

Sept. 19, 1967

J. KLAR

3,341,980

GRINDING MACHINE

Filed July 7, 1964

10 Sheets-Sheet 1

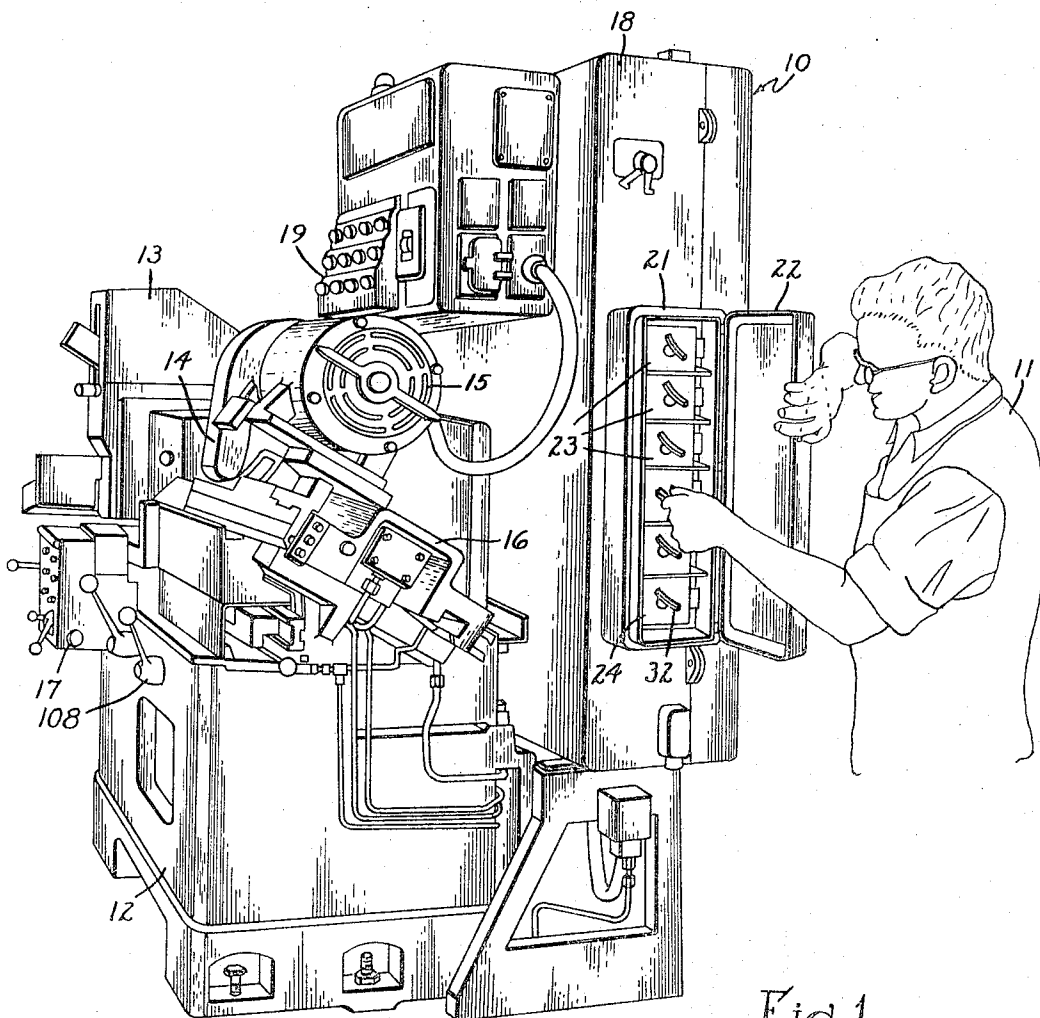


Fig. 1

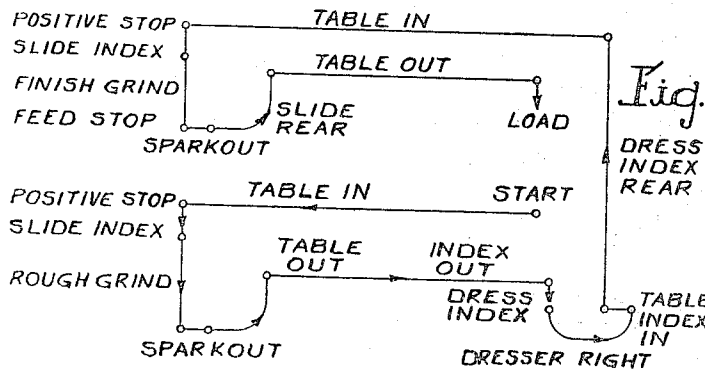


Fig. 14

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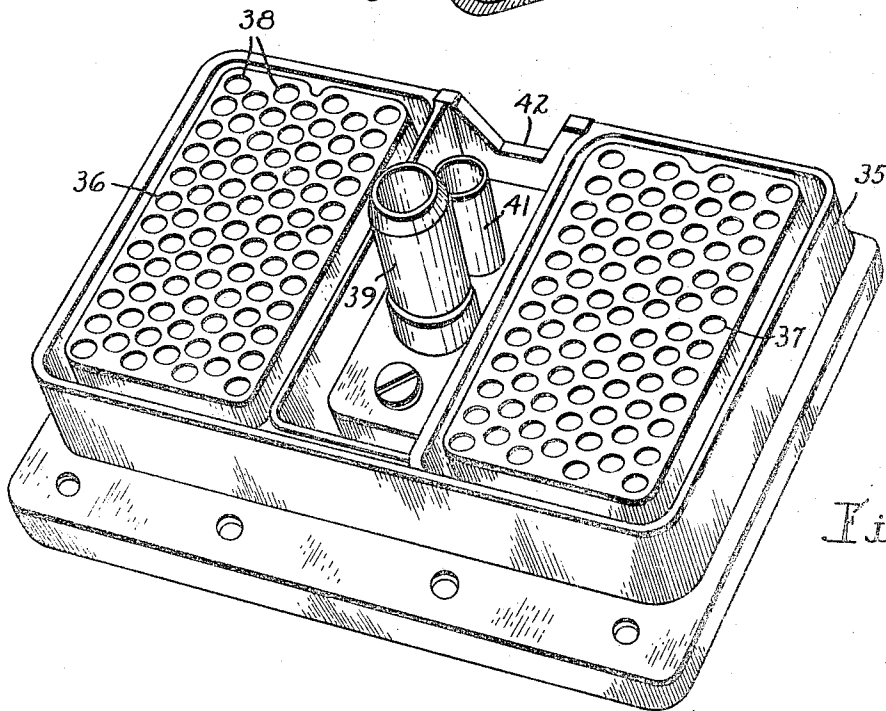
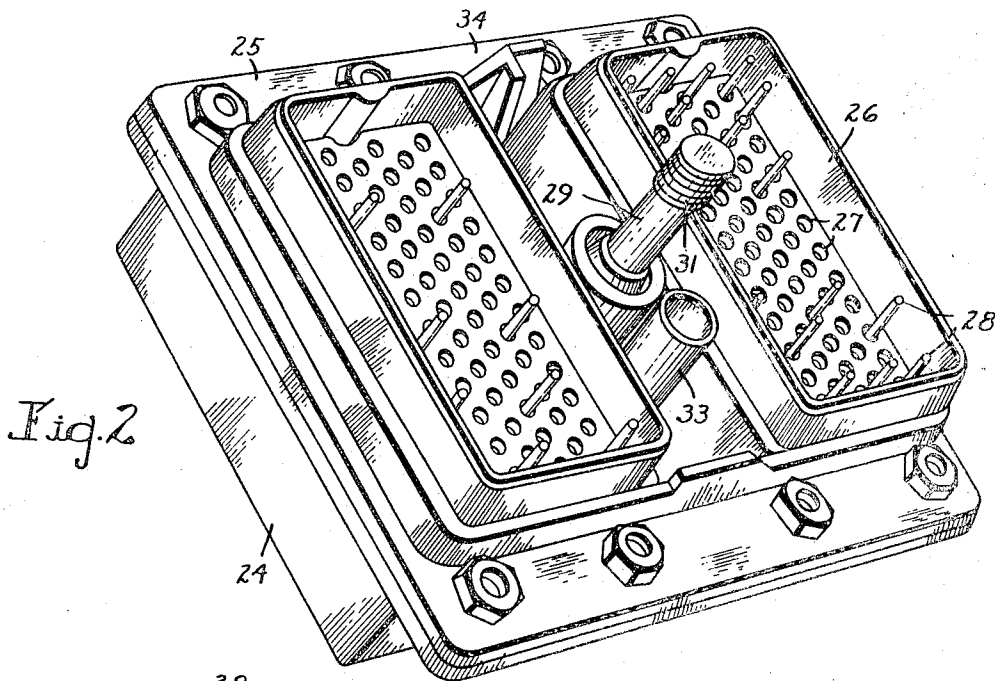
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GRINDING MACHINE

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10 Sheets-Sheet 2



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GRINDING MACHINE

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10 Sheets-Sheet 3

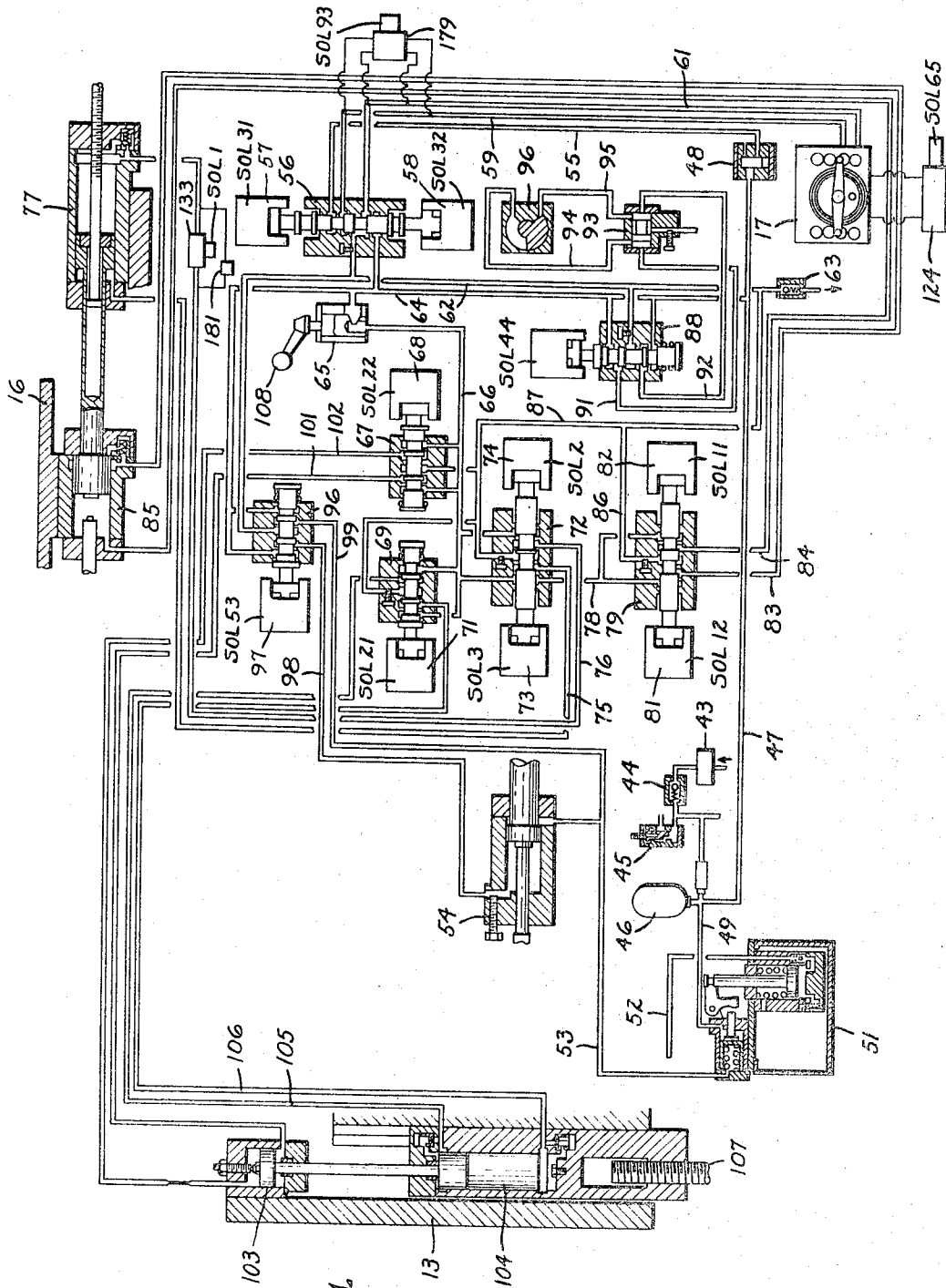


Fig. 4

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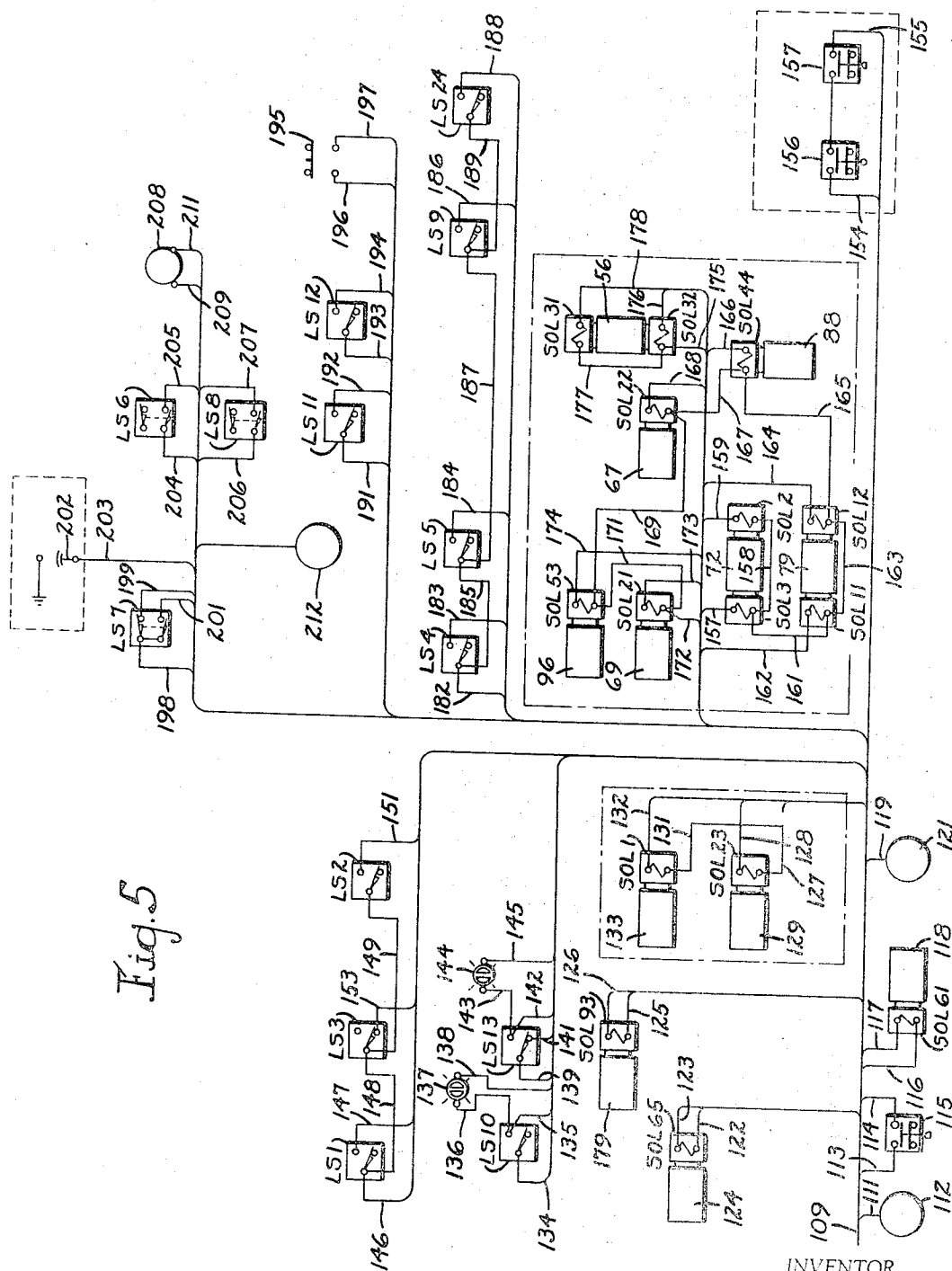
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GRINDING MACHINE

