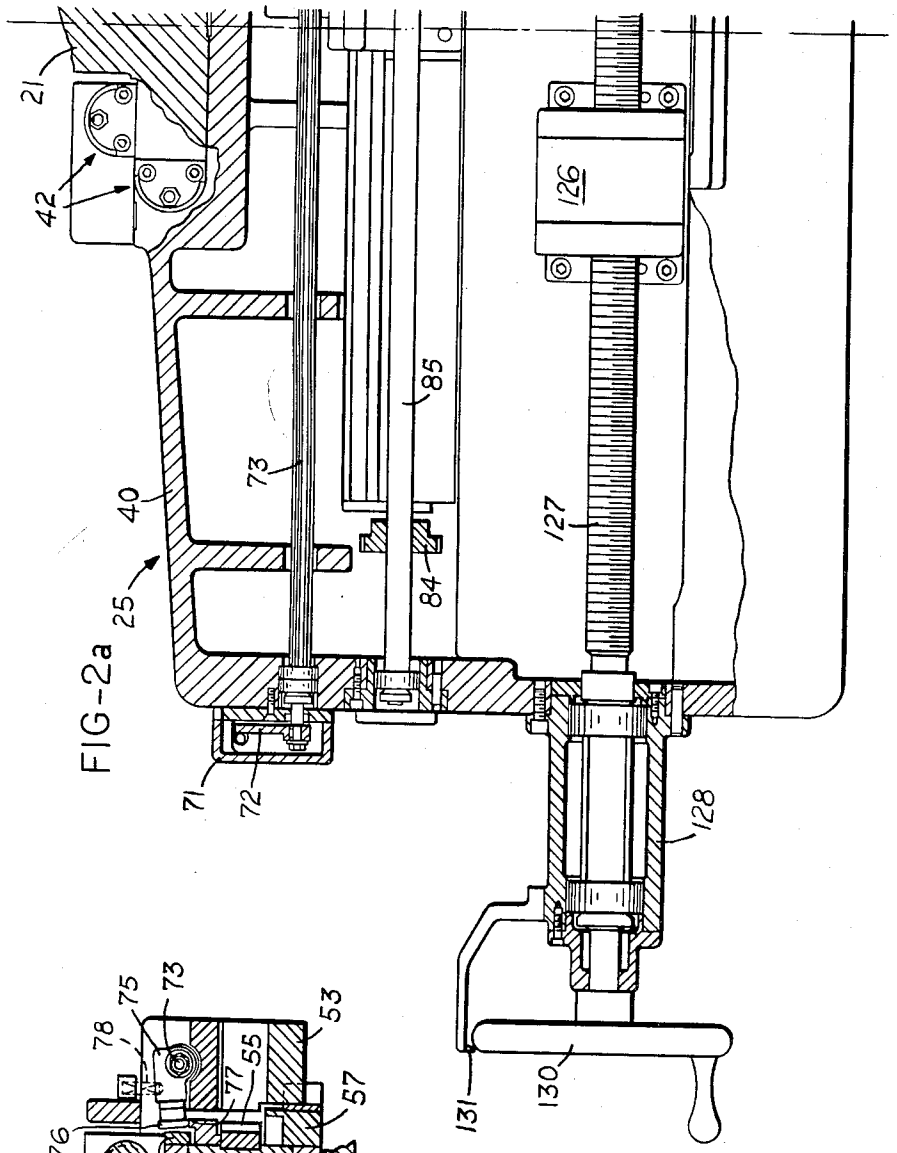


FIG-2a

FIG-3

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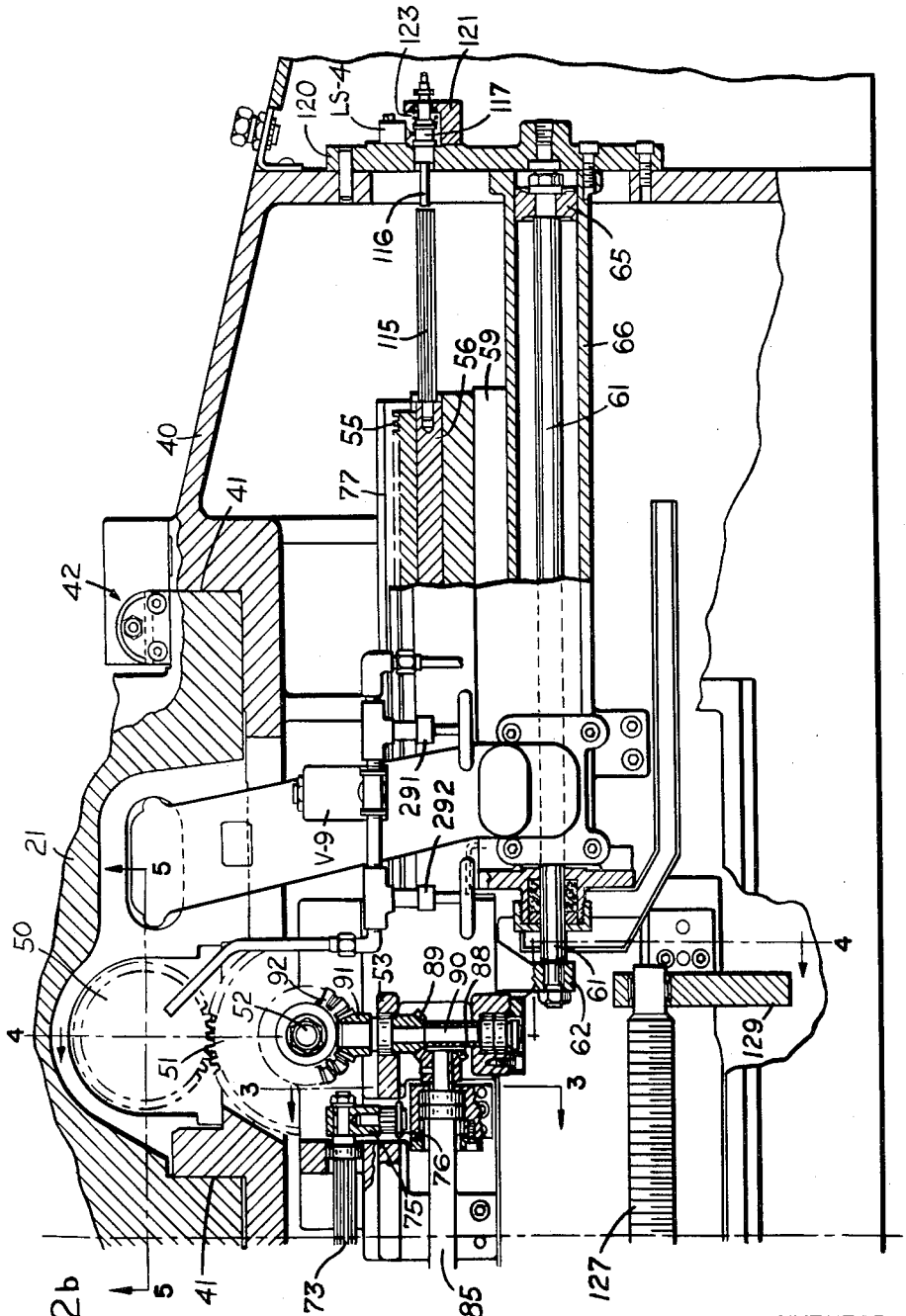


FIG-2b

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GRINDING MACHINES

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FIG-4

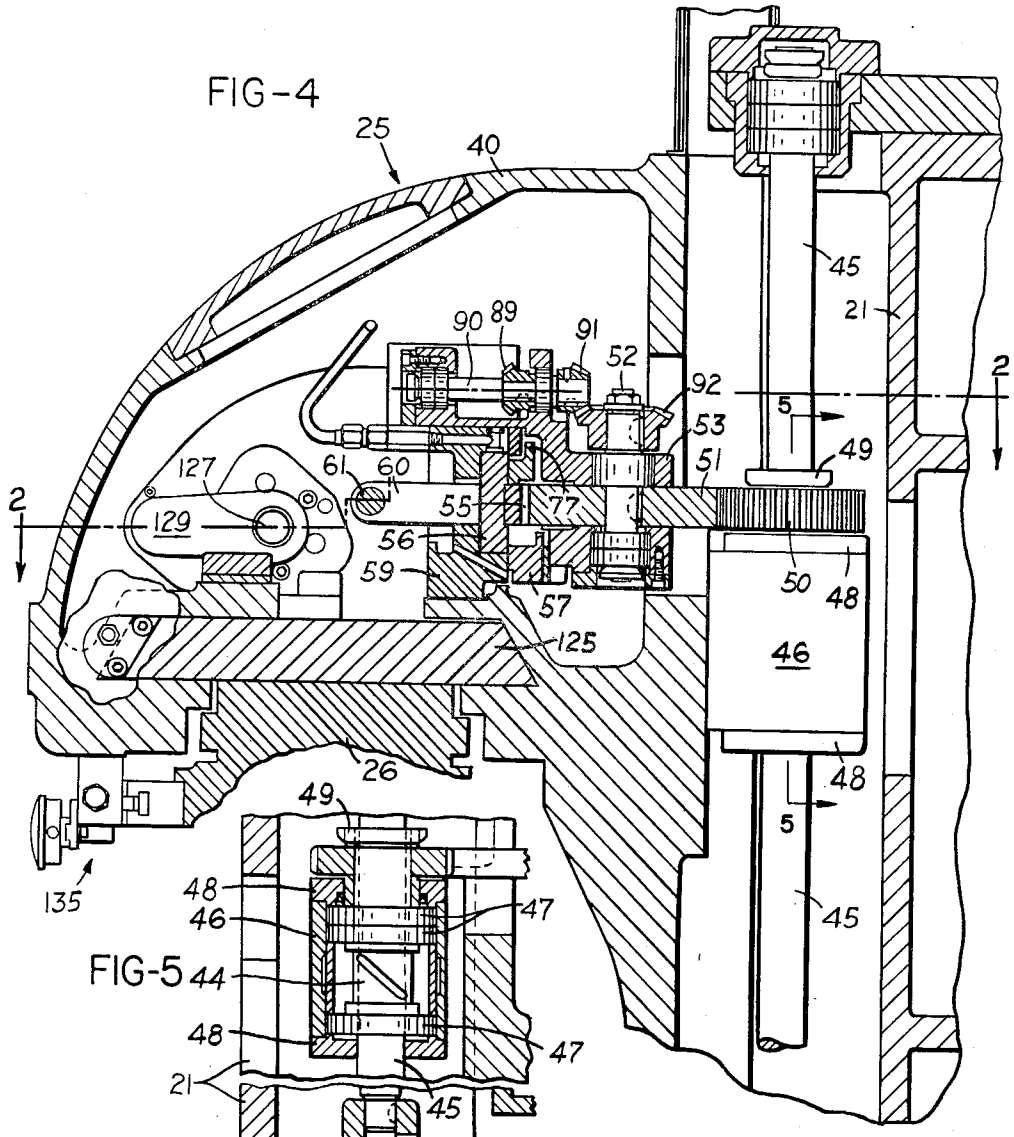
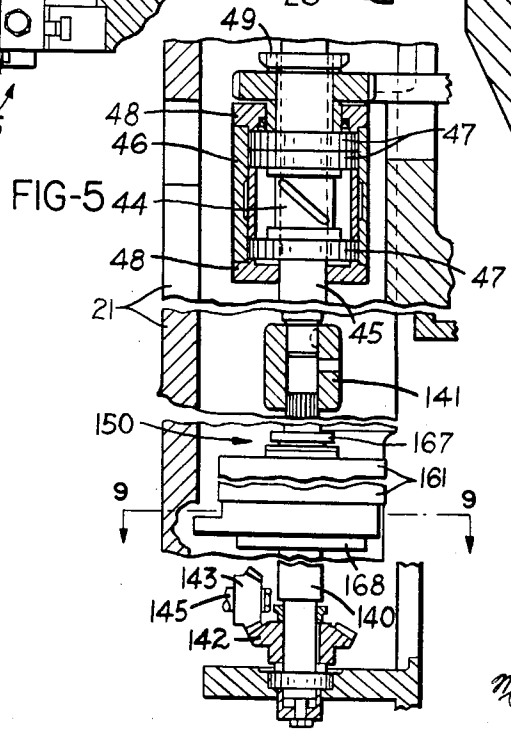


