Oct. 27, 1970 D. E. WARE, JR., ET AL 3,535,828

GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 1

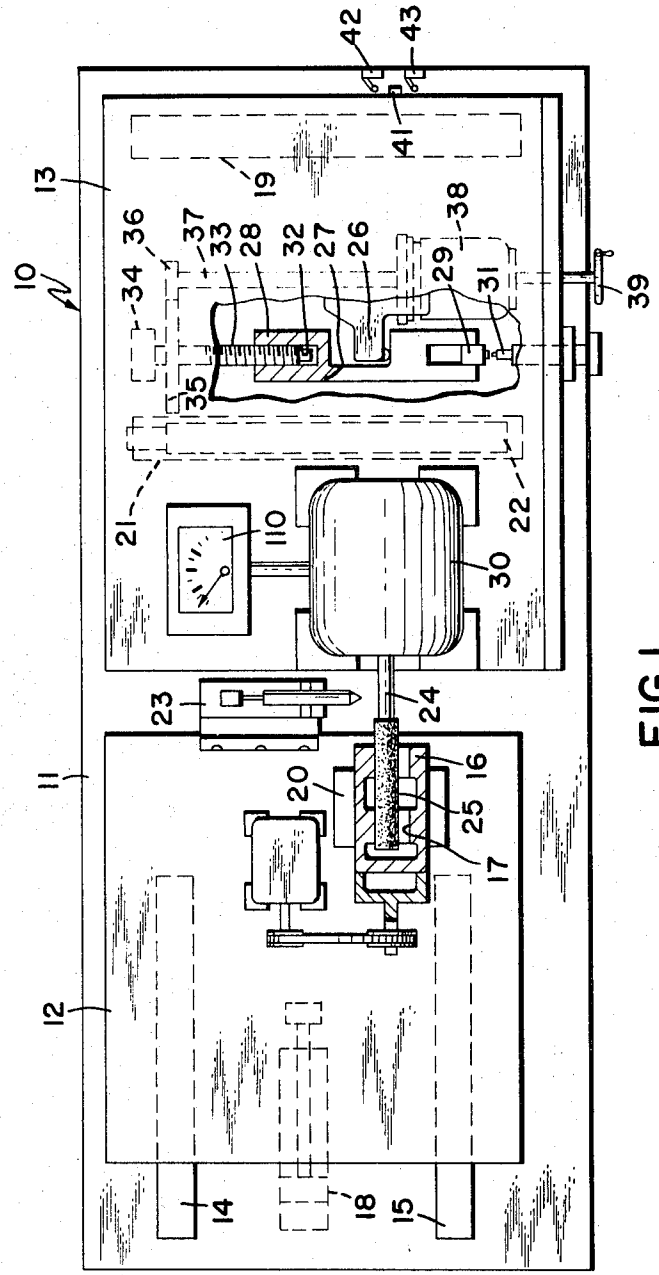


FIG. 1

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GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 2