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10 Sheets-Sheet 4



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GRINDING MACHINE

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10 Sheets-Sheet 5

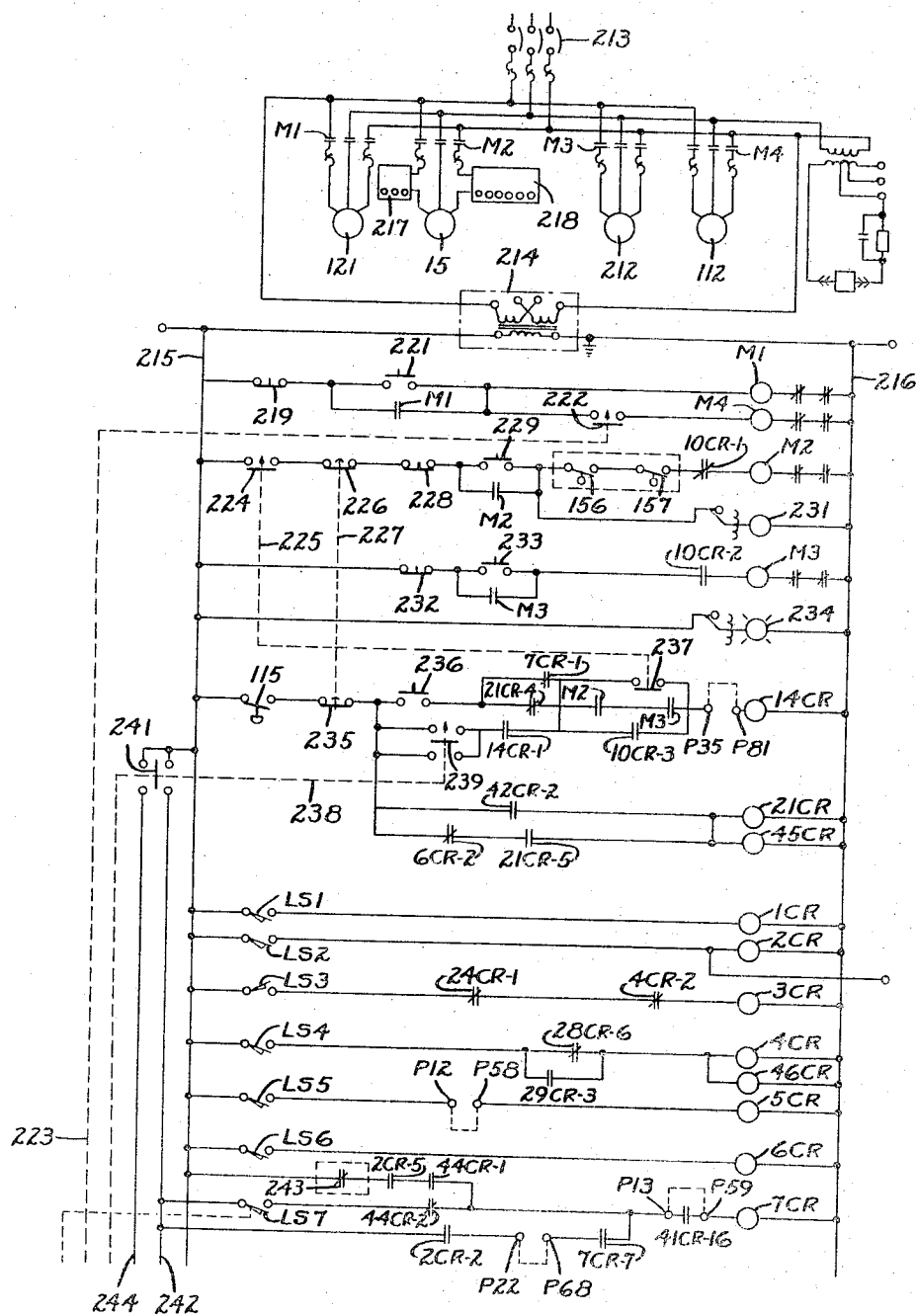


Fig. 6

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GRINDING MACHINE

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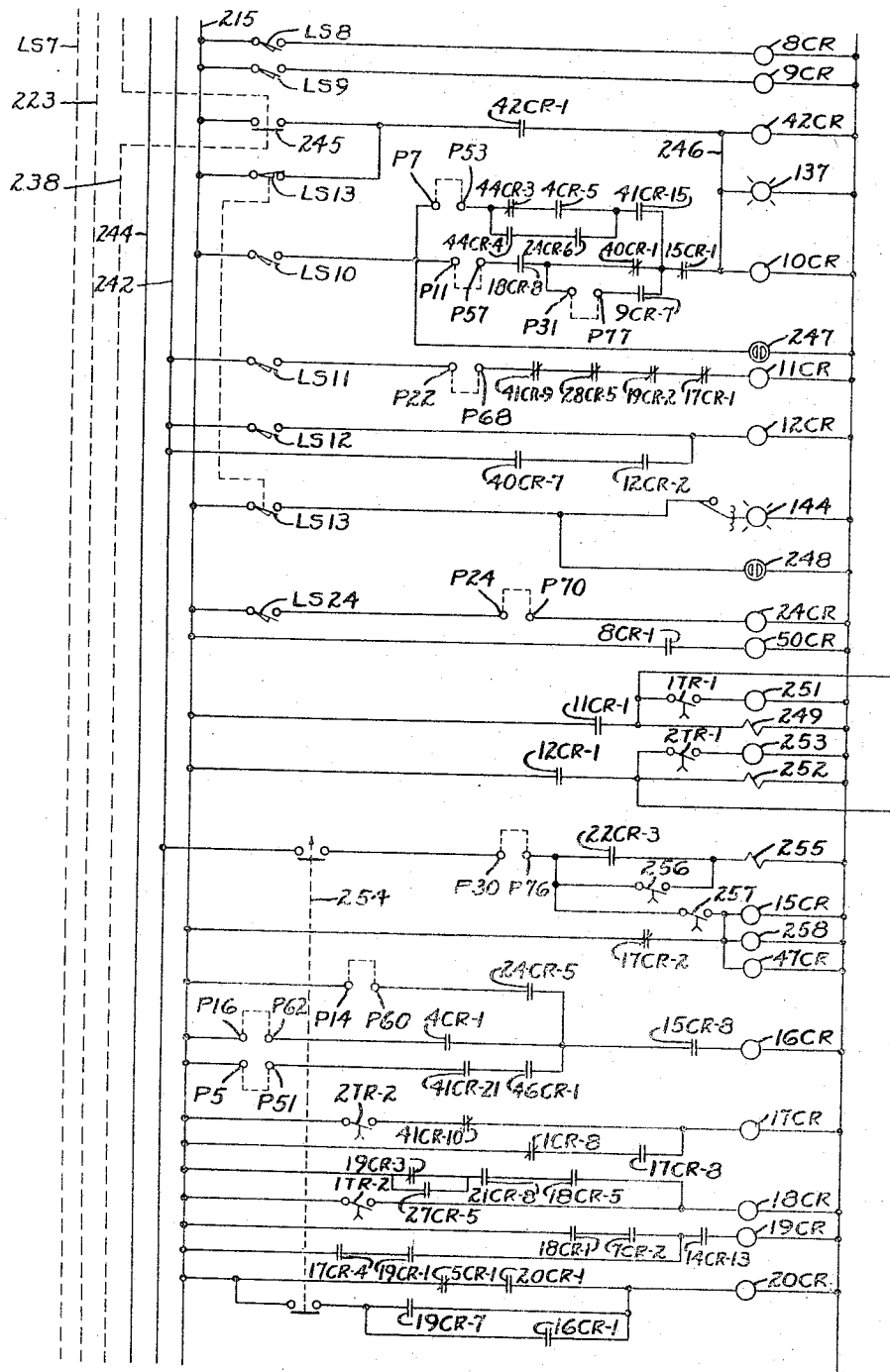