FIG-5



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GRINDING MACHINES

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FIG-6

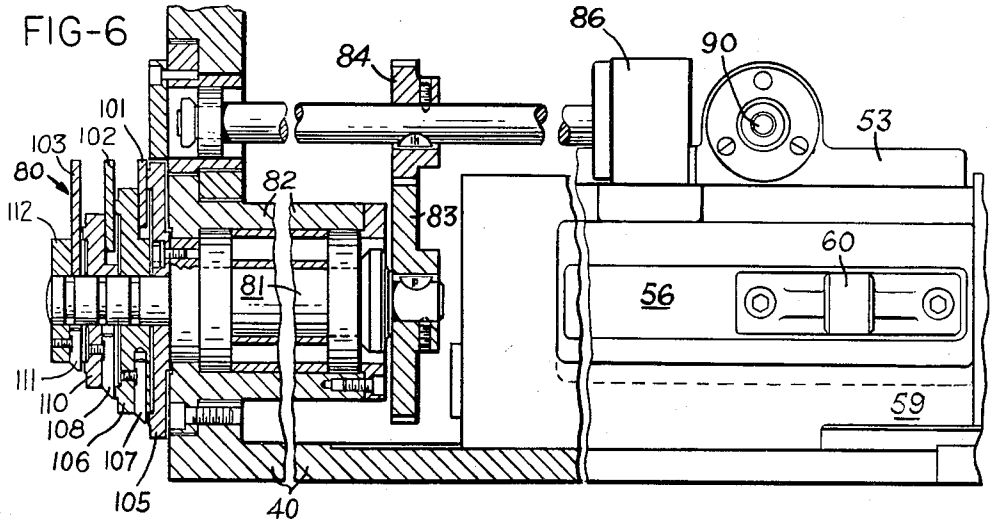


FIG-7

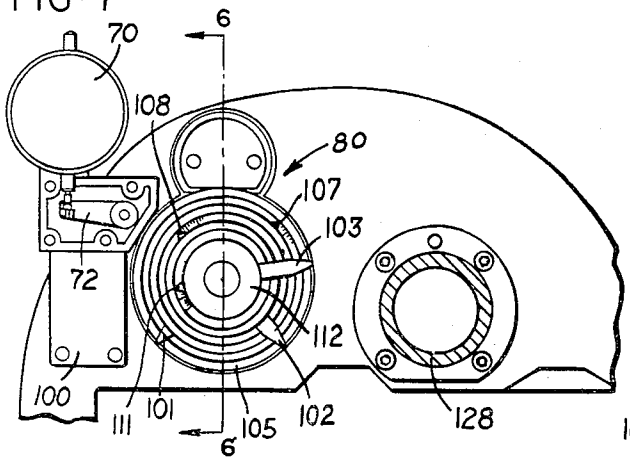


FIG-8

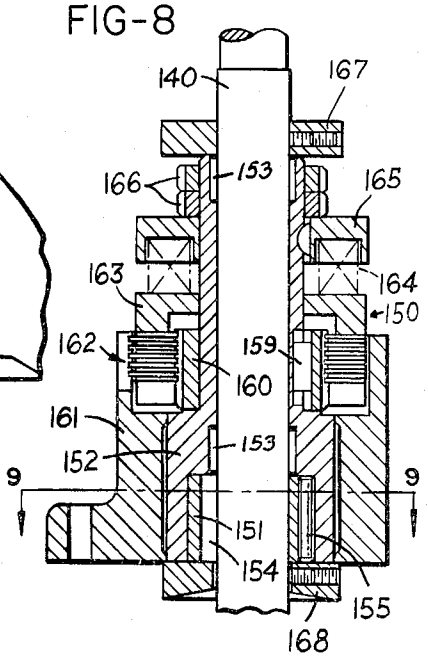
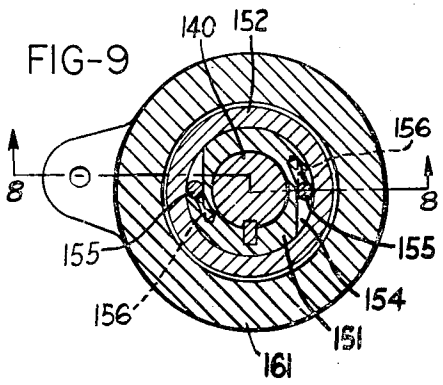


FIG-9



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FIG-10

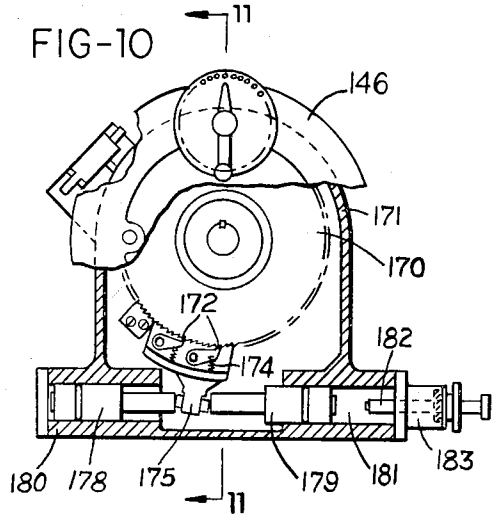


FIG-11

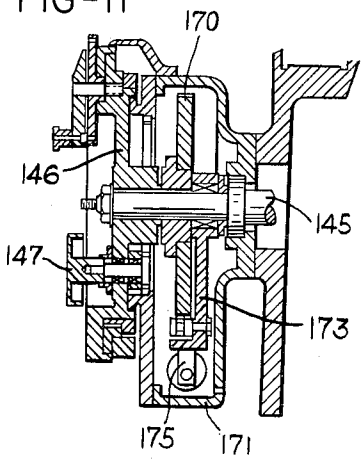
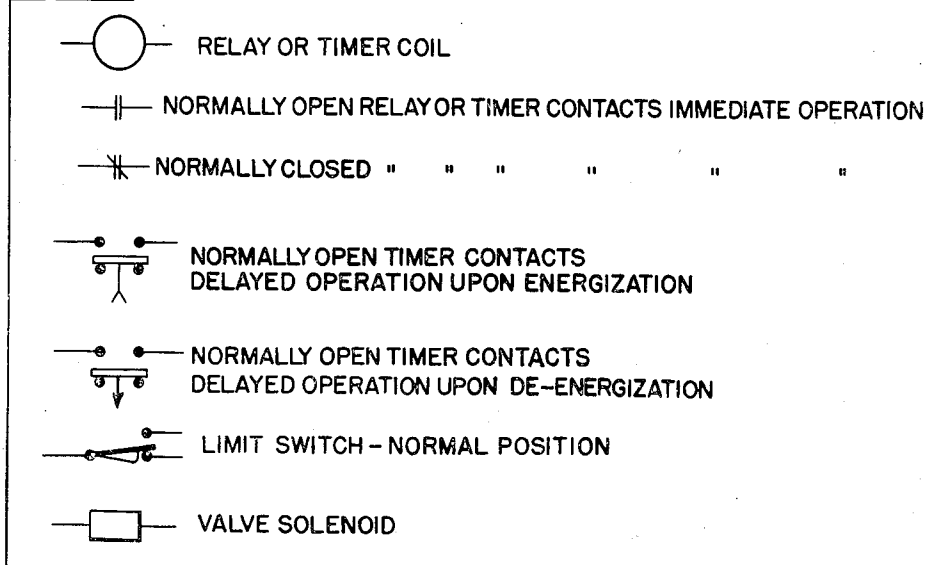