Fig. 7

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10 Sheets-Sheet 7

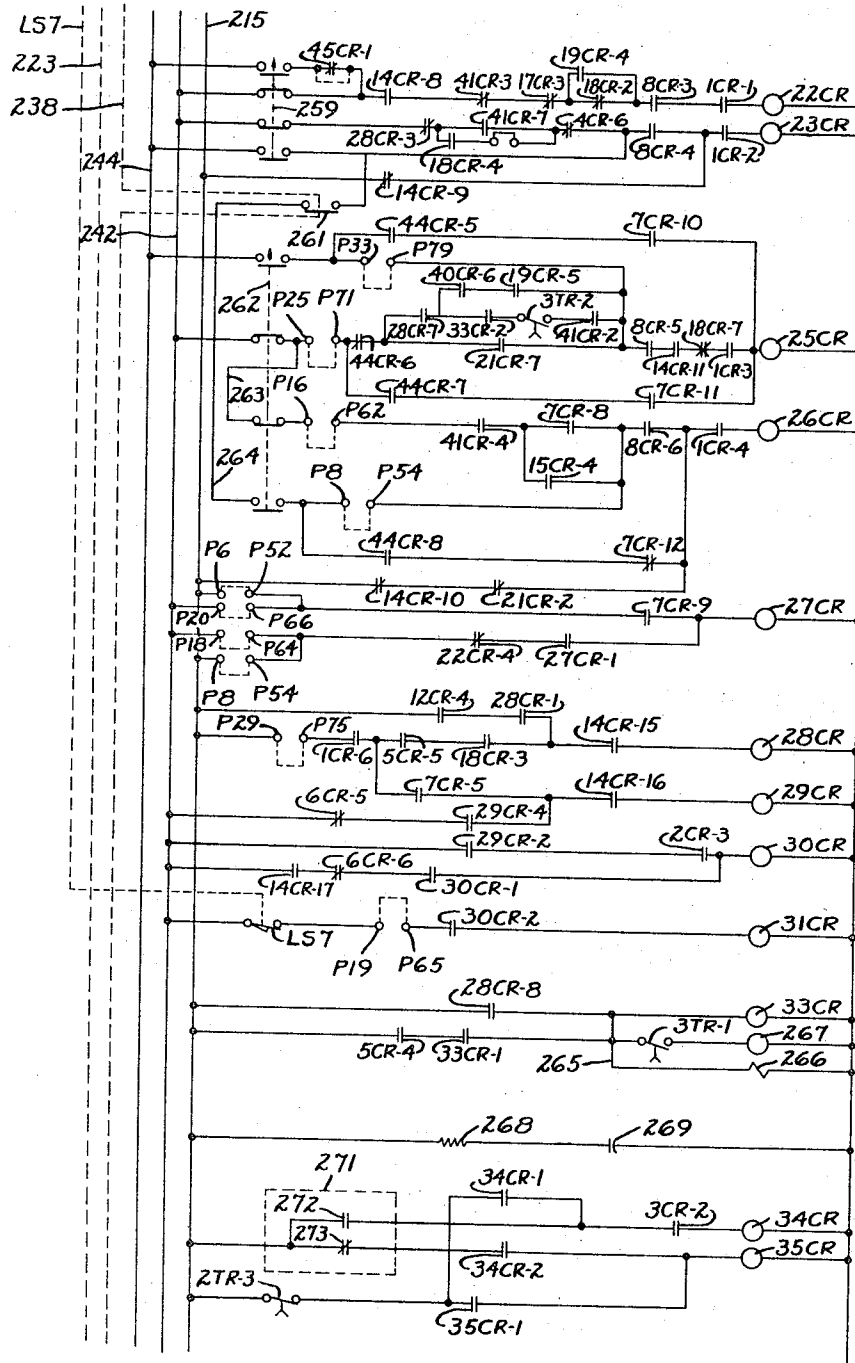


Fig. 8

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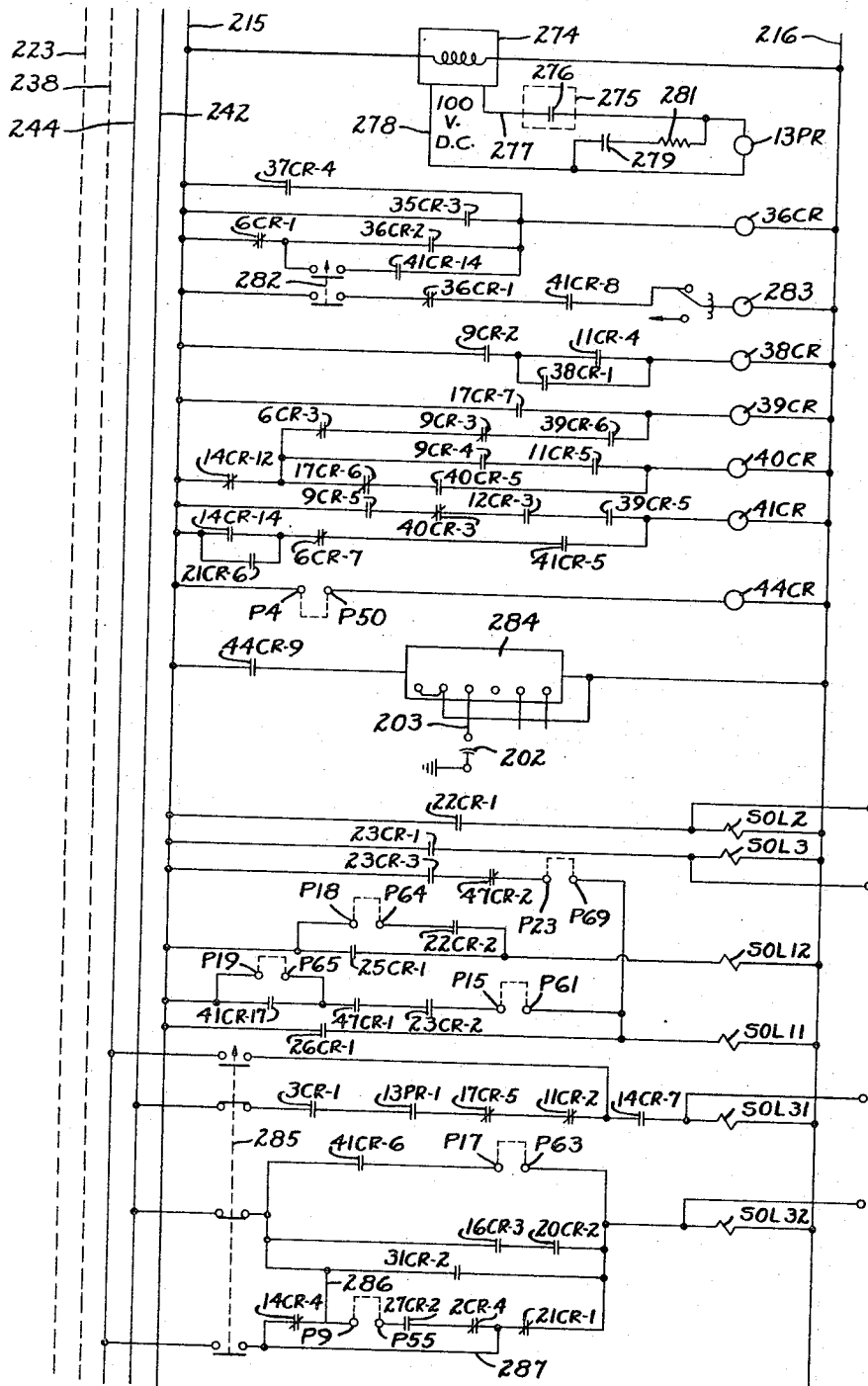


Fig. 9

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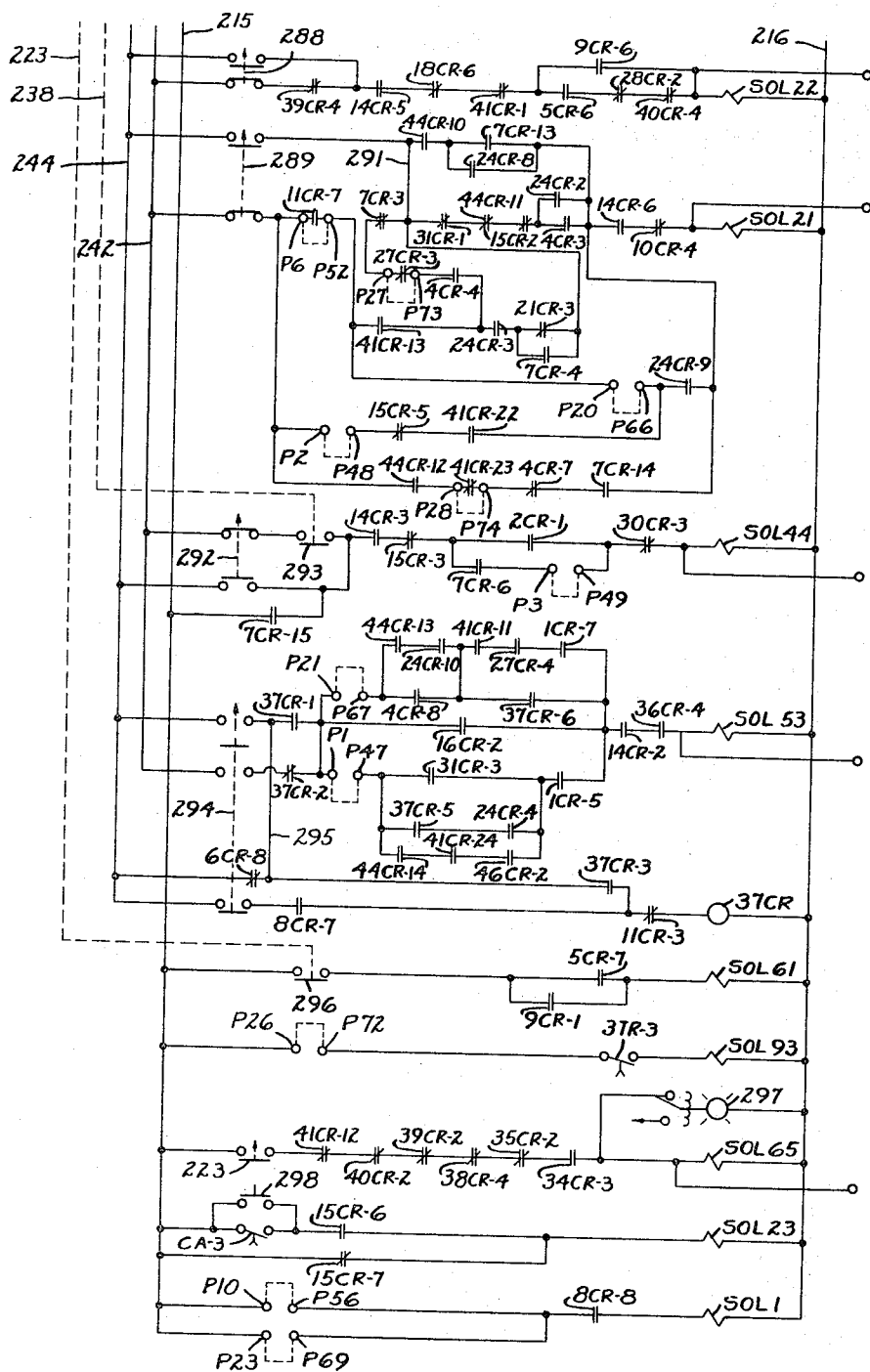


Fig. 10

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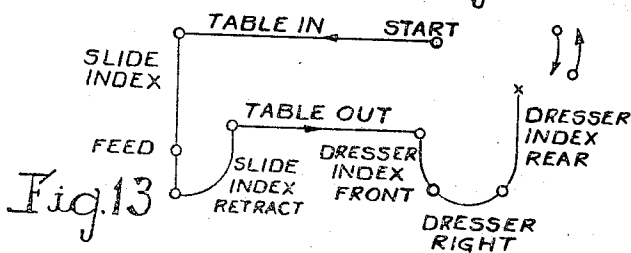
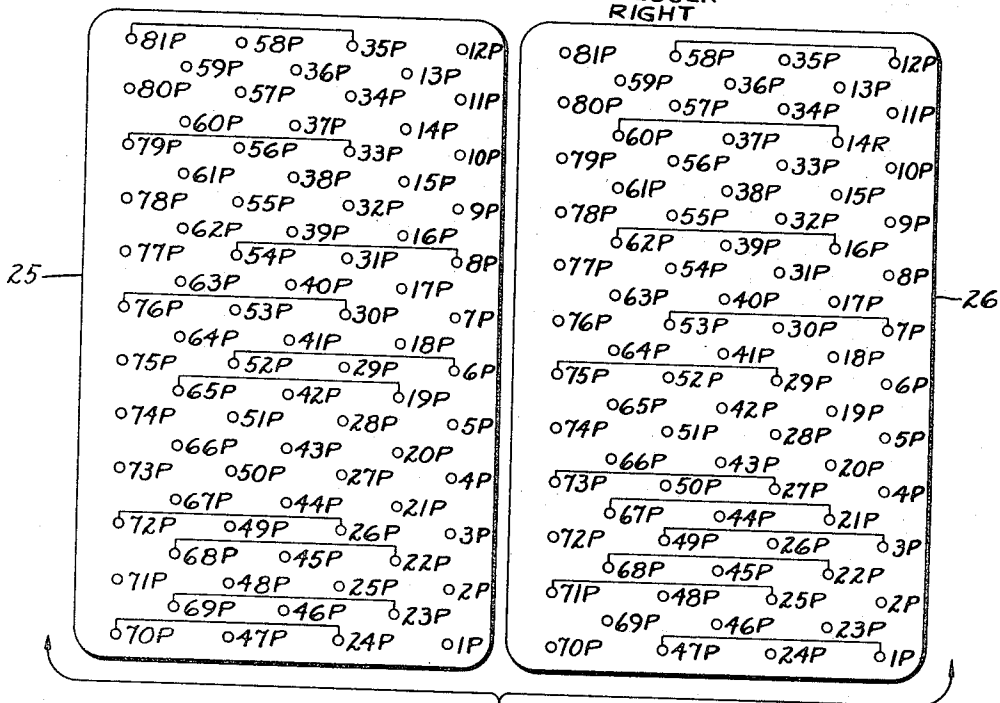
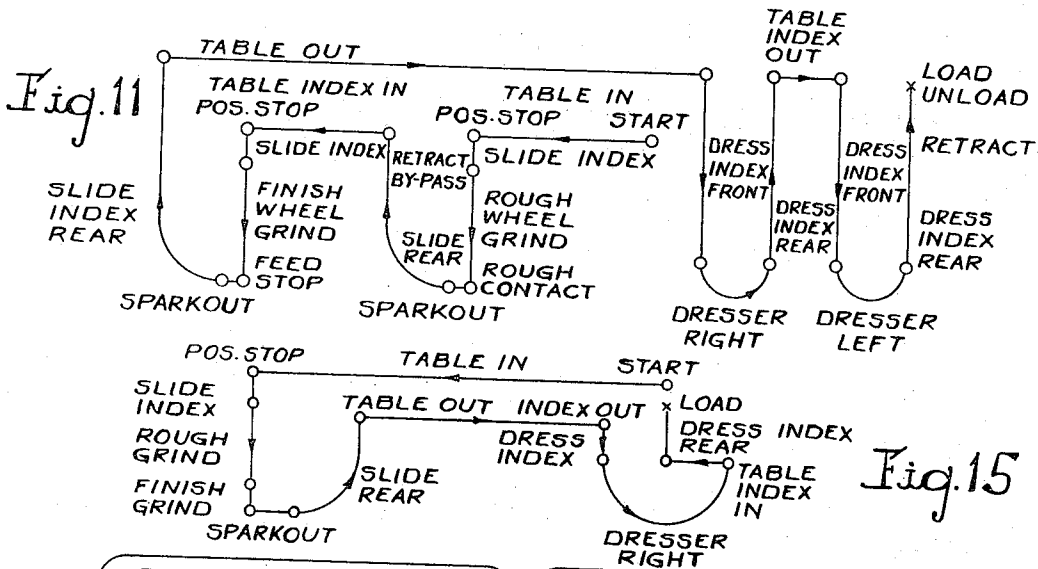
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3,341,980

GRINDING MACHINE

Filed July 7, 1964

10 Sheets-Sheet 10



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3,341,980

GRINDING MACHINE

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Filed July 7, 1964, Ser. No. 380,857

3 Claims. (Cl. 51-165)

This invention relates to a machine tool and, more particularly to apparatus arranged to finish a surface of revolution by the abrasive machining process.

In the design and operation of automatic machine tools, it is common practice to use a variety of different cycles of grinding steps in finishing the surface of a workpiece. In a grinding machine, for instance, the selection of the particular cycle used and the arrangement of the various steps of feeding, grinding, backing off, dressing, and so on, depends on the surface which is to be finished, the tolerances required, the finish which is necessary, and in other similar factors. It has been the general practice, however, to design and manufacture a machine for use with one specific cycle. If one wished to change a machine to a different cycle, it has been necessary to rewire the internals of the machine and, in some cases, to rebuild it. In the manufacturing process, the concept of building a machine for a particular cycle to be used with it means an increased ultimate cost to the consumer because of the fact that each automatic machine tool has to be individually designed and manufactured and it is difficult to obtain the advantages of mass production. To the user of the machine, the fact that his machine is limited to a particular cycle means that, if there is no workpiece available to be machined which uses that cycle, then the machine stands idle. Such idle capital equipment raises the general cost of the other products in the factory and results in an economic waste. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a machine tool capable of being readily changed from one cycle of operation to another.

Another object of this invention is the provision of an automatic machine tool whose cycle can be changed without rewiring and rearrangement of the parts.

A further object of the present invention is the provision of an automatic machine tool in which the cycle can be changed by the operator and without the assistance of persons trained in other trades.

It is another object of the instant invention to provide an automatic machine tool whose cycle may be changed very quickly with a minimum of down-time and in which the types of cycles to be used are limited only by the imagination of the operator.

It is a further object of the invention to provide an automatic machine tool in which all of the machines of a given type will be constructed exactly alike, irrespective of the type of cycle which will be predominantly selected by the operator of the machine.

A still further object of this invention is the provision of an automatic machine tool in which the electrical and hydraulic wiring is standardized, irrespective of the particular cycle with which the machine is to be used.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

The character of the invention, however, may be best understood by reference to one of its structural forms as illustrated by the accompanying drawings in which:

FIG. 1 is a perspective view of a machine tool embodying the principles of the present invention,

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FIG. 2 is a perspective view of a male plug used in the present invention,

FIG. 3 is a perspective view of a female plug used in the present invention,

FIG. 4 is a schematic view of a hydraulic circuitry forming part of the grinding machine,

FIG. 5 is a somewhat schematic view of switches and solenoids forming part of the controls of the present machine,

FIGS. 6, 7, 8, 9, and 10 are schematic diagrams of the electrical circuitry used in the machine,

FIG. 11 is an illustration of a typical cycle used with the present machine,

FIG. 12 is a somewhat schematic view of the plugs used in practicing the cycle shown in FIG. 11,

FIG. 13 shows another cycle which may be used,

FIG. 14 shows a still further cycle, and

FIG. 15 shows another cycle.

Referring first to FIG. 1, wherein are best shown the general features of the invention, a grinding machine, indicated generally by the reference numeral 10, is shown being used by an operator 11. The machine is provided with a base 12 on which is mounted a workhead 13 and a wheelhead 14. The wheelhead has mounted on it a motor 15 which drives a spindle and abrasive wheel (not shown). The wheelhead is mounted on a wheelhead table 16 which is capable of longitudinal movement over the base 12. The workhead 13 carries the workpiece (not shown), rotates it, and is capable of transverse movement over the base 12 under the direction of a feed box 17. The feed box directs the speed of the feed of the workpiece toward and away from the wheel in the transverse direction during the cycle and provides for compensation after dress. Mounted at the back of the machine is the main electrical and hydraulic control box 18 on the front of which is mounted an array 19 of push buttons. At the side of the control box 18 is mounted a rack 21 having a cover 22, the rack containing a series of plugs 23 for storage. At the bottom of the rack is located a plug 24 which is in actual operative relationship with the rest of the machine.

Referring now to FIGS. 2 and 3, the male plug 24 is shown as it would be observed from within the machine looking out. The plug is provided on one side with a receptacle 25 and on the other side with a receptacle 26. The bottom of each receptacle is provided with a series of bores 27 and from some of them extend pegs 28, as will be explained more fully hereinafter. Between the two receptacles extends a shaft 29 which is rotatably mounted in the main body of the plug and which has on its inner end a series of coarse threads 31. The outer end is provided with a handle 32 (see FIG. 1). Parallel to and spaced from the shaft 29 is a short, sturdy peg 33, while on the opposite side of the shaft 29 is located an abutment 34 of a generally trapezoidal configuration having inclined edges. FIG. 3 shows the female plug 35 which is mounted permanently in the lower position in the rack 21. This plug is provided with two receptacles 36 and 37 having bores 38 corresponding exactly with the bores 27 of the plug 24. Between the receptacles 36 and 37 is located an internally-threaded nut 39 adapted to cooperate with the coarse threads 31 of the shaft 29. In addition, spaced from and parallel to the nut 39 is a peg 41. At the same side of the nut 39 as the peg 41 is a trapezoidally-shaped recess 42 adapted to cooperate with the abutment 34 of the plug 24.

FIG. 4 shows the hydraulic circuitry of the invention including a pump 43 operating through a check valve 44 and a relief valve 45 leading to an accumulator 46. One line 47 leads to a feed pressure regulating valve 48, while another line 49 leads to a ways lubrication tank 51 from

which extends a line 52 leading to the ways on which slide the wheelhead table 16 and the workhead 13. Another line 53 leads from the tank 51 to a clamp-and-eject cylinder 54 which acts to clamp the workpiece in the workhead 13 and to eject a finished workpiece. From the pressure-regulating valve 48 extends a line 55 connected to a Feed solenoid valve 56 having a feed coil 57 at one end of its spool and a retract coil 58 connected to the other end of its spool. From the solenoid valve 56 extends a line 59 leading to the feed box 17, this feed box being of the type shown in the patent of Lockwood et al. No. 3,035,378 issued May 22, 1962. From the feed box extends a line 61 leading back to the solenoid valve 56 which, in turn, is connected to a line 62 which is joined to a check valve 63 leading to the drain or tank portion of the hydraulic circuit. The solenoid valve 56 is also connected to a line 64 leading to a throttle valve 65 on the other side of which is connected a line 66. The line 66 is connected to a grind index solenoid valve 67 which is operated by a solenoid 68. The line 66 is also connected to a dress-index solenoid valve 69 operated by a solenoid 71. Also, the line 66 is connected to a table solenoid valve 72 which is operated on one end by a solenoid 73 and at the other end by a solenoid 74. The valve 72 is connected by two lines 75 and 76 to the opposite ends of a cylinder 77 associated with the wheelhead table 16. The table solenoid valve 72 is also connected by a line 78 to a table index solenoid valve 79 which is operated on one end by a solenoid 81 and on the other end by a solenoid 82. Extending from the valve 79 are two lines 83 and 84 which are connected to the opposite ends of a table cylinder 85 also associated with the workhead table 16 and the base 12 of the machine.

The valve 79 is connected by a line 86 to the line 62 leading to drain. Similarly, the valve 72 is connected by a line 87 to drain, as well as the dress-index solenoid valve 69 and the grind-index solenoid valve 67, both of which are also connected to drain in this same manner. The line 62 leading from the feed solenoid valve 56 is connected to a radius-dresser valve 88 which is operated by a solenoid SOL44, this solenoid valve also being connected to the line 62 leading to drain. The valve 88 is connected by two lines 91 and 92 to the opposite ends of a directional-valve 93 which, in turn, is connected by lines 94 and 95 to a radius-dresser vane-type motor 96. The drain line 62 emerging from the feed solenoid valve 56 is also connected to a loading solenoid valve 96 which is operated by a solenoid 97 and which is also connected to the high pressure line 64 emerging from the valve 56 and two lines 98 and 99 lead to the opposite ends of the clamp-and-eject cylinder 54.

The grind-index solenoid valve 67 is connected by two lines 101 and 102 to opposite ends of a short index cylinder 103 associated with the workhead 13. In a similar way, a long index cylinder 104 is connected at one end by a line 105 to the valve 69 and by a line 106 to the same valve. A feed screw 107 associated with the feed box 17 in the usual manner is shown associated with the workhead 13 also. The throttle valve 65 is provided with a handle 108 which also appears in FIG. 1 on the front of the base 12. The retract bypass valve 179 is inserted in the lines 59 and 61 leading from the feed solenoid valve 56 to the feed box 17. A fast feed valve 124 operated by the solenoid SOL65 forms part of the feed box for rapid feed before the wheel comes into contact with the workpiece, thus eliminating the so-called "cutting of air." A table stop valve 133 is inserted in the line 76 leading from the table solenoid valve 72 to the cylinder 77 and this valve 133 is operated by a solenoid SOL1. A check valve 181-bypasses this valve when it is under positive pressure.

FIG. 5 shows the arrangement of some of the basic electrical switches and solenoids. The individual electrical lines are joined together in a cable 109 which is connected back to the main electrical control box 18. A line 111

leads to a coolant motor 112 and two lines 113 and 114 are connected to opposite sides of a coolant pressure switch 115. Two lines 116 and 117 lead to a solenoid SOL61 which operates on a coolant valve 118. A line 119 leads to a main drive motor 121. Lines 122 and 123 are connected to opposite sides of solenoid SOL65 operating on a Fast Feed valve 124. Similarly, two lines 125 and 126 are connected to opposite ends of a solenoid SOL93 which operates on the Feed Solenoid valve 56 for retraction. Two lines 127 and 128 are connected to opposite ends of a solenoid SOL23 which operates on a Compensation valve 129. Two lines 131 and 132 operate on the ends of solenoid SOL1 which operates on a Table Stop valve 133. Also extending from the cable 109 are two lines 134 and 135 connected to opposite sides of the Wheel Wear limit switch LS10. A line 136 leads from the same side of the switch LS10 as the line 135 to one side of the Wheel Wear lamp 137, from the other side of which extends a line 138 leading back to the cable 109 and the main control panel. In a similar way, a line 139 and a line 141 lead to opposite sides of the Wheel Size switch LS13. The switch LS13 has another contact which is connected by a line 142 back to the cable 109 and by a line 143 to one side of a Wheel Size lamp 144, one side of which is connected by a line 145 back to the cable and to the main control panel. Two lines 146 and 147 are connected to opposite sides of the Work Slide Rear micro-switch LS1. A Slide At Grind microswitch LS3 is connected by a line 148 to the same side of the switch LS1 as the line 146. The line 148 is also connected by a line 149 to one side of the Work Slide Front microswitch LS2, the other side of which is connected by a line 151 back to the cable. The other side of the switch LS3 is also connected by a line 153 back to the cable. Out of the cable also emerge two lines 154 and 155 connected to opposite sides of two switches 156 and 157 associated with a mist-lube-unit, the switch 157 being a pressure switch.

The solenoid SOL3 associated with the table valve 72 is connected on one side by a line 157 back through the cable and by a line 158 to one side of the solenoid SOL2, the other side of which is connected by a line 159 back to the cable. Similarly, the solenoid SOL11 associated with the Table Index solenoid valve 79 is connected on one side by a line 161 to the same side of the solenoid SOL3 as the line 158, while the other side of the solenoid SOL11 is connected by a line 162 back to the cable. The side of the solenoid SOL11 is connected to the line 161 and is also connected by a line 163 to one side of the solenoid SOL12, the other side of which is connected by a line 164 back to the cable. The side of the solenoid SOL12 which is connected to the line 163 is connected by a line 165 to one side of the solenoid SOL44 which is connected to the dresser valve 88. The other side of the solenoid SOL44 is connected by a line 166 back to the cable, while the side of the solenoid SOL44 which is connected to a line 165 is connected by a line 167 to one side of the solenoid SOL22 which is associated with the Grind-Index solenoid valve 67. The other side of the solenoid SOL22 is connected by a line 168 back through the cable to the main control panel. The same side of the solenoid SOL22 which is connected to the line 167 is connected by a line 169 to one side of the solenoid SOL53 which is associated with the Loading solenoid valve 96. The same side of the solenoid SOL53 is connected by a line 171 to one side of the solenoid SOL21 associated with the Dress-Index solenoid valve 69, the same side of the solenoid SOL21 being connected by a line 172 back to the cable, the other side of the solenoid SOL21 being connected by a line 173 back to the cable, and the other side of the solenoid SOL53 being connected by a line 174 back to the cable. Two lines 175 and 176 originating in the cable are connected to opposite ends of the solenoid SOL32 associated with the Feed solenoid valve 56. The side of the solenoid SOL32 which is connected to the line 175 is connected by a line

177 to one side of a solenoid SOL31 also associated with the Feed solenoid valve 56, the other side of which is connected by a line 178 back into the cable. Also extending from the cable are lines connected to limit switches associated with the wheelhead table 16, namely, First Dress limit switch LS4, First Groove limit switch LS5, Second Groove limit switch LS9, and Second Dress limit switch LS24. The limit switch LS4 is connected into the cable by lines 182 and 183. The limit switch LS5 is connected to one side into the cable by a line 184 and is connected by a line 185 to the same side of the switch LS4 as is the line 182. The limit switch LS9 is connected into the cable by a line 186 and is also connected by a line 187 to the side of the limit switch LS5 which is connected to the line 185. Similarly, the limit switch LS24 is connected into the cable by a line 188 and is connected by a line 189 to the side of the switch LS9 which is connected to the line 187.

A Rough Contact switch LS11 is connected into the cable by lines 191 and 192, while the Finish Contact switch LS12 is connected into the cable by lines 193 and 194. The Compensation Adjusting switch 195 is connected into the cable by two lines 196 and 197.

A Dresser Right switch LS7 is of the double throw variety leading into the cable on one side by a line 198 and on the other side through lines 199 and 201, while a contactor 202 on the dresser is connected into the cable through a line 203. A Work Unloaded switch LS6 is connected into the cable through lines 204 and 205, while a Work Loaded switch LS8 is connected into the cable through lines 206 and 207. A work chuck 208 is operated through lines 209 and 211.

Referring now to FIG. 6, it can be seen that the main drive motor 121 and the wheelhead motor 15 as well as the workhead motor 112 and the coolant motor 112 are connected to a source 213 of three-phase alternating current electricity. The main drive motor 121 is connected to the source through a motor starting relay M1. The wheelhead motor is connected to the source through a motor starter M2, the workhead motor is connected to a motor starter M3, and the coolant motor 112 is connected to the source through a motor starter M4. Two of the power lines from the supply are connected to the primary coil of the transformer 214, the secondary coil of which is connected to power lines 215 and 216 which, in the preferred embodiment, carry 110 volt alternating current electricity across them. Two load converters 217 and 218 are connected into the lead going to the wheelhead motor and measure the current going to the motor, which current is indicative of the load on the motor. Connected in series from the power line 215 to the power line 216 is a Main Drive Stop push button 219, a Main Drive Start button 221, and the coil of the motor starter M1. Connected across the starter switch 221 is one of the contactors of the motor starter M1; connected from the side of the switch 221 which is not connected to the switch 219 is one side of a contactor 222; this contactor forms part of a coolant switch 233 (see FIG. 10), the other side of the contactor 222 being connected through the coil of the coolant motor starter M4 to the line 216.

Also connected from the line 215 to the line 216 is a contactor 224 forming part of an interlock switch 225, a contactor 226 of an Emergency Stop switch 227, a Wheelhead Motor Stop pushbutton switch 228, a Wheelhead Motor Start pushbutton switch 229, the oil mist unit switches 156 and 157 (which are closed when the pressure and flow are adequate), a normally-closed contactor 10CR-1, and the coil of the wheelhead motor starter M2. Across the starter switch 229 is arranged one of the contactors of the wheelhead motor starter M2. Extending from the side of the switch 229 which is not connected to the switch 228 is the Wheelhead Start lamp 231. Also connected from the line 215 to the line 216 is a Workhead Motor Stop pushbutton switch 232, the Workhead Motor Stop pushbutton switch 233, the normally-open

contactor 10CR-2, and the coil of the workhead motor starter M3. A normally-open contactor of the motor starter M3 is mounted around the switch 233. A Power On lamp 234 extends from the line 215 to the line 216 to indicate the presence of power across these two lines. Connected on one side of a line 215 is the coolant-pressure switch 115, the other side of which is connected to a normally-closed contactor 235 forming part of the Emergency Stop switch 227. The other side of the contactor 235 is connected to one side of a cycle start pushbutton switch 236, the other side of which is connected to the line 216 through a normally-closed contactor 21CR-4, a contactor of the motor starter M2, a contactor of the motor starter M3, and the coil of a relay 14CR. A normally-closed contactor 7CR-1 is connected across the contactor 21CR-4, while a contactor 237 forming part of the interlock switch 225 is connected across the two contactors of the motor starters M2 and M3. Also connected around the two contactors of the motor starters M2 and M3 is a normally-open contactor 10CR-3. A common point between the switches 235 and 236 is connected to one side of a normally-open contactor cycle switch 238 through a normally-open contactor 14CR-1 to the common point between the contactor 21CR-4 and the contactor of the motor starter M2. The common point between the relays 235 and 236 is also connected to a normally-open contactor 42CR-2 and the coil of the relay 21CR to the line 216. At the same time, the common point between the switches 235 and 236 is connected to the line 216 through a normally-closed contactor 6CR-2, a normally-open contactor 21CR-5, and the coil of a relay 45CR; a jumper extends between the sides of the coils of the relays 21CR and 45CR which are not connected to the line 216. The cycle switch 238 is not only provided with the contactor 239 described above, but also with another contactor 241 connected to portions of the apparatus shown in other figures of the drawings.