FIG-12



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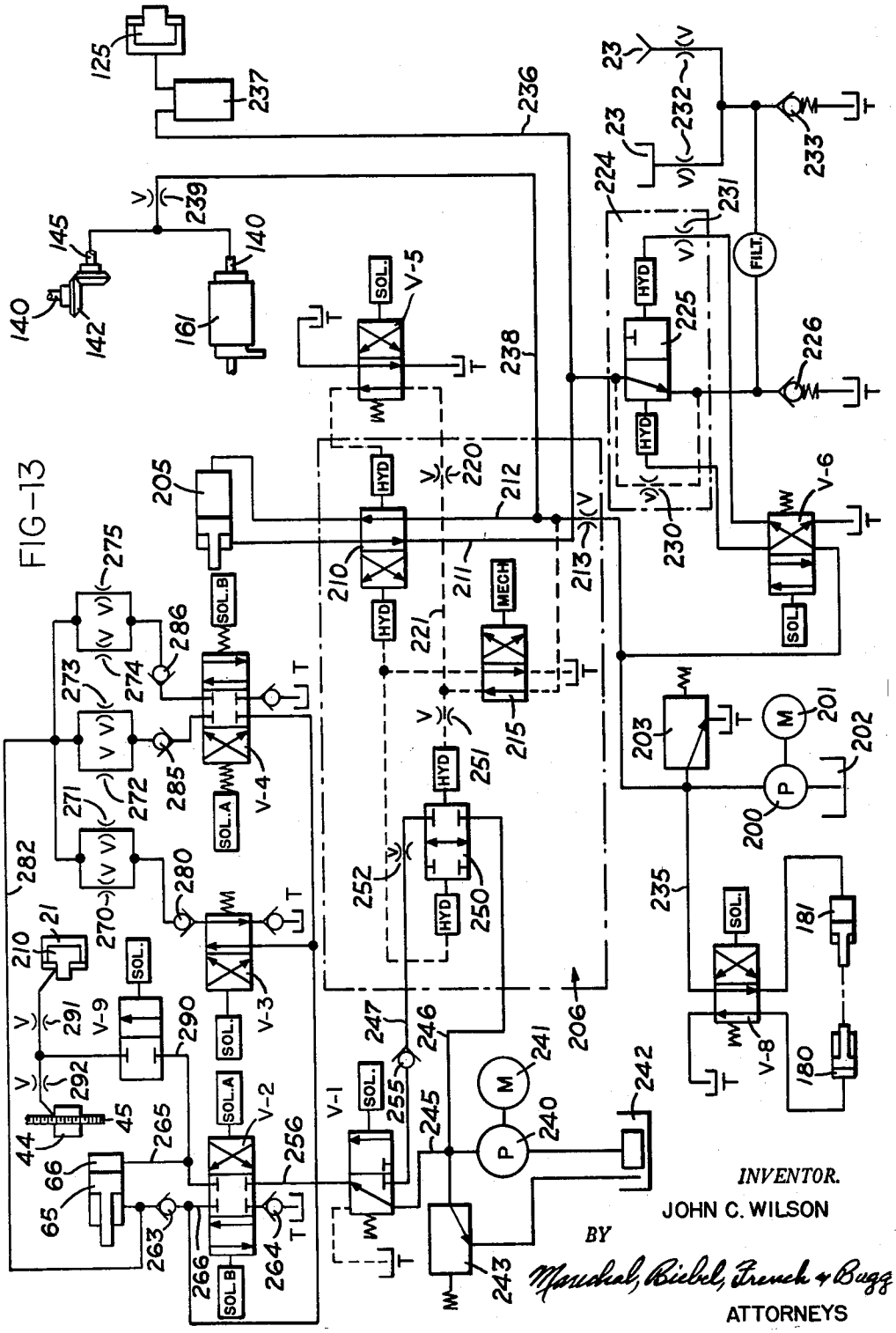
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GRINDING MACHINES

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FIG-13



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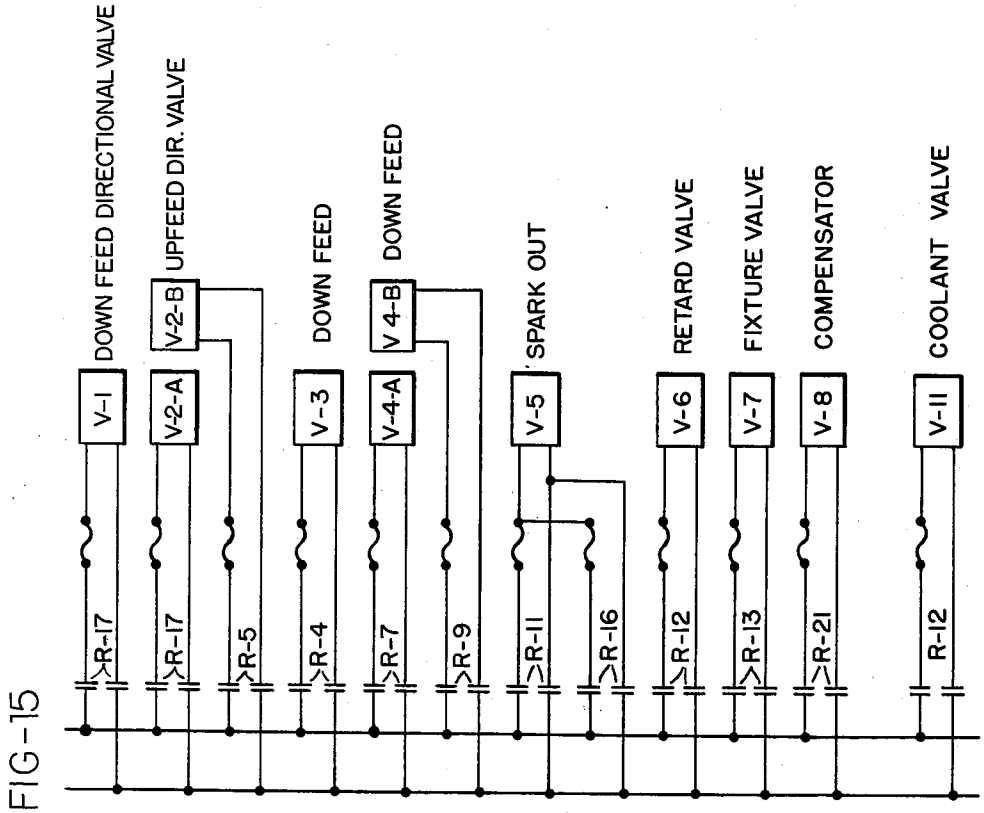


FIG-15

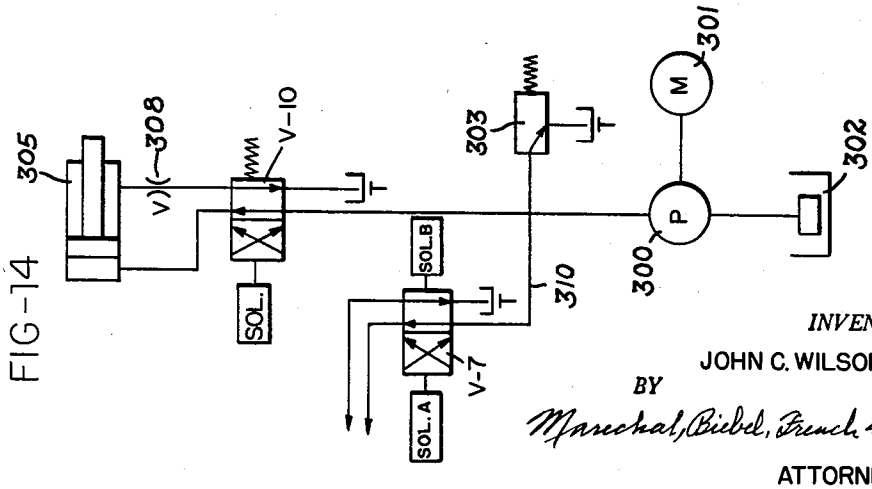


FIG-14

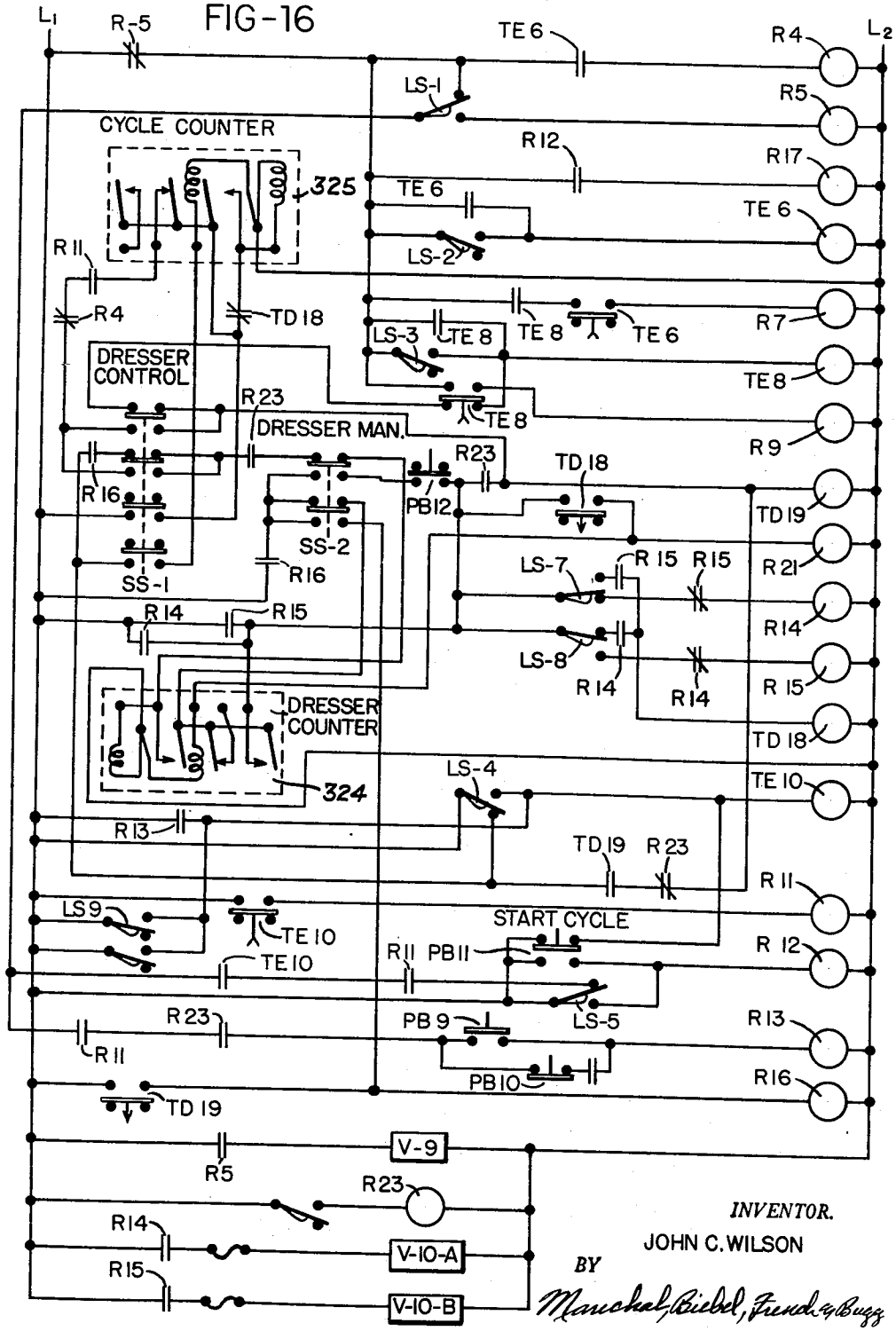
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GRINDING MACHINES