One side of the Work Slide Rear switch LS1 is connected to the line 215 and its other side is connected through the coil of a relay 1CR to the line 216. One side of the Work Slide Front limit switch LS2 is connected to the line 215 and the other side is connected through the coil of a relay 2CR to the line 216. One side of the Slide At Grind switch LS3 is connected to the line 215 and the other side is connected through the normally-closed relay 24CR-1, the normally-closed contactor 4CR-2, and the coil of a relay 3CR to the line 216. One side of the First Dress limit switch LS4 is connected to the line 215, while its other side is connected through a normally-closed contactor 28CR-6 and the coil of a relay 4CR to the line 216. A normally-open contactor 29CR-3 is connected around the normally-closed contactor 28CR-6, while the coil of a relay 46CR is connected from a common point between the contactor 28CR-6 and the coil of the relay 4CR to the line 216. One side of the First Groove limit switch LS5 is connected to the line 215, while the other side is connected through the coil of the relay 5CR to the line 216. One side of the Work Unloaded limit switch LS6 is connected to the line 215, while the other side is connected through the coil of a relay 6CR to the power line 216. One side of the Dresser Right limit switch LS7 is connected to a line 242 extending from the contactor 241 and on its other side is connected through a normally-closed contactor 44CR-2, a normally-open contactor 41CR-16, and the coil of a relay 7CR to the line 216. Connected on one side to the line 215 is a normally-closed switch 243 which is connected through a normally-open contactor 2CR-5 and a normally-open contactor 44CR-1 to a common point between the normally-closed contactor 44CR-2 and the normally-open contactor 41CR-16. The normally-open contactor 2CR-2 is connected on one side to the line 242 and on the other side through the normally-open contactor 7CR-7 to the common point between the normally-closed contactor 44CR-2 and the normally-open contactor 41CR-16. For the pur-

poses of clarity, the reference numeral 244 has been given to the other line connected to the contactor 241. It should be noted that the load converter 217 is connected to a meter on the face of the machine to indicate to the operator the load on the wheelhead motor, and also to operate a peak power control unit. The load converter 218, however, forms part of a so-called "gap eliminator" and serves to provide a rapid infeed of the workpiece toward the wheel until the wheel actually contacts the surface to be finished and the load builds up in the wheelhead motor. This rapid infeed, incidentally, is furnished through the medium of the solenoid valve 124 (FIG. 5) operated by the solenoid SOL65.

Referring to FIG. 7, it can be seen that the operating portion of the coolant switch 223 extends through this drawing as well as the operating element of the switch 238, and an operating element of the switch LS7. Furthermore, the lines 244 and 242 extend into the drawing as well as the power lines 215 and 216. Loaded limit switch LS8 is attached on one side of the line 215 and on the other side is connected through the coil of the relay 8CR to the power line 216. In a similar manner, the Second Groove limit switch LS9 is connected on one side to the line 215 and on the other side is connected through the coil of the relay 9CR to the line 216. Another contactor 245 forming part of the switch 238 is connected on one side to the power line 215. The other side of the contactor is connected through the normally-open contactor 42CR-1 and the coil of a relay 42CR to the line 216. One element of the Wheel Size limit switch LS13 extends from the power line 215 to a common point between the contactor 245 and the normally-open contactor 42CR-1. One side of the Wheel Wear switch LS10 is connected to the power line 215, while the other side is connected through a normally-open contactor 18CR-8, a normally-closed contactor 40CR-1, a normally-closed contactor 15CR-1, and the coil of a relay 10CR to the power line 216. A number of electrical elements are connected from a common point between the limit switch LS10 and the normally-open contactor 18CR-8 to a common point between the normally-closed contactor 40CR-1 and the normally-closed contactor 15CR-1; these elements are a normally-closed contactor 44CR-3, a normally-open contactor 4CR-5, and a normally-open contactor 41CR-15, all mounted in series. Furthermore, a normally-open contactor 44CR-4 and a normally-open contactor 24CR-6 are mounted in series and one end is connected to the common point between the limit switch LS10 and the normally-closed contactor 44CR-3, while they are connected on the end to the common point between the normally-open contactor 4CR-5 and the normally-open contactor 41CR-15. In addition, a normally-open contactor 9CR-7 is connected on one side to a common point between the contactor 18CR-8 and the contactor 40CR-1 and on the other side to the common point between the contactor 40CR-1 and the contactor 15CR-1. A jumper line 246 is connected from the sides of the coils of the relays 42CR and 10CR that are not connected to the line 216; from the center of this line 246 extends the Wheel Wear Stop lamp 137. Furthermore, a lamp 247 is connected from the common point between the limit switch LS10 and the contactor 18CR-8 and the line 216.

The Rough Contact switch LS11 is connected on one side to the line 242 and on the other side through a normally-closed contactor 41CR-9, a normally-closed contactor 28CR-5, a normally-closed contactor 19CR-2, and a normally-closed contactor 17CR-1 as well as the coil of a relay 11CR to the line 216. Similarly, the Finish Contact switch LS12 is connected on one side to the line 242 and on the other side through the coil of a relay 12CR to the line 216; at the same time, the line 242 is connected through a normally-open contactor 40CR-7 and a normally-open contactor 12CR-2 to the common

point between the switch LS12 and the coil of the relay 12CR.

The other element of the Wheel Size limit switch LS13 is connected on one side to the line 215 and on the other side through the Wheel Size light 144 to the line 216 and a neon lamp 248 is connected across this lamp. The Second Dress limit switch LS24 is connected on one side to the line 215 and on the other side through the coil of a relay 24CR to the line 216. Similarly, a normally-open contactor 8CR-1 and the coil of a relay 50CR are connected in series with one another from the line 215 to the power line 216.

A normally-open contactor 11CR-1 is connected on one side to the line 215 and on the other side through the operating coil of a clutch 249. Connected from the common point between the contactor 11CR-1 and the clutch 249 to the line 216 are a contactor of a motor timer 1TR and a timer motor 251, this constituting the timer in the rough stage of grinding. Similarly, a normally-open contactor 12CR-1 is connected on one side to the line 215 and on the other side through the operating coil of a clutch 252. Around the clutch is mounted in series a contactor 2TR-1 forming part of a finish timer and the motor 253.

One contactor of a Skip Dress switch 254 is connected on one side to the line 242 and on the other side through a normally-open contactor 22CR-3 and the electrical actuating coil of a clutch 255 to the line 216. Connected across the contactor 22CR-3 is a switch 256 associated with a counter. Connected to the common point between the switch 254 and the contactor 22CR-3 is a switch 257 which is connected through the coil of a relay 15CR to the line 216. The common point between the switch 257 and the coil of the relay 15CR is connected through a coil 258 to the line 216 and also through the coil of a relay 47CR to the line 216. The sides of the coil of the relay 15CR, the coil 258, and the coil of the relay 247CR which are not connected to the line 216 are connected together and are connected back through a normally-closed contactor 17CR-2 to the line 215. A normally-open contactor 4CR-1 is connected on one side to the line 215 and on the other side through a normally-open contactor 15CR-8 and the coil of the relay 16CR to the line 216. Furthermore, the common point between the contactor 4CR-1 and the contactor 15CR-8 is connected back through a normally-open contactor 24CR-5 to the line 215. This same common point is connected through a normally-open contactor 46CR-1 and a normally-open contactor 41CR-21 to the line 215.

A contactor 2TR-2 associated with the timer 2TR is connected on one side of the line 215 and on the other side is connected through a normally-closed contactor 41CR-10 and the coil of a relay 17CR to the line 216. The common point between the contactor 41CR-10 and the coil of the relay 17CR is connected back through a normally-open contactor 17CR-8 and a normally-closed contactor 1CR-8 to the line 215. Similarly, a contactor 1TR-2 associated with the timer 1TR is connected on one side to the line 215 and on the other side is connected through the coil of a relay 18CR to the line 216. In addition, a common point between the switch contactor 1TR-2 and the coil of the relay 18CR is connected back to the line 215 by a normally-closed contactor 19CR-3, a normally-open contactor 21CR-8, and a normally-open contactor 18CR-5 connected in series. A normally-open contactor 27CR-5 is connected around the normally-closed contactor 19CR-3.

The line 215 is also connected to the line 216 by a normally-open contactor 18CR-1, a normally-open contactor 7CR-2, and a normally-open contactor 14CR-13, and the coil of a relay 19CR, all connected in series. In addition, the common point between the contactor 7CR-2 and the contactor 14CR-13 is connected back to the line 215 through a normally-open contactor 19CR-1 and a normally-open contactor 17CR-4, in series. In addition,

the lines 215 and 216 are connected by the following elements in series: a normally-closed contactor 5CR-1, a normally-open contactor 20CR-1, and the coil of a relay 20CR. Furthermore, the common point between the contactor 20CR-1 and the coil of the relay 20CR is connected to the line 215 through a normally-open contactor 19CR-7 and the other element of a contact element of the skip dress switch 254. Furthermore, a normally-open contactor 16CR-1 is connected around the contactor 19CR-7.

Referring now to FIG. 8, it can be seen that the table switch 259 enters into several lines of circuitry. One side of the uppermost contactor is connected to the line 244 and the other side is connected through the following elements in series to the line 216. A normally-closed contactor 45CR-1, a normally-open contactor 14CR-8, a normally-closed contactor 41CR-3, a normally-closed contactor 17CR-3, a normally-closed contactor 18CR-2, a normally-open contactor 8CR-3, a normally-open contactor 1CR-1, and the coil of a relay 22CR. In addition, a normally-open contactor 19CR-4 is mounted around the switch contactor 18CR-2. A common point between the contactor 45CR-1 and the contactor 14CR-8 is connected back through the second contactor of the switch 259 to the line 242. The third contactor of the switch 259 is connected on one side to the line 242 and the other side is connected to the line 216 through the following elements in series: a normally-closed contactor 28CR-3, a normally-open contactor 41CR-7, a normally-closed contactor 4CR-6, a normally-open contactor 8CR-4, a normally-open contactor 1CR-2, and the coil of a relay 23CR. A normally-open contactor 18CR-4 is connected around the contactor 41CR-7. In addition, a common point between the contactor 4CR-6 and the contactor 8CR-4 is connected back to the line 244 through the fourth contactor of the switch 259. This same common point between the contactor 4CR-6 and the contactor 8CR-4 is connected through a contactor 261 forming part of the switch 238, the other side of the switch 261 being connected elsewhere, as will be described. Furthermore, a common point between the contactor 8CR-4 and the contactor 1CR-2 is connected through a normally-closed relay 14CR-9 to the line 215. It can also be seen that the Table Index switch 262 is provided with three contactors, the second of which is connected on one side to the line 242 and on the other side through the following elements to the line 216: a normally-closed contactor 44CR-6, a normally-open contactor 21CR-7, a normally-open contactor 8CR-5, a normally-open contactor 14CR-11, a normally-closed contactor 18CR-7, a normally-open contactor 1CR-3, and the coil of a relay 25CR. In addition, extending around the contactor 21CR-7 are the following elements in series: a normally-open contactor 28CR-7, a normally-open contactor 33CR-2, a switch 3TR-2 associated with the timer 3TR, and a normally-closed contactor 41CR-2.

Extending from a common point between the contactor 28CR-7 and the contactor 33CR-2 on the one hand and a common point between the contactor 41CR-2 and the contactor 8CR-5 on the other hand are a normally-open contactor 40CR-6 and a normally-open contactor 19CR-5 mounted in series. In addition, the common point between the contactor 41CR-2 and the contactor 8CR-5 is connected back through the top contactor of the switch 262 to the line 244. The side of the upper contactor of the switch 262 which is not connected to the line 244 is connected through a normally-open contactor 44CR-5 and a normally-open contactor 7CR-10 in series to a common point between the contactor 1CR-3 and the coil of the relay 25CR. This last-named common point is connected back through a normally-open contactor 7CR-11 and a normally-open contactor 44CR-7, both in series, to a common point between the contactor 44CR-6 and the second contactor of the switch 262. The side of the second contactor of the switch 262, which is not connected to the line 242, is connected by a line 263 to one side of the

third contactor of the switch 262. The other side of this last-named contactor is connected to the line 216 through a normally-open contactor 41CR-4, a normally-open contactor 7CR-8, a normally-open contactor 8CR-6, a normally-open contactor 1CR-4, and the coil of a relay 26CR, all in series to the line 216. Connected around the contactor 7CR-8 is a normally-open contactor 15CR-4. A common point between the contactor 7CR-8 and the contactor 8CR-6 is connected to one side of the fourth contactor of the switch 262, the other side of which is connected by a line 264 back to one side of the contactor 261 which, it will be recalled, forms part of the switch 238. In addition, the common point between the contactor 8CR-6 and the fourth contactor of the switch 262 is connected through a normally-open contactor 44CR-8 and a normally-closed contactor 7CR-12, in series, to a common point between the contactors 8CR-6 and 1CR-4. This last-named common point is also connected through a normally-closed contactor 21CR-2 and a normally-closed contactor 14CR-10 to the line 215.

Connected from the line 242 to the line 216 is a normally-open contactor 7CR-9 and the coil of a relay 27CR. Also connected from the line 242 to a common point between the contactor 7CR-9 and the coil of the relay 27CR is a normally-closed contactor 22CR-4 and a normally-open contactor 27CR-1, both mounted in series. Extending from the line 215 to the line 216 are the following elements mounted in series: a normally-open contactor 1CR-6, a normally-open contactor 5CR-5, a normally-open contactor 18CR-3, a normally-open contactor 14CR-15, and the coil of a relay 28CR. Extending from a common point between the contactor 18CR-3 and the contactor 14CR-15 to the line 215 are a normally-open contactor 12CR-4 and a normally-open contactor 28CR-1, mounted in series. Connected from a common point between the contactor 1CR-6 and the contactor 5CR-5 to the line 216 are a normally-open contactor 7CR-5, a normally-open contactor 14CR-16, and the coil of a relay 29CR, all mounted in series. The common point between the contactor 7CR-5 and the contactor 14CR-16 is connected back to the line 242 through a normally-open contactor 29CR-4, mounted in series with a normally-closed contactor 6CR-5.

Extending from the line 242 to the line 216 and mounted in series with one another are a normally-open contactor 29CR-2, a normally-open contactor 2CR-3, and the coil of a relay 30CR. The common point between the contactor 2CR-3 and the coil of the relay 30CR is connected back to the line 242 through the following elements in series: a normally-open contactor 30CR-1, a normally-closed contactor 6CR-6, and a normally-open contactor 14CR-17. Underneath this portion of the drawing it will be noticed that the lowermost element of the limit switch LS7 is located with one side connected to the line 242 and the other side connected through a normally-open contactor 30CR-2 and the coil of a relay 31CR to the line 216. Extending between the line 215 and the line 216 are a normally-open contactor 28CR-8 and the coil of a relay 33CR, mounted in series. The common point between the contactor 28CR-8 and the coil of the relay 33CR is connected by a line 265 through the operating coil of a clutch 266 to the line 216. The line 265 is also connected to the line 216 through a switch 3TR-1 and a motor 267 forming part of a timer 3TR for retract.