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FIG-16



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United States Patent Office 2,986,852 Patented June 6, 1961

2,986,852

GRINDING MACHINES

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Filed Jan. 28, 1957, Ser. No. 636,666
20 Claims. (Cl. 51—92)

This invention relates to grinding machines.

The invention has special relation to surface grinding machines of the automatic type employed for precision finishing operations, and it is particularly applicable for such grinding machines intended for closed cycle operation in contour finishing operations requiring variable amounts of down-feed throughout the grinding cycle. Thus the invention is directly related to grinding machines for carrying out contour finishing grinding on workpieces of such nature that maximum production rates can be maintained if the parts are subjected to a heavy initial grind, followed by a reduced cut for a semi-finish grind, and finally by a fine finish grind.

It is a primary object of the invention to provide a surface grinding machine as outlined generally above incorporating an automatic control system and drive mechanism capable of adjustment to cause the machine to carry out a closed cycle of operation which consists of a first range of feeding movement in pre-set comparatively large increments, a second range of feeding movement composed of substantially smaller increments, and a third and final range of feeding movement in desirably fine increments.

A particular object of the invention is to provide such an automatic grinding machine wherein the total amount of feeding movement, the proportion thereof constituting each of the three ranges of the feeding movement, and the specific increments of such feeding movement are each individually adjustable.

An additional object of the invention is to provide such a grinding machine wherein the control system includes provision for causing dressing of the grinding wheel whenever it is needed and also for compensating in the feeding movement of the grinding head for such reduction in the diameter of the wheel as results from dressing thereof.

Another object of the invention is to provide an automatic grinding machine as outlined above wherein dressing of the grinding wheel and compensation therefor in the feeding movement can be caused to take place at a desired stage of each complete cycle or automatically at the conclusion of a predetermined number of complete cycles.

It is also an object of the invention to provide an automatic grinding machine wherein all feeding operations of the grinding head throughout each complete cycle are effected hydraulically, and particularly to provide such an automatic grinding machine wherein the control of the incremental feeding movements of the grinding head is effected by predetermined regulation of the flow of hydraulic fluid to a hydraulic cylinder.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings—

FIG. 1 is a perspective view of an automatic grinding machine constructed in accordance with the invention;

FIGS. 2*a* and 2*b* constitute a horizontal sectional view through the saddle of the grinding machine of FIG. 1 and generally on the line 2—2 of FIG. 4;

FIG. 3 is a fragmentary section on the line 3—3 of FIG. 2*b*;

FIG. 4 is a partial vertical section on the line 4—4 of FIG. 2*b*;

FIG. 5 is a fragmentary vertical section on the line 5—5 of FIG. 2*b* and FIG. 4;

FIG. 6 is an enlarged fragmentary section taken as indicated by the line 6—6 of FIG. 7;

FIG. 7 is a fragmentary front elevational view of the saddle;

FIG. 8 is an enlarged fragmentary section on the line 8—8 of FIG. 9;

FIG. 9 is a section on the line 9—9 of FIG. 8 and also of FIG. 5;

FIG. 10 is a fragmentary view partly in front elevation and partly broken away in vertical section showing the compensating drive for the saddle;

FIG. 11 is a section on the line 11—11 of FIG. 10;

FIG. 12 illustrates the electrical symbols employed in the wiring diagram of FIGS. 15 and 16;

FIG. 13 is the main hydraulic diagram for the apparatus of FIGS. 1–11;

FIG. 14 is a supplemental hydraulic diagram;

FIG. 15 is a wiring diagram for the solenoid valves in the hydraulic diagrams of FIGS. 13 and 14; and

FIG. 16 is the main electrical diagram for the apparatus of FIGS. 1–11.

Referring to the drawings, which illustrate preferred embodiments of the invention, the main base of the grinding machine is indicated generally at 20, and it includes an upstanding column 21 at the back thereof. The work table 22 is mounted on ways 23 on top of the front portion of the base for reciprocating movement lengthwise thereof. The saddle 25 which supports the grinding head 26, including the grinding wheel 27, is supported on the column 21 for vertically guided movement with respect to the work table. A fixture 30 or chuck on the work table holds the workpieces to be ground, and this fixture is shown in FIG. 1 as of the magnetically operated type which has proved particularly satisfactory for use with flat work pieces but may also be of conventional hydraulically operated types as described in connection with the electric and hydraulic diagrams.

During actual grinding operations, the work table will ordinarily reciprocate near the middle of its total possible range, namely over a reduced range approximately equal to the length of the fixture 30, but at the end of each cycle during loading of the part or parts to be ground during the next cycle, it is located at the extreme right-hand end of its total possible stroke. The work table also occupies this position during dressing operations on the grinding wheel, and FIG. 1 shows a dresser 33 mounted on the left-hand end portion of the work table which is therefore located directly below the wheel when the table is in its loading position. The dresser 33 is shown as of a conventional type supported for reciprocating movement laterally of the work table, but a conventional dresser of the type mounted directly on the grinding head 26 may be used, as will be readily understood by those skilled in the art. FIG. 1 also indicates at 35 the main electric control panel for the machine mounted on a bracket 36 at one end of the base.

In a typical complete working cycle in accordance with the invention, the new part or parts to be ground are loaded on the fixture 30 while the table is in loading position and the saddle has moved to the upper limit of the predetermined total grinding range. At the start of the cycle, the fixture is energized, if of the magnetic type, or otherwise locked to hold the work securely thereon, and the table moves from loading position to its reciprocating range and then continues to reciprocate in that range. The saddle down-feeds a predetermined increment each time the table reverses its direction, and the first range of down-feed will normally be in the largest increments. When this range has concluded in accordance with the presetting of the controls, the second range of down-feed commences at the desired reduced increment, and a

similar change to fine increments takes place at the conclusion of the second range of down-feed.

Depending upon the nature of the work, the invention provides alternatively for dressing either at the conclusion of the second range of down-feed in each cycle or at the conclusion of the third range of down-feed after a predetermined number of cycles. In the first case, at the conclusion of the second range of down-feed, the table will automatically return to its loading position and remain there until the dressing operation has been carried out. The table will then resume its normal reciprocating movement while the third range of down-feed is completed, after which it will again move to its loading position while the saddle up-feeds. If dressing is carried out after a number of cycles, this also will be done automatically while the table is in loading position and will be followed by up-feeding of the saddle, and loading of the table can be done during dressing in this case. Whichever dressing procedure is followed, the invention provides automatic compensation for the reduction in diameter of the wheel by dressing without affecting the preset position of the controls for the actual grinding operations.

The internal construction of the saddle **25** is shown in detail in FIGS. 2*a* and 2*b* and also in FIGS. 3 and 4. The main saddle casting **40** is mounted for vertcal movement on the column **21** by means of suitable slideways **41** and gibs **42**. The vertical movements of the saddle are effected and controlled through an elevation nut **44** threaded on the elevation screw **45** which is mounted in vertically extending position in the column **21** as best seen in FIG. 5. In order to minimize friction, the nut **44** and screw **45** are both desirably of the ball type, and the nut is retained within the housing **46** by suitable spacers, bearings **47**, and retainers **48**.

In the working movements of the saddle **25** according to the invention, the screw **45** remains stationary, and the nut **44** is secured in fixed vertical relation with the saddle and rotated on the screw to cause vertical movement of the saddle. Referring to FIGS. 2*b* and 3, the nut housing **46** is bolted directly to the saddle housing **40**. A gear **50** is secured to the nut **44**, as by a locknut **49**, and meshes with an intermediate gear **51** on a short shaft **52** journaled in a bracket **53** mounted on the saddle housing **40**. This intermediate gear **51** meshes with a rack **55** bolted or otherwise secured to a slide **56** supported by retainers **57** and **58** in a carrier **59** which is secured to the saddle casting **40**.

With this construction, since the saddle casting and the nut assembly remain fixed horizontally with respect to the base, movement of the slide **56** in the saddle will cause rotation of the nut **44** and resulting movement of the saddle. Such movement is imparted to the slide **56** through a laterally projecting bracket **60** thereon which is secured to the rod **61** of the piston **65** in a hydraulic cylinder **66** secured to the saddle casting **40**. The arrangement of these parts is such that when pressure is supplied to the smaller side of the piston to cause retraction of the piston rod, the nut **44** will rotate in clockwise direction as viewed from above to travel down the screw **45** and thus lower the saddle. Application of pressure to the large end of the piston will therefore cause the reverse movement for an upward stroke of the saddle.