A line 215 is connected through a 100 ohm resistor 268 and a 4 microfarad capacitor 269 to the line 216. A gap eliminator 271 is shown as containing a normally-open contactor 272 and a normally-closed contactor 273. One side of each of these two contactors is connected together and connected back to the line 215. The other side of the contactor 272 is connected to the line 216 through a normally-open contactor 3CR-2 and the coil of a relay 34CR, in series. The other side of the contactor 273 is connected to the line 216 through a normally-open contactor 34CR-2 and the coil of the relay 35CR, in series.

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The common point between the contactor 34CR-2 and the coil of the relay 35CR is connected back to the line 215 through a normally-open contactor 35CR-1 and a switch 2TR-3. Furthermore, the common point between the switch 2TR-3 and the contactor 35CR-1 is connected by a normally-open contactor 34CR-1 to the common point between the contactor 272 and the contactor 3CR-2.

Referring now to FIG. 9, the machine is provided with a magnetic backing plate 274 whose operating coil is connected from the line 215 to the line 216. The machine is also provided with a peak power control unit 275 containing a normally-open contactor 276. A magnetic backing plate has a 100 volt D.C. output one line 277 being connected through the normally-open contactor 276 to one side of the coil of a power relay 13PR. The other side of the power relay is connected to the line 278 constituting the other side of the 100 volt D.C. Connected from the line 278 to the common point between the coil of the power relay 13PR and the contactor 276 is a 10 microfarad capacitor 279 and a 500 ohm resistor 281, mounted in series.

The line 215 is connected to the line 216 through a normally-open contactor 35CR-3 and the coil of a relay 36CR, connected in series. The common point between the contactor 35CR-3 and the coil of the relay 36CR is connected back to the line 215 through a normally-open contactor 37CR-4. In addition, this same common point is connected back to the line 215 through a normally-open contactor 36CR-2 and a normally-closed contactor 6CR-1, mounted in series. Extending from the last-named common point to the common point between the contactor 6CR-1 and the contactor 36CR-2 is a normally-open contactor 41CR-14 in series with the upper contactor of a No-Parts switch 282. The lower contactor of the No-Parts switch 282 is connected on one side to the line 215, and the other side is connected to the line 216 through the following elements arranged in series: a normally-closed contactor 36CR-1, a normally-open contactor 41CR-8, and a No-Part lamp 283. Connected from the line 215 to the line 216 are a normally-open contactor 9CR-2, a normally-open contactor 11CR-4, and the coil of a relay 38CR, all mounted in series; in addition, connected around the contactor 11CR-4 is a normally-open contactor 38CR-1. A normally-open contactor 17CR-7 and the coil of a relay 39CR are mounted in series with one another from the line 215 to the line 216. The common point between these two elements is connected back to the line 215 through the following elements in series: a normally-open contactor 39CR-6, a normally-closed contactor 9CR-3, a normally-closed contactor 6CR-3, and a normally-closed contactor 14CR-12. The common point between the contactor 14CR-12 and the contactor 6CR-3 is connected to the line 216 through a normally-open contactor 9CR-4 and a normally-open contactor 11CR-5 and the coil of a relay 40CR, all in series. This last-named common point is connected through a normally-closed contactor 17CR-6, and a normally-open contactor 40CR-5, in series with one another to the common point between the contactor 11CR-5 and the coil of the relay 40CR.

The line 215 is connected to the line 216 by the following elements in series: a normally-open contactor 9CR-5, a normally-closed contactor 40CR-3, a normally-open contactor 12CR-3, a normally-open contactor 39CR-5, and the coil of a relay 41CR. In addition, the common point between the contactor 39CR-5 and the coil of the relay 41CR is connected back to the line 215 through a normally-open contactor 41CR-5, a normally-closed contactor 6CR-7, and a normally-open contactor 14CR-14, all in series. A normally-open contactor 21CR-6 is connected around the contactor 14CR-14. The coil of a relay 44CR is connected from the line 215 to the line 216 directly.

Forming part of the machine is an electronic D.C. switch 284. One side of this is connected through a nor-

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mally-open contactor 44CR-9 to the line 215, while the other side is connected directly to the line 216. A portion of this electronic D.C. switch is connected by the line 203 to the dresser contact 202.

The line 215 is connected through a normally-open contactor 22CR-1 and a solenoid SOL2 to the line 216, which is the table in solenoid. The line 215 is also connected through the normally-open contactor 23CR-1 through the table out solenoid SOL3 to the line 216. A normally-open contactor 23CR-3 is connected on one side to the line 215 and on the other side through a normally-closed contactor 47CR-2 and the Table Index In (second groove grind, first dress) solenoid SOL12 to the Table Index Out (first groove grind, second dress) solenoid SOL11. The line 215 is connected through a normally-open contactor 25CR-1 and the Table Index In (second groove grind, first dress) solenoid SOL12 to the line 216. Connected around the contactor 25CR-1 is a normally-open contactor 22CR-2.

The side of the solenoid SOL11 opposite the side which is connected to the line 216 is connected back to the line 215 through a normally-open contactor 26CR-1. This same side of the solenoid SOL11 is connected back to the line 215 through a normally-open contactor 23CR-2, a normally-open contactor 47CR-1, and a normally-open contactor 41CR-17. The lower part of the drawing is occupied by the feed switch 285 which, it will be noted, is provided with four contactors. The second contactor of the switch 285 is connected on one side to the line 242 and on the other side is connected to the line 216 through the following elements in series: a normally-open contactor 3CR-1, a normally-open contactor 13PR-1, a normally-closed contactor 17CR-5, a normally-closed contactor 11CR-2, a normally-open contactor 14CR-7, and the feed solenoid SOL31. In addition, the common point between the contactor 11CR-2 and the contactor 14CR-7 is connected back to the line 244 through the uppermost contactor of the switch 285. The third contactor of the switch 285 is connected on one side to the line 242 and on the other side is connected to the line 216 through a normally-open contactor 41CR-6, and the retract solenoid SOL32, in series. Connected around the contactor 41CR-6 are a normally-open contactor 16CR-3 and a normally-open contactor 20CR-2, mounted in series. Also connected around the contactor 41CR-6 is a normally-open contactor 31CR-2. The side of the contactor 31CR-2, which is connected to the third contactor of the switch 285, is connected to a line 286. The fourth contactor of the switch 285 is connected on one side to the line 244 and on the other side is connected through a normally-closed contactor 14CR-4, a normally-open contactor 27CR-2, a normally-closed contactor 2CR-4, and a normally-closed contactor 21CR-1, all in series, to the common point between the contactor 41CR-6 and the solenoid SOL32. The other end of the line 286 is connected to the common point between the contactor 14CR-4 and the contactor 27CR-2. Furthermore, the line 287 is connected between the common point between the contactor 14CR-4 and the lower or fourth contactor of the switch 285, on the one hand, and the common point between the contactor 2CR-4 and the contactor 21CR-1, on the other hand.

Referring now to FIG. 10, the line 242 is connected to the line 216 through the following elements mounted in series: a lower contactor of a Work Index switch 288, a normally-closed contactor 39CR-4, a normally-open contactor 14CR-5, a normally-closed contactor 18CR-6, a normally-open contactor 41CR-1, a normally-open contactor 5CR-6, a normally-closed contactor 28CR-2, a normally-closed contactor 40CR-4, and the Slide Grind solenoid SOL22. The common point between the contactor 39CR-4 and the contactor 14CR-5 is connected through the upper contactor of the switch 288 to the line 244. A common point between the contactor 41CR-1

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and the contactor 5CR-6 is connected through a normally-open contactor 9CR-6 to the common point between the contactor 40CR-4 and the solenoid SOL22. Next in the drawing is shown the Dresser Index switch 289 which has two contactors. The lower contactor is connected on one side to the line 242 and on the other side is connected to the line 216 through the following elements arranged in series: a normally-open contactor 11CR-7, a normally-open contactor 41CR-13, a normally-open contactor 24CR-3, a normally-closed contactor 21CR-3, a normally-closed contactor 31CR-1, a normally-closed contactor 44CR-11, a normally-closed contactor 15CR-2, a normally-open contactor 4CR-3, a normally-open contactor 14CR-6, a normally-closed contactor 10CR-4, and the Dress Index solenoid SOL21. Connected around the contactor 21CR-3 is the normally-open contactor 7CR-4. A common point between the contactor 4CR-3 and the contactor 14CR-6 is connected back to the line 244 through a normally-open contactor 7CR-13, a normally-open contactor 44CR-10, and the upper contactor of the switch 289, all in series. In addition, a normally-open contactor 24CR-8 is connected around the contactor 7CR-13. A line 291 extends from the common point between the contactor 44CR-10 and the upper contactor of the switch 289, on the one hand, and the common point shared by the contactor 31CR-1 and the contactor 21CR-3, on the other hand. The line 291 is connected through a normally-closed contactor 7CR-3, and a normally-closed contactor 27CR-3, as well as a normally-open contactor 4CR-4 to a common point between the contactor 41CR-13 and the contactor 24CR-3. The open contactor 24CR-2 is connected between a common point between the contactor 15CR-2 and the contactor 4CR-3, on the one hand, and a common point between the contactor 14CR-6 and the contactor 7CR-13, on the other hand. This last-named common point is connected through a normally-open contactor 24CR-9 to the common point between the contactor 41CR-13 and the contactor 11CR-7. This last-named common point is also connected through a normally-open contactor 41CR-22 and a normally-closed contactor 15CR-5 to a common point between the contactor 11CR-7 and the lower contactor of the switch 289. Finally, a normally-open contactor 44CR-12, a normally-closed contactor 41CR-23, a normally-closed contactor 4CR-7, and a normally-open contactor 7CR-14 are all connected in series and the ends of this array are connected to the common point between the contactor 11CR-7 and the lower contactor of the switch 289, on the one hand, and the common point between the contactor 24CR-9 and the contactor 14CR-6, on the other hand.

In the next part of the drawing can be seen the presence of the Dresser switch 292 which has two contactors. The upper contactor of the switch 292 is connected on one side to the line 215. On the other side it is connected to the line 216 through a contactor 293 forming part of the switch 238, a normally-open contactor 14CR-3, a normally-closed contactor 15CR-3, a normally-open contactor 2CR-1, a normally-closed contactor 30CR-3, and the Dresser Right solenoid SOL44, all mounted in series. A normally-open contactor 7CR-6 is connected around the contactor 2CR-1. Furthermore, a common point between the contactor 293 and the contactor 14CR-3 is connected back to the line 244 through the lower contactor of the switch 292. Furthermore, the common point between the lower contactor of the switch 292 and the contactor 14CR-3 is connected through a normally-open contactor 7CR-15 to the line 215.

Next on the drawing it can be seen that the Loading switch 294 is provided with three sets of contact elements. The upper contactor is connected on one side to the line 244 and is connected to the line 216 on the other side through the following elements mounted in series: a normally-open contactor 37CR-1, a normally-open contactor

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16CR-2, a normally-open contactor 14CR-2, a normally-open contactor 36CR-4, and the loading valve solenoid SOL53. The common point between the contactors 37CR-1 and the contactor 16CR-2 is connected, on the one hand, to the common point between the contactor 16CR-2 and the contactor 14CR-2 by a normally-open contactor 4CR-8 and a normally-open contactor 37CR-6, mounted in series. Connected across the contactor 4CR-8 are a normally-open contactor 44CR-13 and a normally-open contactor 24CR-10, mounted in series. Similarly, connected around the contactor 37CR-6 are a normally-open contactor 41CR-11, a normally-open contactor 27CR-4, and a normally-open contactor 1CR-7, all mounted in series. The second contactor of the switch 294 is connected, on the one hand, to the line 242. On the other hand, it is connected through a normally-closed contactor 37CR-2, a normally-open contactor 31CR-3, and a normally-open contactor 1CR-5 to the common point between the contactor 16CR-2 and contactor 14CR-2. Connected around the contactor 31CR-3 are a normally-open contactor 37CR-5 and a normally-open contactor 24CR-4, mounted in series. Similarly, mounted around the contactor 31CR-3 are a normally-open contactor 44CR-14, a normally-open contactor 41CR-24, and a normally-open contactor 46CR-2, all mounted in series. Connecting the line 244 to the line 216 are the bottom contactor of the switch 294, a normally-open contactor 8CR-7, a normally-closed contactor 11CR-3, and the coil of a relay 37CR, all in series. The common point between the contactor 8CR-7 and the contactor 11CR-3 is connected back to the line 244 through a normally-open contactor 37CR-3 and a normally-closed contactor 6CR-8, in series. A line 295 connects the common point between the contactor 37CR-1 and the upper contactor of the switch 294, on the one hand, and the common point between the contactor 6CR-8 and the contactor 37CR-3, on the other hand.

Next in the electrical schematic comes a contactor 296 forming part of the switch 223. One side of this contactor 296 is connected to the line 215 and the other side is connected to the line 216 through a normally-open contactor 5CR-7 and the coolant valve solenoid SOL61, mounted in series. Electrically connected around the contactor 5CR-7 is an open contactor 9CR-1. The line 215 is also connected to the line 216 through a switch 3TR-3 and the Retract Bypass solenoid SOL93. The line 215 is also connected to the line 216 through the following elements mounted in series: the coolant switch 223, a normally-open contactor 41CR-12, a normally-closed contactor 40CR-2, a normally-closed contactor 39CR-2, a normally-closed contactor 38CR-4, a normally-closed contactor 35CR-2, a normally-open contactor 34CR-3, and the fast feed valve solenoid SOL65. The common point between the contactor 34CR-3 and the solenoid SOL65 is connected to the line 216 through the "gap eliminator" lamp 297. The line 215 is connected to one side of the switch CA3, the other side of which is connected to the line 216 through a normally-open contactor 15CR-6 and the Feed Compensation solenoid SOL23. Connected around the switch CA-3 is a Compensation Adjust pushbutton switch 298. Also, a normally-closed contactor 15CR-7 connects the line 215 to a common point between the contactor 15CR-6 and the solenoid SOL23. The line 215 is also connected to the line 216 through a normally-open contactor 8CR-8 and the Table Stop valve SOL1 which, incidentally, deenergizes to stop the table.