The extent of this vertical movement of the saddle is indicated visually by an indicator **70** (FIG. 7) mounted on the outer front end of the saddle casting **40**. The operating mechanism for the indicator **70** is enclosed within a cover **71** and includes an arm **72** secured on the outer end of a rock shaft **73** journaled in the casting **40**. An arm **75** on the inner end of shaft **53** carries a roller **76** which rides on an inclined cam **77** bolted to the rack slide **56**, and a spring retainer **78** holds these parts in continuous engagement. Thus as the cam **77** moves with the slide **56**, the shaft **73** will rock and act through the arm **72** to operate the indicator **70**.

The controls for the vertical movement of the saddle include a cam assembly indicated generally at **80** in FIGS. 6 and 7 which is mounted on a stub shaft **81** journaled in a housing **82** mounted in the front end wall of the saddle casting **40**. The shaft **81** carries a gear **83** at its inner end which meshes with a gear **84** on an extended shaft **85** journaled at opposite ends in the front wall of the casting **40** and a bearing housing **86**. A bevel gear **88** on the inner end of shaft **85** meshes with a bevel gear **89** on a cross shaft **90** journaled in the bracket **53**. A second bevel gear **91** on shaft **90** meshes with a bevel gear **92** on the intermediate gear shaft **52** to transmit the drive from the intermediate gear to the shaft **85**, and thence to the cam shaft **81**.

The cam assembly **80** is shown in detail in FIG. 6 and cooperates with three limit switches LS–1, LS–2 and LS–3 mounted within the cover **100** on the front end of the saddle. These three switches are operated by strikers **101**, **102** and **103** respectively which are adjustably positioned on the shaft **81** in cooperation with individually associated dials. Thus the dial **105** is fixed on the housing and measures the upward feed of the saddle from the lowermost or spark-out position of the grinding wheel **27**. The striker **101** is secured on a dial **106** adjustably mounted on shaft **81** and carrying on its opposite side a pointer **107** registering with the figures on the dial **105**. The dial **106** measures the first range of downward feed in cooperation with a pointer **108** carried by a dial **110** which also carries the striker **102**, and the dial **110** measures the second range of downward feed in cooperation with a pointer **111** carried by a retainer knob **112** which also carries the striker **103**.

The functions of the above limit switches are described hereinafter in connection with the wiring diagram, but at this point it may be noted that the striker **101** operates switch LS–1 to terminate upward feed of the saddle from the spark-out position and thus establishes the total amount of downward feed in accordance with the setting of pointer **107** with respect to dial **105**. The switches LS–2 and LS–3 are operated by the strikers **102** and **103** in succession to terminate the first and second ranges of downward feed in accordance with the settings of the pointers **107** and **108** with respect to the dials **106** and **110** respectively. The third range of downward feed is the remainder of the total up-feed minus the first two ranges of down-feed, and it is terminated by bottoming of the piston **65** in cylinder **66**. This is the spark-out position for the grinding wheel, and it is signaled in the electrical system by a limit switch LS–4 mounted in the rearward portion of the saddle and operated by a push rod **115** projecting from the rack slide **56** for engagement with a rod **116** carried by a spool **117** which actuates switch LS–4. As shown in FIG. 2*b*, the spool **117** is mounted for limited back and forth sliding movement by means of suitable bushings in the end plates **120** of the casting **40** and a bracket **121**. A spring **123** biases spool **117** to the left in FIG. 2*b*, and the rod **116** is adjustable axially in the bushing to assure properly timed operation of switch LS–4.

The grinding head **26** is provided with the usual laterally adjustable mounting in the saddle **25**. Referring to FIGS. 2*a*, 2*b* and 4, the head **26** depends from a slide **125** supported for sliding movement in the lower part of the saddle casting **40**. An anti-friction nut assembly **126** is secured on the upper side of the slide **125** and received therethrough a screw **127** journaled in a housing **128** mounted on the front wall of the casting **40** and a bracket **129** secured within the casting. A hand wheel **130** on the outer end of screw **127** provides for manual rotation of this screw, and this hand wheel includes suitable dial indicia on its forward surface cooperating with a pointer **131** to measure the position of the grinding head laterally of the machine as a whole or longitudinally of the saddle. Fine adjustments of the grinding head may be effected by the conventional adjusting mechanism indicated

generally at 135 in FIG. 4 for machines intended for contour grinding, and it will be understood that a conventional cross feed reciprocating drive for the grinding head can be incorporated in the saddle if desired.

When the saddle is being moved downwardly by the piston 65 as described in detail hereinafter in connection with the hydraulic and electric diagrams, the elevation screw 45 is held stationary, but provision is also made for rotating this screw to raise or lower the saddle for compensating or other adjusting purposes. Referring to FIGS. 5, 10 and 11, the lower end of the screw 45 is secured to the upper end of the elevation shaft 140 by a coupling 141. The shaft 140 is supported vertically in the column 21 by suitable bearings as shown, and it carries a bevel gear 142 meshing with a bevel pinion 143 on the end of a cross shaft 145 which extends to the front of the base and carries a handwheel 146 which is also shown as incorporating a vernier adjusting mechanism indicated generally at 147. A reversible power drive may also be provided for cross shaft 145 if desired.

The elevation screw 140 is provided with a brake assembly 150 which restrains the shaft frictionally from rotation in the direction to lower the saddle but which provides for free rotation of the shaft in the direction to raise the saddle. Referring to FIGS. 5, 8 and 9, a rotor 151 is keyed on shaft 140 and forms a part of a one-way clutch assembly with the drum 152 which is rotatably mounted on the shaft by means of bearings 153. The rotor 151 is slotted at 154 to receive rollers 155 which are normally biased by springs 156 towards their positions of wedging engagement between rotor and drum. Thus rotation of shaft 140 in clockwise direction as viewed in FIG. 9 will cause engagement of these clutch rollers, but the shaft is free to turn independently of drum 152 in clockwise direction.

The drum 152 is also keyed at 159 to the inner member 160 of a friction clutch assembly, the outer member of which is the housing 161 secured in fixed relation with the base. The friction disks 162 are operated by a pressure plate 163 through a plurality of springs 164 and an adjustable pressure pad 165 keyed on rotor 151 and held in adjusted relation thereon by the pair of nuts 166. The clutch assembly 160–162 therefore provides a frictional connection between the rotor 151 and the stationary housing 161 which is transmitted to the shaft 140 through the one-way clutch rollers 155 when the shaft is turning in counterclockwise direction but is not effective with respect to the shaft when it is turning in clockwise direction, and this assembly is held in place by collars 167 and 168.

The cross shaft 145 is also provided with a power drive which is employed as described hereinafter to effect accurately controlled vertical adjustment of the saddle compensating for dressing of the grinding wheel. Referring to FIGS. 10 and 11, a ratchet wheel 170 is keyed on shaft 145 within the housing 171 for cooperation with a pair of pawls 172 carried by lever 173 journaled on the cross shaft 145 and carrying the pawl springs 174. An arm 175 on ratchet lever 173 extends between the projecting rod portions of a pair of pistons 178 and 179 in hydraulic cylinders 180 and 181 formed integrally with the lower portion of the housing 171, and an adjustable screw 182 projects through the end cap 183 of cylinder 181 to limit the movement of the piston rod 179.

The pistons 178 and 179 and the cylinders 180 and 181 cooperate to provide essentially the same functions as a double-acting cylinder. Thus when pressure is applied to the outer end of cylinder 180, the piston 178 will move the lever 173 in counterclockwise direction and act through the pawls 172 to move the ratchet wheel 170 the distance determined by the stroke of the cylinder established by the setting of the stop screw 182. This movement of the ratchet wheel will be transmitted by cross shaft 145 into corresponding rotation of the shaft 140 and screw 45 in the direction to lower the saddle, and this rotation will be against the friction of the brake assembly 150. Reversal of the pressure supply to cylinder 181 will return the pistons 178 and 179 to their previous positions while the pawls track on the ratchet wheel.

Hydraulic system

The main hydraulic system shown in FIG. 13 operates the work table 22 and the compensating cylinders 180 and 181, and it also provides pilot pressure for controlling the down-feed cylinder 66. This system includes a pump 200 having a drive motor 201 and supplying hydraulic fluid from a reservoir 202 through a pre-set relief valve 203. The reciprocating movements of the table are effected by a double-acting cylinder 205, and the oil flow to this cylinder and also to the down-feed cylinder 66 are controlled by a master valve identified generally as 206 and incorporating the table reverse spool 210 which controls the direction of oil flow to and from table cylinder 205 by way of pressure and exhaust lines 211 and 212 respectively.

The pressure line 211 is connected with the pump 200 through a throttle valve 213 having a control lever 214 (FIG. 1) on the front of the base and which may be completely shut off to stop all movement of the table. The table reverse spool 210 is controlled by a mechanically operated pilot spool 215 in the master valve which has an operating lever 216 located on the front of the base for actuation by the adjustable dogs 217 and 218 on the front of the table.

In order to minimize shock on the table during reversal of its movements, an adjustable throttling valve 220 is connected in the line 221 from the pilot valve 215 to one end of the table reverse spool 210, and this throttling valve may be adjusted to provide just sufficient overrun of the table after the lever 216 has been shifted to cause reversal of the table without undue shock. The line 221 also leads through the pressure ports of a solenoid valve V–5 having a spring return which is energized only during spark-out and dressing operations as described hereinafter in connection with the wiring diagram. When valve V–5 is energized, it blocks the pilot flow of oil to the spool 210 and thereby prevents reversal of the table and instead causes it to travel to its extreme right hand position for dressing and/or loading for the next working cycle.

Provision is also made for retarding the movement of the table as it approaches the end of a full stroke to its loading and dressing position. This is accomplished by a retard valve indicated generally at 224 which is connected to the exhaust line 212 from cylinder 205. The valve 224 incorporates a hydraulically operated two-position valve 225 which is controlled by a solenoid pilot valve V–6 having a spring return. During the major portions of each stroke of the table, the valve V–6 is energized to the position shown in the diagram which holds valve 225 open to deliver the discharge from cylinder 205 to tank through a check valve 226. Pilot valve V–6 is de-energized when the table is approaching its loading or dressing through actuation of limit switch LS–5 by a cam 227 (FIG. 1) on the table, and another cam 229 on the table actuates limit switch LS–6 when the table is in its extreme right-hand position. When the valve V–6 is closed, it forces the return from cylinder 205 to by-pass through an adjustable needle valve 230, and another needle valve 231 is connected between pilot valve V–6 and one end of retard valve 225 to prevent operation of the retard valve from being either so slow that the table is not retarded quickly enough or so fast that a shock will be produced.

The return oil from table cylinder 205 is used to lubricate the ways 23 which support the work table on the base 20 of the machine, and this lubricating flow is controlled by needle valves 232 and a check valve 233 connected as shown with the drain line from retard valve 224. The main pump 200 also supplies pressure oil by a line 235 to the compensator cylinders 180 and 181.

This line is controlled during dressing of the grinding wheel by a reversing solenoid valve V–8 having a spring return as described hereinafter in connection with the wiring diagram.

The oil flow to and from the table cylinder 205 is also shown as employed for additional lubrication purposes. The branch line 236 from pressure line 211 leads to a pump unit 237 for supplying a controlled flow of oil to the head slide 125 in saddle casting 40, this lubrication system being particularly desirable if a cross-feed drive is provided for the head. Another branch line 238 from line 212 leads to a needle valve 239 from which branch lines lead to the clutch-brake assembly in the housing 161 and to the bevel gears 142—143.

The oil for operation of the down-feed cylinder 66 is supplied from an auxiliary pump 240 having a drive motor 241 and supplying hydraulic fluid from a reservoir 242 through a preset relief valve 243. The pressure line from valve 243 divides, and one branch line 245 leads to a solenoid valve V–1 having a spring return which is deenergized as shown in the diagram during up-feed of the saddle and is energized to its other position during down-feed. The other branch pressure line 246 ultimately connects with a line 247 which also leads to valve V–1, and the connection between lines 246 and 247 includes a free piston metering valve 250 in the master valve 206 for metering the flow of oil through line 247.

This metering valve 250 is in the form of a spool which is hydraulically operated at each table reversal by pilot pressure from table pilot valve 215 to provide a momentarily open passage between opposed ports in the body of valve 206 which are in turn connected with the lines 246 and 247. The duration of each such open connection is determined by the speed of movement of the valve spool 250, and this is controlled by a throttle valve 251 in one of the pilot pressure connections between valves 215 and 250. An additional throttle valve 252 in master valve 206 between valve 250 and line 247 has a control lever 253 (FIG. 1) on the front of the base and may be completely shut off, and the line 247 also includes a check valve 255.

The single pressure line 256 from valve V–1 leads to a three-position solenoid valve V–2 having a closed center and a pair of control solenoids identified in the wiring diagram as V–2–A and V–2–B respectively. The solenoid V–2–B is energized to cause up-feed of the saddle by supplying pressure to the larger end of down-feed piston 65, and in this position the smaller side of the piston is connected to tank through a check valve 263, the exhaust port of valve V–2 and a foot valve 264. When valve solenoid V–2–B is energized, valve V–1 is deenergized, and therefore the full line pressure is supplied through line 265 to the larger end of piston 65 to insure rapid up-feed of the saddle.

The solenoid V–2–A is energized during down-feed of the saddle to supply oil through line 266 to the smaller side of piston 65 in increments provided at each table reversal during the open interval of the metering valve 250, and each of the three downward ranges established by the limit switches LS–1, LS–2 and LS–3 has its own such increment. The amount of the increment for each range is individually established and maintained by the settings of three pairs of metering valves 270–275, the controls for which are designated by the same reference characters on the front of base 20 in FIG. 1. The valves of each such pair are connected in parallel with each other and are adapted respectively for coarse and fine adjustment to provide extremely accurate control of the incremental oil flow therethrough.

During the first range of down-feed of the saddle, the solenoid valve V–3 has its control solenoid energized to connect the pressure line 266 from valve V–2 with the metering valves 270 and 271 through a check valve 280. Under these conditions, on each stroke of the metering spool 250, a small increment of oil will flow through the valves 270 and 271 to the line 282 leading to the small side of the piston 65. The piston will, therefore, move a distance determined by the increment of oil supplied thereto, and this motion will produce rotation of the elevation nut 44 as previously described. The discharge from the large side of the piston will be exhausted to the tank through the foot valve 264, which should provide sufficient back pressure to keep the lines full of oil and also to prevent possible downward creeping of the saddle.

When the first downward range of movement terminates, valve V–3 closes, and control of the flow is transferred to a three-position closed center solenoid valve V–4 having operating solenoids V–4–A and V–4–B. During the second range of down-feed, solenoid V–4–A is energized to supply pressure to the line 282, by way of the check valve 285 and the pair of metering valves 272 and 273. During the third range of down-feed, valve V–4 is reversed by energizing of solenoid V–4–B, and the oil flow to line 282 is then by way of check valve 286 and the pair of metering valves 274 and 275.

This hydraulic system in combination with the down-feed drive in the saddle as described provides for extremely accurate control of the incremental down-feed, and particularly for a selected different increment during each range, and particularly for a more or less rough grind during the first range, a finer grind during the second range, and a very fine grind during the third range. For example, in one successful commercial embodiment of the invention, provision is made for a total movement of .270 inch above the lowermost or spark-out position of the wheel. Any amount of this total may be utilized, which may be divided as desired between the three ranges, and the increment for each range may be any desired fraction of an inch up to .020 inch.

For example, if the total vertical travel of the wheel is selected as .200 inch, three-quarters of this distance may be allocated to the first range in relatively large increments such as .010 inch. The total extent of travel is established by presetting the pointer 107 for striker 101 on the ".200" mark of dial 105, and the extent of the first down-feed range is similarly established by setting the pointer 108 for striker 102 on the ".150" mark of dial 106. The incremental advance during the first range is similarly established by appropriate presetting of the pair of metering valves 270 and 271. If the extent of the second range is then to be .040 inch, this is established by setting the pointer 111 for striker 103 on the ".040" mark on dial 110, and the increment for the second range is similarly established by appropriate presetting of metering valves 272 and 273. The extent of the third range has then already been established as the balance of .010 inch remaining from the total movement of .200 inch, and the increment for the third range is established by appropriate presetting of metering valves 274 and 275.

Provision is made for utilizing the oil supply for down-feed cylinder 66 to effect controlled lubrication of the mounting of the saddle and also the elevation nut 44 and its associated screw and gears. A branch line 290 leads from the larger end of the piston 65 to a solenoid valve V–9 having a spring return which is energized periodically, during up-feed of the saddle, to provide oil by way of metering valves 291 and 292 to the saddle ways and the elevation mechanism as indicated in the diagram.

FIG. 14 shows a separate hydraulic circuit for supplying pressure to operate the dresser 35, and if the fixture 30 is of the hydraulically operated type, the same circuit may be used for operation thereof. It includes a pump 300 having a drive motor 301 and supplying hydraulic fluid from a reservoir 302 through a preset relief valve 303. The pressure line from pump 300 to the dresser cylinder 305 is controlled by a two-position double solenoid valve V–10 having operating solenoids V–10–A and V–10–B, and one of the lines between valve V–10 and cylinder 305 is shown as including a metering valve

308 to control the speed of reciprocation of the dresser. The pump 300 may also be used to operate a hydraulic fixture, by means of a branch line 310 connected therefrom to a solenoid valve V–7 having a spring return. When the fixture 30 is of the magnetically or mechanically operated type, this portion of the hydraulic diagram will not be used.

Electrical system

The electric controls and the sequence of operation of the grinding machine of the invention are illustrated by the wiring diagrams in FIGS. 15 and 16, which include only those portions of the wiring related to control of the movements of the work table, the saddle and the dresser, and which omit the controls for the several motors and pumps since the latter may be of any desirable conventional type. The symbols employed in the wiring diagrams are explained in FIG. 12, and it will be noted that each of the limit switches is shown as normally having its arm in its lower position for movement to the upper position thereof. The wiring diagram also includes two types of timers designated by the reference letters TD and TE, which indicate a time delay in operation upon deenergization and upon energization respectively.

As already noted, the invention provides alternatively for dressing of the wheel either at the end of the second range of down feed in each cycle or upon completion of the third range of down feed after a predetermined number of complete cycles, and the sequence of operation will initially be described in connection with the first case. In this description, it is assumed that the necessary motors and pumps are in operation, and it is further assumed that the table has reached its loading position at the limit of its right hand travel and that the saddle has reached its limit of up feed at the conclusion of the previous cycle. FIG. 16 illustrates this set of conditions, with limit switch LS–1 having been moved to its upper position by operation of striker 101 to open relay R–5 and thereby to deenergize the operating solenoid for valve V–1. Similarly with the work table in loading position, the cam 229 will be holding limit switch LS–6 closed to energize cycle relay R–23, and cam 227 will be holding limit switch LS–5 in its upper position to open relay R–12 and thereby to deenergize pilot valve V–6 for a retarding action by retard valve 225 as the table approached loading position.

In addition to these operated limit switches, at this point in the cycle the spark-out timer TE–10 and spark-out relay R–11 will have remained energized from the end of the previous cycle, and valve V–5 will therefore have been energized by relay R–11 to block reversal of the table and cause it to go to loading position. Relay R–13 may then be closed to unlock the fixture 30 through operation of solenoid valve V–7 to change workpieces, after which the fixture is again locked by opening relay R–13 through push bottom switch PB–10. The same sequence is followed when fixture 30 is of the magnetic type, and in such event the diagrammatic showing V–7 in FIG. 15 would represent the control solenoid for the magnetic fixture. Limit switch LS–9 is a safety switch which is closed when the fixture opens and remains closed to hold in timer TE–10 until the fixture has completely closed.

The next cycle is commenced by depression of push button switch PB–11. This drops out timer TE–10 and thereby also drops out relay R–11, which in turn deenergizes valve V–5 and thus causes the table to start away from loading position. The back contacts of switch PB–11 energize relay R–12 to operate retard pilot valve V–6, and since limit switch LS–5 shifts to its normally closed contacts as soon as the table moves, it holds relay R–12 energized. At this point, relay R–4 would already be closed through the back contacts of relay R–5 and timer TE–6 to cause valve V–3 to open, but no down feed occurs until closing of relay R–12 energizes relay R–17 and thereby operates valve solenoids V–1 and V–2–A.