FIG. 11 shows schematically a cycle which may be used by the selection of a proper plug 24, while FIG. 12 shows the arrangement of the male plug 24 in order to obtain that particular cycle. The cycle shown in FIG. 11 would operate the machine in such a way that the determination of the final size of the workpiece would be determined from the position of the cross-slide, i.e., the position of the workhead 13 relative to the wheel rather than by use of a gage at the workpiece bore. This partic-

ular cycle would be used for grinding the groove on the outer race of a ball bearing where only a single groove would be ground, but the wheel would be a double wheel, one a rough wheel and one for finishing. Furthermore, according to this cycle, the wheel would be dressed after the workpiece had been finished, rather than during an interruption between rough and finish grind. Because an annular groove is being ground (in contrast to a cylindrical bore), the dresser would be a radius dresser mounted on a workhead 13. Furthermore, a sparkout period would be allowed after "rough" grinding and after "finish" grinding to permit removal of any deflection in the wheel spindle. It will be noted in the electrical diagram shown in FIGS. 6 through 10 that various points in the diagram have been given the designations P1 through P81. Wires are brought out from these points to corresponding bores 38 in the female plug 35 and, of course, the bores 27 in the male plug exactly correspond to those of the female plug. These numbers are shown beside the bores in FIG. 12, the bores on the left-hand receptacle 25 being the same as those in the right-hand receptacle 26. It is possible to obtain a large variety of cycles by using the plug 24 to "jump" certain points in the electrical wiring. When it is desired to connect two points (for instance, points P35 and P81 in FIG. 6), it is only necessary to insert a pin 28 into each of these two bores in the plug and to connect the pins 28 by a wire. For instance, in order to obtain the cycle in FIG. 11, a plug 24 is inserted into the plug 35 and the various points indicated in FIG. 12 are connected together, so that the machine operates automatically to give the cycle shown in FIG. 11. Other cycles can be obtained by preparing plugs 24 that have pegs 28 and wires connecting them in various arrangement of parts, as will be described more fully hereinafter.

The operation of the invention will now be readily understood in view of the above description. Before the machine 10 is started up, the operator 11 inserts a plug 24 into the bottom position in the rack 21. For the purpose of illustration, let us assume that he has selected the male plug arranged in the manner shown in FIG. 12. He inserts the shaft 29 into the nut 39 and turns the handle 32 so that the threads 31 engage the nut and draw the plugs together. The pegs 28 enter bores 38 in the female plug 35 and make electrical contact. In order to insure that the plug 24 is inserted in the proper relationship to the female plug 35, the pegs 33 and 41 are provided. It can be seen that it will be impossible to fit the two together unless the peg 41 is on one side and the peg 33 is on the other side of the line joining the shaft 29 and the nut 39. In addition, the trapezoidally-shaped abutment 34 fits into the recess 42 in the female plug 35. The cover 22 has been closed and the machine is started up in the usual way. The main drive motor 121 is energized and rotated, as well as the coolant motor 112, the wheelhead motor 115, and the workhead motor 212. With these machines operating, with the coolant fluid available, and with the lubrication fluid available, the machine is ready to operate. During the operation, all longitudinal motion of the wheelhead table 16 carrying the wheelhead 14 and the motor 15 takes place under the impetus provided by the cylinders 77 and 85. Transverse motion of the workhead relative to the wheel to provide for feed of the wheel and workpiece relative to one another to bring about the grinding operation takes place under the control of the feed box 17 operating the feed screw 107. Additional rapid transverse motion of the workhead 13 can take place by means of the cylinder 103 and the cylinder 104. In order to provide the cycle shown in FIG. 11, which is a single-groove double-wheel cycle, the operator 11 first sets all selector switches to "Auto" and "On" positions. The first part of the cycle is "Table In" portion, meaning that the wheelhead table 16 moves longitudinally toward the workhead 13 bringing the wheel into the bore in the workpiece. The operator presses the

"Cycle Start" pushbutton switch 236 (FIG. 6) which results in energization of the relay 14CR. This closes the contactor 14CR-8 (at the top of FIG. 8) and this energizes the relay 22CR. Thus, the contactor 22CR-1 is closed, energizing solenoid SOL2 (in the middle portion of FIG. 9). Solenoid SOL2 moves the spool of the table solenoid valve 72 to the right (FIG. 4) and this allows oil to flow to the table cylinder 77 and moves the wheelhead table 16 and the wheelhead 14 toward the workhead 13 (FIG. 11), so that the table moves from the Start position to the Positive Stop position.

The next step in the cycle is the slide index. With the wheelhead table 16 at the First Groove position, the limit switch LS5 (FIG. 5) closes, thus energizing the relay 5CR (FIG. 6). The operation of the relay 5CR closes the contactor 5CR-6, thus energizing the solenoid SOL22. Referring to FIG. 4, the solenoid SOL22, when energized, moves the spool of the Grind Index solenoid valve 67 which sends oil to the cylinder 103, thus starting the slide index.

The next portion of the cycle involves the feeding of the workhead and the workpiece forwardly on the machine. With the cross-slide at the grinding position the Grind Position limit switch LS3 is closed, thus energizing the relay 3CR (FIG. 6). The energization of the relay 3CR, in turn, results in the closing of the contactor 3CR-1 (FIG. 9) which, in turn, results in the energization of the solenoid SOL31, which (referring to FIG. 4) operates the spool of the feed solenoid valve 56 which passes oil to the feed box 17. At the same time, the energization of the relay 3CR results in the closing of the contactor 3CR-2 (bottom of FIG. 8) which energizes the relay 34CR. The contactor 34CR-3 (bottom of FIG. 10) is closed, which results in the energization of the solenoid SOL65. The solenoid SOL65 (FIG. 4) operates the gap eliminator valve 124 and permits a fast feed until such time as the load converter 218 indicates that the wheel is being loaded and that the wheel is in contact with the surface of the workpiece. When the wheel comes into contact with the part, the contacts in the gap eliminator reverse the energization of the relay 35CR (FIG. 8) so that the contactor 35CR-2 (which is normally closed) opens and deenergizes the solenoid SOL65. The valve 124 is closed again and permits the feed box 17 to operate in the ordinary way at slow feed.

Referring to FIG. 11, therefore, the cross-slide has now moved from the Positive Stop position to the beginning of Rough Grind. The next step is the slide index return. The limit switch LS11 (FIG. 5) closes when the cross-slide reaches the rough size position. The closing of the switch LS11 energizes the relay 11CR (top of FIG. 7). This opens the contactor 11CR-2 which is a normally-closed contactor lying in the circuitry of the solenoid SOL31 (FIG. 9). This drops out the solenoid and returns the feed valve 56 to its normal, neutral position; this stops the flow of fluid to the feed box 17 and also stops the feed of the wheelhead transversely of the machine. At the same time, the energization of the relay 11CR closes the contactor 11CR-1 (center of FIG. 7) and this causes the energization of the coil 249, thus energizing the timer 1TR. After the timer has timed out, the contactor 1TR-2 (bottom of FIG. 7) closes, thus energizing the relay 18CR. The contactor 18CR-6 (which is normally closed) opens and de-energizes the solenoid 22 (top of FIG. 10), thus retracting the slide index because the spool of the valve 67 returns to its normal position.

The next portion of the cycle is the Retract Bypass portion. The energization of the relay 18CR described above also closes the contactor 18CR-3 (middle of FIG. 8) and results in the energization of the relay 28CR. This, in turn, results in the closing of the contactor 28CR-8 and results in the energization of the timer 3TR. After the timer times out, the contactor 3TR-3 closes (FIG. 10) and energizes the solenoid SOL93. The solenoid SOL93 (FIG. 4) operates the Retract Bypass valve 179 resulting

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in the reversal of the feed box 17 and reversal of rotational direction of the feed screw 107 so that the workhead 13 moves rearwardly again.

The next step in the cycle is the wheelhead table 16 indexing inwardly. After the time has passed on the timer 3TR, the contactor 3TR-2 (top of FIG. 8) closes and energizes the relay 25CR. This, in turn, results in the closure of the contactor 25CR-1 (FIG. 9) and results in the energization of the solenoid SOL12. Referring to FIG. 4, the solenoid SOL12, of course, operates the Table Index solenoid valve 79, thus causing oil to flow to the cylinder 85 so that the wheelhead table 16 moves longitudinally further into the workpiece and brings the finish wheel into position opposite the groove which is to be ground. The table, therefore, moves along the slide index line in FIG. 11.

The next portion of the cycle is the indexing of the slide. When the table reaches the point where the wheel is opposite the second groove, the limit switch LS9 (FIG. 5) is closed and this results in the energization of the relay 9CR (top of FIG. 7). This relay, in turn, when energized, closes the contactor 9CR-6 (top of FIG. 10) which, in turn, results in the energization of the solenoid SOL22, thus starting the slide index, which operates the valve 67 and introduces oil to the cylinder 103 causing the workhead 13 to move forwardly on an index motion. When the slide reaches the grinding position, the limit switch LS3 closes again, which results in feed being resumed in a manner described above, except that no fast feed takes place.

The next portion of the cycle is the slide index return. When the workpiece reaches finish size, the Finish Contact switch LS12 is closed, thus energizing the timer 2TR and stops the feed. After the timer times out, the contactor 2TR-3 opens and deenergizes the relay 35CR (bottom of FIG. 8). At the same time, the contactor 2TR-2 closes and energizes the coil 17CR (bottom of FIG. 7). This, in turn, causes the contactor 17CR-5 (bottom of FIG. 9) to open and deenergize the solenoid SOL31 which returns the feed valve 56 to its neutral position and stops the feed. The closing of the contactor 17CR-7 energizes the relay 39CR (top of FIG. 9) which results in the closure of the contactor 39CR-5 (top of FIG. 9) and the energization of the relay 41CR. This brings about the opening of the contactor 41CR-1 which is in the circuitry of the solenoid SOL22 (top of FIG. 10), resulting in the retracting of the slide index.

In the next portion of the cycle, the wheelhead table moves out. When the workhead slide reaches the rear position, the limit switch LS1 (FIG. 5) closes and energizes the relay 1CR (FIG. 6). This closes the contactor 1CR-2 (top of FIG. 8) and energizes the relay 23CR. The contactor 23CR-1 (FIG. 9) energizes the solenoid SOL3. Referring to FIG. 4, the energization of the solenoid SOL3 causes the Dress Index solenoid valve 72 to operate the cylinder 77 in the opposite direction and to send the workhead table to the right (as the operator 11 faces the machine).

Referring to FIG. 9, the next step of the cycle is the Dress Index Front. When the wheelhead table reaches the First Dress position, the limit switch LS4 closes, thus energizing the relay 4CR (bottom of FIG. 6) which, in turn, results in the closing of the contactors 4CR-4 and 4CR-3 (top of FIG. 10) and results in the energization of the solenoid SOL21. Referring to FIG. 4, the operation of the solenoid SOL21 moves the Dress Index solenoid valve 69 resulting in the movement of the wheelhead table toward the dresser on the Dress Index motion shown in FIG. 11. The hydraulic fluid operates on a cylinder 104 and moves the workhead 13 forwardly along the Dress Index path shown in FIG. 11. When the workhead gets to the front of the machine, the limit switch LS2 (FIG. 5) is closed and this closure results in the energization of the relay 2CR (FIG. 6). Thus, the contactor 2CR-1 is closed and energizes the solenoid SOL44 (middle of FIG. 10). Re-

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ferring to FIG. 4, the solenoid SOL44 operates the Radius Dresser valve 88 which operates through the directional valve 93 to operate the radius dresser vane motor 96. The dresser, therefore, rotates to the right.

With the dresser at the right, the limit switch LS7 (FIG. 5) closes and energizes the relay 7CR (bottom of FIG. 6). The relay 7CR opens the normally-closed contactor 7CR-3, which is in the circuitry of the solenoid SOL21 in FIG. 10, and results in the deenergization of that solenoid. Referring to FIG. 4, the fact that the solenoid SOL21 has been deenergized permits the valve 69 to return to its normal condition; this retracts the dress index cylinder 104, so that the workhead moves rearwardly of the machine along the Dress Index Rear portion of the cycle shown in FIG. 11.

When the workhead gets to the rear of the machine, it closes the limit switch LS1, thus energizing the relay 1CR and closing the contactor 1CR-4 (top of FIG. 8) to energize the relay 26CR. This relay closes the contactor 26CR-1 (bottom of FIG. 9) and results in the energization of solenoid SOL11. Referring to FIG. 4, solenoid SOL11 operates the right-hand side of the Table Index solenoid valve 79 and operates on the cylinder 85, so that the table moves along the line indicated as Table Index Out in FIG. 11.

The next portion of the cycle involves moving the dresser index toward the front. When the table reaches the second dress position, the limit switch 24 (FIG. 5) is closed and this energizes the relay 24CR (center of FIG. 7). The energization of the relay 24CR results in the closure of the contactors 24CR-2 and 24CR-3 (see top of FIG. 10) and results in the energization of the solenoid SOL21. This solenoid operates on the Dress Index solenoid valve 69 and results in the operation of the cylinder 104 so that the workhead moves forwardly along the line indicated in FIG. 11 as Dress Index Front.

When the workhead reaches the front, it closes the limit switch LS2 which energizes the relay 2CR (FIG. 6). The contactor 2CR-3 is, therefore, closed to energize the relay 30CR (FIG. 8). This opens the normally-closed contactor 30CR-3 (FIG. 10) and results in the energization of the solenoid SOL44. Referring to FIG. 4, it can be seen that the solenoid SOL44 moves the Radius Dresser valve 88 and brings about the operation of the dresser motor 96 sending the dresser to the left.

When the dresser has finished dressing the second wheel, it closes the limit switch LS7 (bottom of FIG. 6) which results in the energization of the relay 31CR. This relay opens the contactor 31CR-1 (top of FIG. 10) which lies in the circuit of the solenoid SOL21 and results in the deenergization of this solenoid. When the solenoid 21 is deenergized, the valve 69 is returned to its normal position and this causes the workhead to move rearwardly along the line indicated in FIG. 11 as Dress Index Rear.

When the workhead reaches the rear of the machine, it closes the limit switch LS1 again and energizes the relay 1CR. The closure of the contactor 1CR-5 energizes the solenoid 53 (middle of FIG. 10) resulting in the operation of the valve 96 (FIG. 4); this operates the loading cylinder 54 and loading, therefore, takes place. When the loading arm reaches its "up" position, the limit switch LS6 becomes closed, which action energizes the relay 6CR (FIG. 6). This opens the contactor 6CR-1 (top of FIG. 9) and deenergizes the solenoid 36CR. The contactor 36CR-4 is, therefore, opened, thus deenergizing the solenoid SOL53 and sending the loading arm down with a new workpiece.

At the start of the new cycle (with the load arm down), the limit switch LS8 operates to energize the relay 8CR (top of FIG. 7). With the energization of this latter relay, the contactor 8CR-3 is closed, thus energizing the relay 22CR (top of FIG. 8) and closing the contactor 22CR-1 (top of FIG. 10), resulting in the energization

of the solenoid SOL22, which sends the table in to start the new cycle.