The first range of down-feed continues at the incremental rate established by valves 270 and 271 until striker 102 operates limit switch LS–2 as previously described. This energizes timer TE–6, which locks itself in and also opens relay R–4 to permit valve V–3 to close. Relay R–7 therefore closes and energizes valve solenoid V–4–A to initiate the second range of down-feed, which continues at the incremental rate established by valves 272 and 273 until the striker 103 operates limit switch LS–3.

Closing of switch LS–3 energizes timer TD–19 through back contacts of timer TE–8, and timer TD–19 locks itself in through back contacts of cycle relay 23. Timer TE–8 then also closes and locks itself in, but relay R–9 is prevented from closing by the opening of the back contacts of timer TD–19 in its energizing circuit. When timer TD–19 closes, interlock relay R–16 closes and thereby energizes the operating solenoid for valve V–5, and when this valve closes, it operates as previously described to cause the table to travel all the way to the right until the limit switch LS–6 is closed to energize cycle relay 23.

The dresser control selector switch SS–1 will have been set to the position of its contacts shown in FIG. 16, and when relay R–23 closes, it completes a signal circuit to the clutch coil of dresser counter 324 through the closed front contacts of relay R–16. The dresser limit switches LS–7 and LS–8 are operated momentarily at opposite ends of the stroke of the dresser, and one of them will remain operated when the previous dresser cycle ceased. Therefore as soon as the dresser circuit is completed, the timer TD–18 will be energized to complete an energizing circuit for the relay R–12 which controls compensator solenoid valve V–8. The resulting oil flow to the compensator cylinder 180 will cause the saddle to lower the wheel through the predetermined distance established by the setting of stop screw 182 as previously described without affecting the position of the indicator shaft 81 at the end of the second range of down feed. The dresser will then make the predetermined number of strokes set on the dresser counter 324, with the dresser control relays R–14 and R–15 being actuated at the end of each stroke of the dresser by the limit switches LS–7 and LS–8 as shown.

After the predetermined number of strokes of the dresser have been completed, the dresser will stop, timer TD–19 and relay R–16 will open, and solenoid valve V–5 will be released to terminate its blocking action on the reciprocating movement of the work table. The table will therefore resume its reciprocating movements, and since relay R–9 will then have closed through the back contacts of timer TD–19 to operate valve solenoid V–4–B, this initiates the third range of down-feed, which continues at the incremental rate established by valves 274 and 275 until piston 65 bottoms out as previously described. The resulting operation of switch LS–4 energizes spark-out timer TE–10, but this timer does not close until its predetermined timing interval has elapsed during which the table will continue to reciprocate without down-feed of the saddle while the wheel sparks out.

At the completion of the spark-out time, timer TE–10 will close to energize spark-out relay R–11 and thereby operate solenoid valve V–5 to prevent further reversal of the table and again cause the table to run again all the way to the right until switch LS–6 is closed to close cycle relay R–23. When limit switch LS–5 is operated as the table approaches loading position, this completes an energizing circuit for relay R–5 through limit switch LS–1, the back contacts of relay R–16 and front contacts of timer TE–10. This in turn drops out timer TE–6, timer TE–8 and relays R–9 and R–17, and it also energizes valve solenoid V–2–B to shift V–2 to its up-feed position. Since valve V–1 is also deenergized when relay R–17 drops out, the full line pressure is then supplied to

the large end of piston 65 for a continuous up stroke which is terminated as previously described by operation of its limit switch LS–1 by striker 101. The saddle and table remain in the resulting positions until the next cycle is initiated by operation of push button switch PB–11.

If instead of dressing each cycle, it is desired to dress after a selected number of cycles, selector switch SS–1 is shifted to the lower position of its contacts. Under these conditions, each cycle will proceed as previously described except that the dressing operation will be omitted. Therefore, when switch LS–3 is operated at the conclusion of the second range of down-feed, timer TD–19 will remain deenergized, and relay R–9 will immediately close to initiate the third range of down-feed, followed by spark-out and up-feed as previously described.

At the end of each complete down-feed, operation of cycle relay R–23 will provide a signal to the cycle counter 325. When the desired number of cycles preset on counter 325 has been reached, timer TD–19 is energized to initiate the dressing cycle in the same manner as previously described, with the compensator cylinder 180 also being operated at the start of the dressing cycle in the same manner as when dressing occurs each cycle. Then when timer TD–19 and relay R–16 open, relay R–5 will close to effect up feeding of the saddle in the same manner as already described. During up-feed with either dressing procedure, while the relay R–5 is closed, it operates solenoid valve V–9 to cause a shot of oil to pass therethrough for lubrication of the rack slide 56 and the elevation screw assembly.

The selector switch SS–2 provides for operation of the dresser under manual control in combination with push button switch PD–12, the normal positions of the contacts of switch SS–2 being as shown in FIG. 16. The wiring diagram in FIG. 15 for the valves also illustrates a solenoid valve V–11 which controls the main flow of coolant to the wheel in the conventional coolant system (not shown). As indicated, the valve V–11 is closed when relay R–12 is closed in order to shut off the main coolant flow during dressing of the wheel.

This grinding machine construction and control system provide a high degree of controlled accuracy in closed cycle operation of the machine on many duplicate workpieces, and also provide great flexibility, particularly from the standpoint of selection of the extent and speed of the grinding operations. For example, the total extent of the working movement of the saddle during grinding can be selected as any desired fraction of the total available movement provided by the drive from cylinder 66, and the speed with which each grinding operation is completed is determined by the amount of incremental feed throughout each portion of the total down feed. Thus while the operation has been described in connection with three respectively rough, semi-finish and finish grinds provided by respectively large, medium and small increments of down-feed, it would be equally possible to establish two ranges by adjusting two consecutive pairs of the metering valves 270–275 to the same setting, or even to adjust all pairs of these valves to the same setting and thereby to provide for the same speed of grinding throughout the entire operation. Irrespective of these many variations, the invention assures that whatever cycle is selected will be repeated with maintained accuracy.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. In a grinding machine having a work table and a grinding wheel supported for forward feeding movement with respect to said table, the combination of power means for effecting said forward movement in a series of increments, adjustable control means for said power means for determining the total extent of said forward feeding movement, means for determining the individual extent of each of a plurality of groups of forward feeding movements within and together constituting said total extent of movement, and adjustable means for selectively establishing the amount of the increment of the feeding movement in each of said groups of movement.

2. In a grinding machine having a work table and a grinding wheel supported for forward feeding movement with respect to said table, the combination of power means for effecting said forward movement in a series of increments, adjustable control means for said power means for determining the total extent of said forward feeding movement, means for determining the individual extent of each of a plurality of groups of forward feeding movements within and together constituting said total extent of movement, adjustable means for selectively establishing the amount of the increment of the feeding movement in each of said groups of movement, and means for causing a return movement of said wheel in response to completion of said total extent of forward feeding movement.

3. In a grinding machine having a work table and a grinding wheel supported for forward feeding movement with respect to said table, the combination of power means for effecting said forward movement in a series of increments, adjustable control means for said power means for determining the total cut to be taken, means for determining the individual extent of each of a plurality of groups of forward feeding movements within and together constituting said total cut, adjustable means for selectively establishing the amount of the increment of the feeding movement in each of said groups of movement, and means for subjecting said wheel to a dressing operation following a selected one of said groups of movement.

4. In a grinding machine having a work table and a grinding wheel supported for forward feeding movement with respect to said table, the combination of power means for effecting said forward movement in a series of increments, adjustable control means for said power means for determining the total extent of said forward feeding movement, means for determining the individual extent of each of a plurality of groups of forward feeding movements within and together constituting said total extent of movement, adjustable means for selectively establishing the amount of the increment of the feeding movement in each of said groups of movement, means for subjecting said wheel to a dressing operation following a selected one of said groups of movement, and means for advancing said wheel in conjunction with said dressing operation by an amount to compensate for the material removed during said dressing operation while retaining the same pattern of feeding movements in each of said groups thereof.

5. In a grinding machine having a work table and a grinding wheel supported for forward feeding movement with respect to said table, the combination of power means for effecting said forward movement in a series of increments, adjustable control means for said power means for determining the total extent of said forward feeding movement, means for determining the individual extent of each of a plurality of groups of forward feeding movements within and together constituting said total extent of movement, adjustable means for selectively establishing the amount of the increment of the feeding movement in each of said groups of movement, means for subjecting said wheel to a dressing operation following an intermediate one of said groups of movement, and means for advancing said wheel in conjunction with said dressing operation by an amount to compensate for the material removed during said dressing operation while retaining the same pattern of feeding movements in the remaining group thereof and the same total extent of movement.

6. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of power means for

effecting said feeding movement of said grinding wheel in increments, adjustable control means for establishing a plurality of ranges of said feeding movement of said grinding wheel, adjustable means for selectively establishing an individually predetermined increment of movement for each said range, and means for causing return movement of said grinding wheel following the last of said feeding ranges of movement.

7. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of power means for effecting said feeding movement of said grinding wheel in increments, adjustable control means for establishing a plurality of ranges of said feeding movement of said grinding wheel, adjustable means for selectively establishing an individually predetermined increment of movement for each said feeding range, means for causing return movement of said grinding wheel following the last of said feeding ranges of movement, and means responsive to the conclusion of a predetermined one of said feeding ranges of movement for effecting dressing of said grinding wheel.

8. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of power means for effecting said feeding movement of said grinding wheel in increments, adjustable control means for establishing a plurality of ranges of said feeding movement of said grinding wheel, adjustable means for selectively establishing an individually predetermined increment of movement for each said feeding range, means for causing return movement of said grinding wheel following the last of said feeding ranges of movement, means responsive to the conclusion of a predetermined one of said feeding ranges of movement for effecting dressing of said grinding wheel, and means associated with said dressing means and effective prior to the next said feeding range for causing movement of said wheel compensating for reduction in the diameter thereof by said dressing means and without affecting said control means.

9. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of power means for effecting said feeding movement of said grinding wheel in increments, adjustable control means for causing operation of said power means in a cycle including three feeding ranges followed by a return stroke, adjustable means for selectively establishing an individually predetermined increment of movement for each said feeding range, means responsive to conclusion of a predetermined one of said ranges of feeding movement for effecting dressing of said grinding wheel, and means associated with said dressing means and effective prior to the next said feeding range for causing movement of said wheel compensating for reduction in the diameter thereof by said dressing means and without affecting said control means.

10. In a grinding machine including a work table and a grinding wheel supported for feeding and return movement with respect to said table, the combination of drive means including a double acting hydraulic cylinder for effecting feeding movement of said wheel in response to application of hydraulic pressure to one end of said cylinder and return movement of said wheel in response to application of hydraulic pressure to the other end of said cylinder, means providing a supply source of hydraulic fluid for said cylinder under substantially constant pressure, means for periodically connecting said pressure source with said one end of said cylinder to cause feeding movement of said wheel in increments, means for metering the flow of said fluid through said connecting means to establish the extent of each said increment, and means responsive to a predetermined total extent of feeding movement of said wheel for connecting the other end of said cylinder directly with said supply source to cause a return stroke of said wheel.

11. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of means including a hydraulic cylinder for effecting said feeding movement of said wheel, means providing a supply source of hydraulic fluid for said cylinder at substantially constant pressure, means for periodically connecting said cylinder with said supply source to cause feeding movement of said wheel in increments, means for metering the flow of said fluid from said connecting means to said cylinder to establish the extent of each said increment, and means responsive to a predetermined extent of said feeding movement of said wheel for changing the effective setting of said metering means to establish a plurality of ranges of feeding movement of said wheel and to establish an individually predetermined said increment for each said range.

12. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of means including a hydraulic cylinder for effecting said feeding movement of said wheel, means providing a supply source of hydraulic fluid for said cylinder at substantially constant pressure, means for periodically connecting said cylinder with said supply source to cause feeding movement of said wheel in increments, means including a plurality of adjustable metering valves establishing a plurality of different flow paths controlled by said connecting means for said fluid to said cylinder, means for selecting each of said flow paths in predetermined sequence to establish a corresponding plurality of ranges of feeding movement for said wheel, and means for separately regulating said metering valves to establish an individually predetermined said increment for each said range.

13. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of means including a hydraulic cylinder for effecting said feeding movement of said wheel, means providing a supply source of hydraulic fluid for said cylinder at substantially constant pressure, means for periodically connecting said cylinder with said supply source to cause feeding movement of said wheel in increments, means including a plurality of adjustable metering valves establishing a plurality of different flow paths controlled by said connecting means for said fluid to said cylinder, means for selecting each of said flow paths in predetermined sequence to establish a corresponding plurality of ranges of feeding movement for said wheel, means for adjusting said selecting means to preset the vertical extent of each said range of feeding movement, means for separately regulating said metering valves to establish an individually predetermined said increment for each said range, and means responsive to conclusion of the last said range of feeding movement for effecting a return upward stroke of said wheel.

14. In a grinding machine including a work table and a grinding wheel supported for feeding movement with respect to said table, the combination of means including a hydraulic cylinder for effecting said feeding movement of said wheel, means providing a supply source of hydraulic fluid for said cylinder at substantially constant pressure, means for periodically connecting said cylinder with said supply source to cause feeding movement of said wheel in increments, means including a plurality of adjustable metering valve establishing a plurality of different flow paths controlled by said connecting means for said fluid to said cylinder, means for selecting each of said flow paths in predetermined sequence to establish a corresponding plurality of ranges of feeding movement for said wheel, means for separately regulating said metering valves to establish an individually predetermined said increment for each said range, means

for dressing said wheel, means for operating said dressing means at the conclusion of one of said ranges of feeding movement, and means separate from said cylinder and effective before commencement of the next said range of feeding movement for causing movement of said wheel toward said table compensating for reduction of the diameter thereof by said dresser means and without affecting said cylinder.

15. In a grinding machine having a work table supported on a base and having also a saddle including a grinding wheel supported for feeding movement on said base with respect to said table, the combination of a drive screw mounted on said base, friction means for holding said screw against rotation with respect to said base, a nut mounted on said saddle in threaded relation with said screw, main drive means in said saddle constructed to rotate said nut on said screw in increments to cause working movement of said saddle, and auxiliary drive means in said base for rotating said screw with respect to said friction means to cause adjusting movement of said saddle.

16. In a grinding machine having a work table supported on a base and having also a saddle including a grinding wheel supported for feeding movement on said base with respect to said table, the combination of a drive screw mounted on said base, friction means for holding said screw against rotation with respect to said base, a nut mounted on said saddle in threaded relation with said screw, main drive means including a hydraulic cylinder in said saddle constructed to rotate said nut on said screw in increments to cause working movement of said saddle, and auxiliary drive means in said base for rotating said screw independently of said main drive cylinder and with respect to said friction means to cause adjusting movement of said saddle.

17. In a grinding machine having a work table supported on a base and having also a saddle including a grinding wheel supported for feeding movement on said base with respect to said table, the combination of a drive screw mounted on said base, a nut mounted on said saddle in threaded relation with said screw, main drive means including a double acting hydraulic cylinder in said saddle for causing feeding movement of said saddle, means forming a driving connection between said cylinder and said nut causing rotation of said nut on said screw in the direction to cause feeding movement of said saddle in response to a supply of hydraulic fluid to one end of said cylinder and causing rotation of said nut in the direction to cause return movement of said saddle in response to supply of hydraulic fluid to the other end of said cylinder, means providing a supply source of hydraulic fluid for said cylinder under substantially constant pressure, means for periodically connecting said pressure source with said one end of said cylinder to cause feeding movement of said wheel in increments, means for metering the flow of said fluid through said connecting means to establish the extent of each said increment, and means responsive to a predetermined total extent of feeding movement of said wheel for connecting the other end of said cylinder directly with said supply source to cause a return stroke of said saddle.

18. In a grinding machine having a work table supported on a base and having also a saddle including a grinding wheel supported for feeding movement on said base with respect to said table, the combination of a drive vertically extending elevation screw mounted on said base, a nut mounted on said saddle in threaded relation with said screw, main drive means including a double acting hydraulic cylinder in said saddle for causing feeding movement of said saddle, means forming a driving connection between said cylinder and said nut causing rotation of said nut on said screw in the direction to cause feeding movement of said saddle in response to a supply of hydraulic fluid to one end of said cylinder and causing rotation of said nut in the direction to cause return movement of said saddle in response to supply of hydraulic fluid to the other end of said cylinder, means providing a supply source of hydraulic fluid for said cylinder under substantially constant pressure, means for periodically connecting said pressure source with said one end of said cylinder to cause feeding movement of said wheel in increments, means for metering the flow of said fluid through said connecting means to establish the extent of each said increment, selectively operable drive means for rotating said screw to cause movement of said saddle independently of said cylinder, and means responsive to a predetermined total extent of feeding movement of said wheel for connecting the other end of said cylinder directly with said supply source to cause a return stroke of said saddle.

19. In a grinding machine having a work table supported on a base and having also a saddle including a grinding wheel supported for feeding movement on said base with respect to said table, the combination of a drive screw mounted on said base, a nut mounted on said saddle in threaded relation with said screw, main drive means including a double acting hydraulic cylinder in said saddle for causing feeding movement of said saddle, means forming a driving connection between said cylinder and said nut causing rotation of said nut on said screw in the direction to cause feeding movement of said saddle in response to a supply of hydraulic fluid to one end of said cylinder and causing rotation of said nut in the direction to cause return movement of said saddle in response to supply of hydraulic fluid to the other end of said cylinder, means providing a supply source of hydraulic fluid for said cylinder under substantially constant pressure, means for periodically connecting said pressure source with said one end of said cylinder to cause feeding movement of said wheel in increments, means for metering the flow of said fluid through said connecting means to establish the extent of each said increment, means responsive to a predetermined extent of said feeding movement of said wheel for changing the effective setting of said metering means to establish a plurality of feeding ranges of movement of said wheel and to establish an individually predetermined said increment for each said range, and means responsive to a predetermined total extent of feeding movement of said wheel for connecting the other end of said cylinder directly with said pressure source to cause a return stroke of said wheel.

20. In a grinding machine having a work table supported on a base and having also a saddle including a grinding wheel supported for vertical movement on said base with respect to said table, the combination of a drive screw mounted on said base, a nut mounted on said saddle in threaded relation with said screw, main drive means including a double acting hydraulic cylinder in said saddle for causing feeding movement of said saddle, means forming a driving connection between said cylinder and said nut causing rotation of said nut on said screw in the direction to cause feeding movement of said saddle in response to a supply of hydraulic fluid to one end of said cylinder and causing rotation of said nut in the direction to cause return movement of said saddle in response to supply of hydraulic fluid to the other end of said cylinder, means providing a supply source of hydraulic fluid for said cylinder under substantially constant pressure, means for periodically connecting said pressure source with said one end of said cylinder to cause feeding movement of said wheel in increments, means for metering the flow of said fluid through said connecting means to establish the extent of each said increment, means responsive to a predetermined extent of said feeding movement of said wheel for changing the effective setting of said metering means to establish a plurality of feeding ranges of movement of said wheel and to establish an individually predetermined said increment for each said range, dressing means for said wheel, means for operating said dressing means at the

conclusion of one of said feeding ranges, means operative before the commencement of the next said feeding range for rotating said screw through a distance causing movement of said saddle compensating for reduction in the diameter of said wheel by said dressing means, and means effective at the conclusion of all feeding movement of said saddle for connecting the other end of said cylinder directly with said pressure source to cause a return stroke of said saddle.

References Cited in the file of this patent

UNITED STATES PATENTS

1,299,717	Halstead	Apr. 8, 1919
1,923,762	Stevens	Aug. 22, 1933
1,991,953	Nenninger	Feb. 19, 1935
2,639,563	Swainey	May 26, 1953
2,740,236	Flygare et al.	Apr. 3, 1956
2,780,895	Silven et al.	Feb. 12, 1957

FOREIGN PATENTS

374,918	Great Britain	June 9, 1932
702,366	Great Britain	Jan. 13, 1954