Let us assume that the operator wishes to set the machine up for an automatic cycle similar to that shown in FIG. 13 where one wheel grinds a groove and performs a single finish grind operation and then, of course, is dressed once after the cycle is finished. First of all, the operator would replace the plug 24 with a plug having different pins 28 connected in different ways. Instead of the arrangement shown in FIG. 12, pins would be inserted in the bores P7, P9, P10, P21, P20, P6, P18, P16, P15, P35, P30, P52, P53, P55, P56, P64, P65, P61, P62, P66, P67, P76 and P81. Furthermore, in order to produce the cycle shown in FIG. 13, the following pins on the plug 24 are connected together: P35 and P81; P15 and P61; P16 and P62; P30 and P76; P18 and P64; P6 and P52; P20 and P66; P21 and P67; P10 and P56; P9 and P55; P7 and P53; and P19 and P65. In performing this cycle, the operator turns all the selector switches to "Auto" and "On" positions. In order to produce the Table In portion of the cycle, the operator pushes the Cycle Start pushbutton 236, thus energizing the relay 14CR. This closes the contactor 14CR-8 (top of FIG. 8) which energizes the relay 22CR. The contactor 22CR-1 (center of FIG. 9) closes and energizes the solenoid SOL2 which operates the table solenoid valve 72 and sends the table in on the portion of the cycle labeled Table In in FIG. 13. The energization of the relay 22CR also causes the closure of the contactor 22CR-2 (bottom of FIG. 9) which results in the energization of the solenoid SOL12, which sends the valve 74 to the position to send the table to the left. When the wheelhead table 16 reaches the point where the wheel is opposite the groove in the workpiece, the limit switch LS9 is closed, which energizes the relay 9CR. This closes the contactor 9CR-6 (top of FIG. 10) which energizes solenoid 22. The solenoid 22 operates to move the Grind Index solenoid valve 67 which operates on the cylinder 103 to move the table workhead toward the front.

When the table reaches the grind position, the limit switch LS3 closes and energizes the relay 3CR. The closure of the contactor 3CR-2 energizes the relay 34CR and the contactor 34CR-3 closes and energizes the solenoid 65 (bottom of FIG. 10). The solenoid 65 operates the Fast Feed valve 124 associated with the feed box 17 and rapid feed takes place, the table moving forwardly. When the workpiece comes into contact with the wheel, the gap eliminator 261 (bottom of FIG. 8) recognizes this fact and its contacts are operated to energize the relay 35CR. The normally-closed contactor 35CR-2 opens to deenergize the solenoid 65 (bottom of FIG. 10) to return the apparatus to slow feed. The wheel feeds into the work until the final size is reached and the limit switch LS12 is closed and energizes the relay 12CR. The contactor 12CR-1 then closes, thus energizing the timer 2TR. Eventually, the timer times out and closes its contactor 2TR-2 (bottom of FIG. 7) and this results in the energization of the relay 17CR. The contactor 17CR-5 opens to deenergize the solenoid SOL31 (bottom of FIG. 9) which stops the feed. At the same time, the contactor 17CR-7 closes and energizes the relay 39CR. Following this, the normally-closed contactor 39CR-4 opens to deenergize the solenoid SOL22 (top of FIG. 10), thus retracting the slide index because of the fact that the deenergization of the solenoid SOL22 results in the valve 67 returning to its normal position. The cross-movement of the workhead moves the relationship between the wheel and workpiece along the line indicated in FIG. 13 as Slide Index Retract.

With the workhead at the rear of the machine, the limit switch LS1 is closed, thus energizing the relay 1CR. The closure of the contactor 1CR-2 results in the energization of the relay 23CR and this closes the contactor 23CR-1, resulting, finally, in the energization of the solenoid SOL3 (center of FIG. 9) to send the table out.

Furthermore, the closing of the contactor 23CR-2 causes the energization of the solenoid SOL11 sending the table index out, also.

When the apparatus is moved along the line labeled Table Out in FIG. 13, eventually a point is reached at the dress position, at which point the limit switch LS4 is closed. When this happens, the relay 4CR is energized, thus closing the contactors 4CR-3 and 4CR-4 (see top of FIG. 10). This results in the energization of the solenoid SOL21 which sends the table on a motion indicated as Dresser Index Front. The workhead moves toward the front of the machine, carrying the dressing diamond with it. When the workhead has been moved toward the front and strikes the limit switch LS2, this last-named switch is closed and causes the energization of the relay 2CR. The contactor 2CR-1 is then closed, thus energizing the solenoid SOL44 (center of FIG. 10), which moves the dresser on a right-hand stroke. When the dresser has finished its stroke and the wheel has been dressed, the limit switch LS7 is engaged and closed, thus energizing the relay 7CR and resulting in the closure of the contactor 7CR-9. This last action causes the energization of the relay 27CR and the closure of the contactor 27CR-2 associated therewith. This energizes the solenoid SOL32 (bottom of FIG. 9) and results in the retracting feed operation. At the same time, the normally-closed contactor 27CR-3 opens and de-energizes the solenoid SOL21 (top of FIG. 10), thus resulting in the retraction of the dressing diamond. The apparatus moves along the line indicated as Dresser Index Rear in FIG. 13. With the dresser, the workhead, and the dressing diamond at the rear, the limit switch LS2 opens to deenergize the relay 2CR. This results in the opening of the contactor 2CR-1 and the deenergization of the solenoid SOL44 which sends the dresser to the left again.

When the work slide reaches the rear of the machine, the limit switch LS1 is closed to energize the relay 1CR. The closure of the contactor 1CR-7 energizes the solenoid 53 for the loading operation. With the load arm in the upper position, the limit switch LS6 is closed, resulting in the energization of the relay 6CR. Its contactor 6CR-1 opens to deenergize the relay 36CR. The contactor 36CR-4 thus opens and deenergizes the solenoid 53 sending the load arm down with a new part. At the start of the new cycle with the load arm down, the limit switch LS8 is closed, thus energizing the relay 8CR. This energization results in the closure of the contactor 8CR-3 and the energization of the relay 22CR. The contactor 22CR-1 closes and energizes the solenoid SOL2. Furthermore, the contactor 22CR-2 closes and energizes the solenoid SOL12 to send the table in for a new cycle.

FIG. 14 shows another cycle which may be used by simply replacing the plug 24 by a plug having suitable pins and connections. In this cycle, the size of the finish workpiece will be determined by the transverse position of the workhead 13; it would be used for grinding a ball track having a single groove and an adjacent bore. This cycle would use a single grinding wheel and would interrupt for dress between the rough grind and the finish grind with a sparkout at the end of the rough grind and a sparkout at the end of the finish grind with a radius formed dresser on the work slide. In order to produce this cycle, a plug would be provided with pins in the bores P1, P4, P6, P8, and P11, P13, P15, P17, and P23, P24, P30, P31, P35, P50, P54, P52, P47, P68, P66, P64, P59, P61, P63, P69, P70, P81, P76, P77, and P71. The jumper wires would extend between the following pins: P35 to P81; P11 to P57; P15 to P61; P17 to P63; P4 to P50; P23 to P69; P24 to P70; P13 to P59; P31 to P77; P8 to P54; P30 to P76; P18 to P64; P6 to P52; P20 to P66; P22 to P68; P25 to P71; and P1 to P47. Once this last-described plug has been inserted in connection with the female plug 35 and locked in place, the machine is ready for the cycle shown in FIG. 14. The operation of the electrical elements will be similar to that

described above in connection with the cycle shown in FIGS. 11 and 13. In the case of the cycle shown in FIG. 14, the table will move along the Table In portion of the cycle until the wheel reaches the location of the groove. Then the wheelhead table will stop and the workhead 13 will move forwardly; first, it will move on a slide index under the control of the gap eliminator and, when contact takes place between the workpiece and the wheel, the feed mechanism will produce a rough grind. The workpiece will move forward so that the wheel gives a rough grind to the groove and, when the relationship between the wheel and the workpiece is at a predetermined relationship, the feed will stop, but the wheel will remain in the groove for a short sparkout period determined by the timer. After the timer has timed out and the sparkout has permitted most of the deflection to be worked out of the wheel-head spindle, the workhead will move rearwardly while the table moves the wheel out of the work. The wheelhead goes on an extended traverse to the right until the dress position is reached, then the table stops and the wheelhead moves forwardly to bring the dressing mechanism adjacent the wheel. At this time, the workhead moves along the Dress Index portion of the cycle of FIG. 14. At that point, the dresser is actuated and moves around the workpiece on the Dresser Right portion of the cycle and when it reaches its right-hand position, the table is indexed away from the diamond and the workhead moves rearwardly, carrying the diamond with it. The diamond is returned automatically to its left-hand position during this movement. When the dresser has been moved to the rear position (and, of course, the workhead has been moved that way, too), the table moves longitudinally on the second Table In portion of the cycle until the wheel is opposite the groove again. Then, the workhead indexes forwardly until the gap eliminator indicates that the wheel and workpiece are in contact. When this is done, the finish grind portion of the cycle starts and the newly-dressed wheel finishes the groove until the final feed stop position is reached, at which time the feed is stopped. Then, the timer permits a short sparkout period to relieve any deflection in the wheel spindle. Then, the workhead moves rearwardly while the table moves laterally and the wheel comes out of the work and moves along the Table Out portion of the cycle until, eventually, a load position is reached.

The cycle shown in FIG. 15 may be obtained by replacing the plug 24 with another plug arranged with pins in the following bores: P2, P4, P5, P7, P9, P13, P18, P23, P21, P20, and P15, P35, P30, P28, P24, P25, P50, P48, P51, P53, P55, P59, P64, P69, P67, P66, P64, P61, P70, P74, P76, P81, P71. The jumpers would be extended between the pins in the following manner: between P35 and P81; P15 and P61; P30 and P76; P18 and P64; P28 and P74; P20 and P66; P4 and P30; P21 and P67; P2 and P48; P23 and P69; P24 and P70; P13 and P59; P9 and P55; P7 and P53; P18 and P64; P5 and P51; P25 and P71; P23 and P69. With a plug of this type in cooperation with the female plug 35, the machine will automatically run through the cycle shown in FIG. 15 in accordance with the general scheme described above in connection with the other cycles.

The type of cycle which may be ground automatically with this machine is limited only by the imagination of the operator. For instance, with a suitable plug, it would be possible to produce a cycle with this machine in which a double groove ball track would be ground using a double wheel with a single dressing mechanism which would dress the wheels alternately with a skip-dress cycle and a skip-compensation cycle and with the dress taking place at runout after the workpiece has been finished. In this case, both grooves would be ground at the same time, the same wheel being used both for the rough grind and for the finish grind with a sparkout at the end.

Another cycle that might be used by a judicious selection of the connections in the plug would be one in which

a double groove bearing race would have the grooves ground using a single wheel, the wheel being used for the rough grind on each groove and the finish grind with a dressing of the wheel in between roughing and finish grind on each groove and with a sparkout at the end of each finish grind for each groove. In this last-named cycle, the wheelhead table would be moved in until the wheel was opposite the first groove, the workhead would move forwardly bringing the wheel into contact with the groove for the rough grind, after which a short sparkout period the workhead would move rearwardly and the table would move out to the dressing position. The dresser would move forwardly into contact with the wheel, perform the dressing operation, and then would move rearwardly again. Then the table would move in until the wheel came opposite that same groove again and the workhead would move forwardly to permit the wheel to perform the finish grinding operation, after which there would be a sparkout to relieve deflection in the wheel spindle. Following the finish grind on the first groove the wheelhead would move rearwardly and the wheel would move longitudinally to bring the table in to the position of the second groove. The wheel would immediately be moved into the second groove on a rough grind followed by a sparkout. Following the rough grind, the wheelhead would move outwardly clearing the wheel of the groove and the wheelhead table would move out to carry the wheel over into the dressing position. The workhead would move forwardly carrying the diamond with it until the diamond came close to the wheel. Then, the dresser would perform the dressing operation and, after finishing the dressing operation, the workhead would move rearwardly again carrying the diamond with it. When the dresser has cleared the wheel, the wheelhead table would move the wheel toward the workpiece and the wheel would enter the bore until it came adjacent the second groove of the workpiece. The workhead would move forwardly again, bringing the wheel into contact with the second groove for the finish operation in that groove followed by a sparkout. After the finish grind in the second groove, the workhead would move away from the wheel and the wheel would move longitudinally out to the load position, thus finishing the cycle.

Another cycle that could be arranged by the proper selection of the male plug would be one in which the workpiece was a ball track having a double groove in which the machine would use a double wheel and each wheel would perform both the roughing and finish operation on its own groove, but the wheels would be moved out for dressing operation on each one of them before they would move back in again for the finish grind.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to be secured by Letters Patent is:

1. A grinding machine, comprising

(a) operative apparatus having parts including a base, a workhead slide, a wheelhead table having an abrasive wheel, and a dresser,

(b) a control apparatus to produce relative movement between certain of the parts of the apparatus including a "table in" movement relay, a "slide index" movement relay, a "rough grind" relay, a "finish grind" relay, a sparkout relay, a "slide retraction" movement relay, a "table out" movement relay, a "dresser index front" movement relay, a "dresser index rear" movement relay, a "table index in" movement relay, a "table index out" movement relay, and a "loading operation" relay,

(c) a plurality of electrical lines extending from said

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relays of the control apparatus to a permanent receptacle,

- (d) a plug-in unit insertable in the receptacle for connecting various lines from the relays together, and
 (e) interengageable means extending between the permanent receptacle and the plug-in unit, including a plurality of connectors on the permanent receptacle, each connected to one of the said lines, including a plurality of connectors on the plug-in unit exactly matching those on the permanent receptacle, and including bridging lines within the plug-in unit joining certain of its connectors so that, by insertion of the plug-in unit in the permanent receptacle, certain connectors of the permanent receptacle are electrically joined.

2. A grinding machine as recited in claim 1, wherein the permanent receptacle consists of a female plug having a socket for each such line and the plug-in unit consists of a male plug having a plurality of pins adapted to engage the sockets, pairs of the pins being electrically connected to select a particular sequence of operation of the relays to produce a desired grinding cycle.

3. A grinding machine as recited in claim 1, wherein the control apparatus also includes a first means bringing about relative feeding movement from one of several positions to another between the workhead slide and the wheelhead table transversely of the axis of the abrasive

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wheel, the first means including a feed screw, a long index cylinder, and a short index cylinder, the control apparatus also including a second means for bringing about relative movement from one of several positions to another between the workhead slide and the wheelhead table longitudinally of the wheel axis, the second means comprising a main table cylinder and a table index cylinder, the control apparatus also including a limit switch located at each of the said several positions, a feed solenoid valve, a feed box including a feed cylinder for operating the said feed screw, a dresser solenoid valve for regulating the operation of the dresser, a grind index solenoid valve for regulating the operation of the short index cylinder, a dress index solenoid valve for regulating the operation of the long index cylinder, a table solenoid valve for regulating the operation of the main table cylinder, and a table index solenoid valve for regulating the operation of the table index cylinder.

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