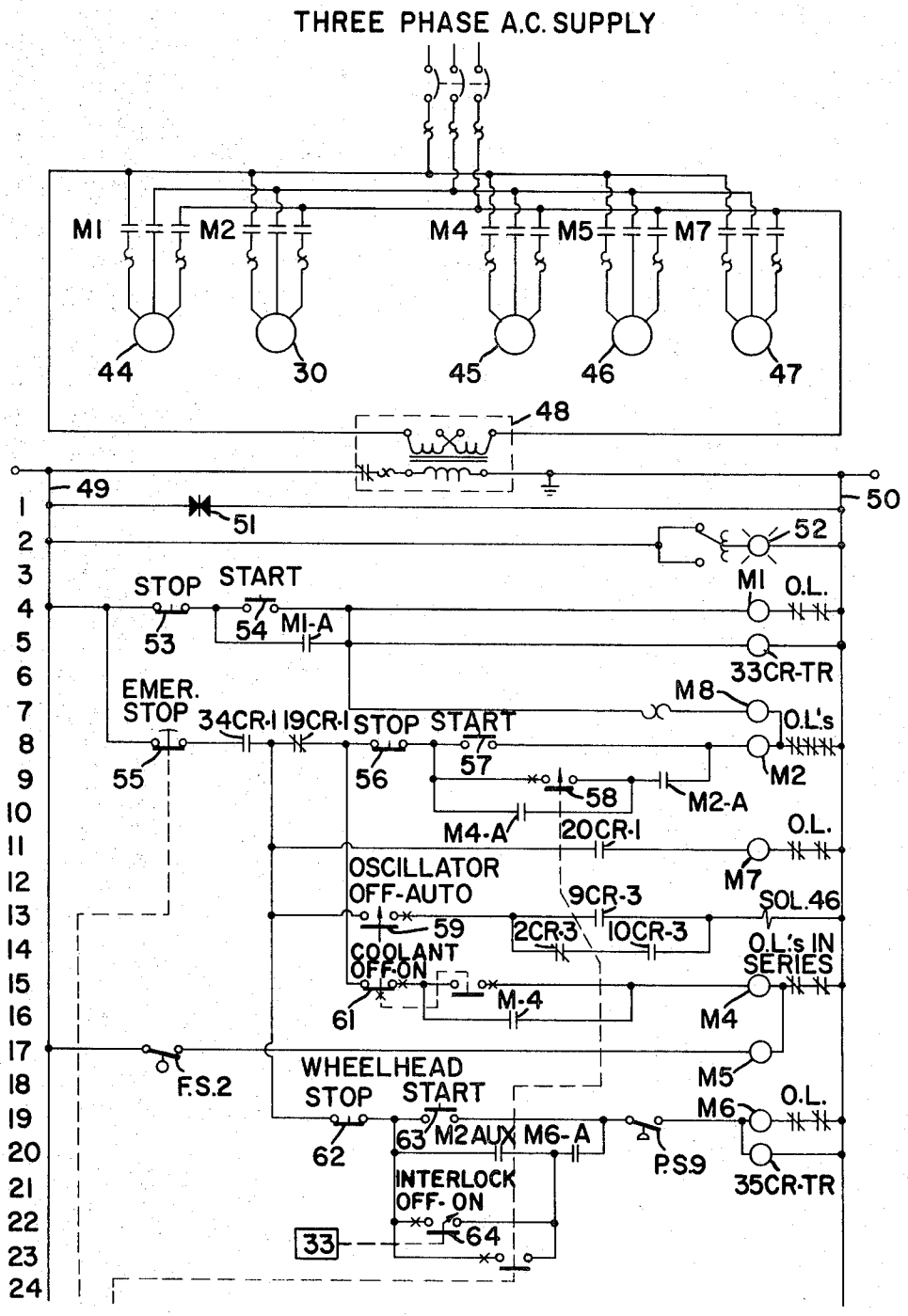


FIG.2

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GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 3

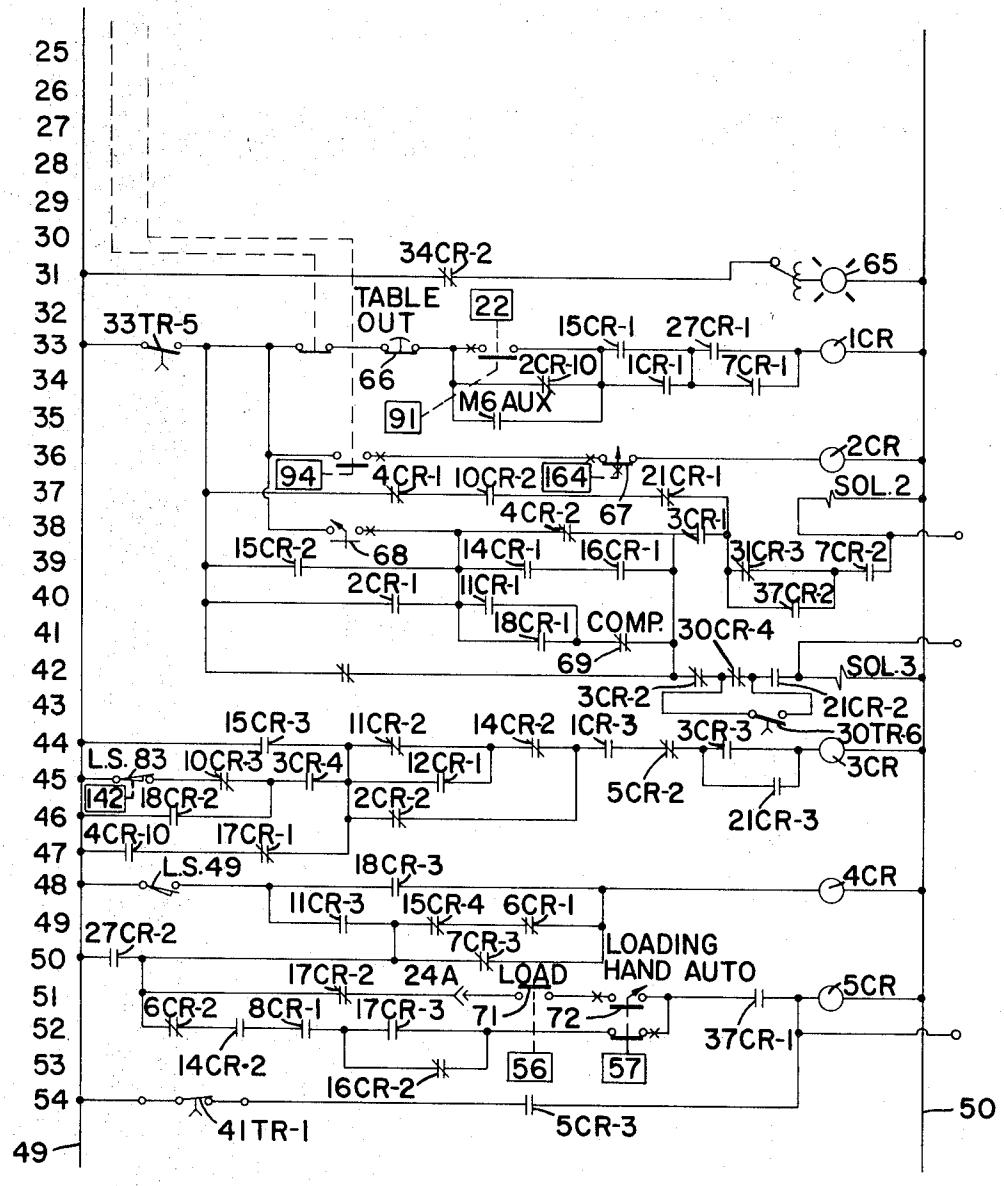


FIG.3

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GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 4

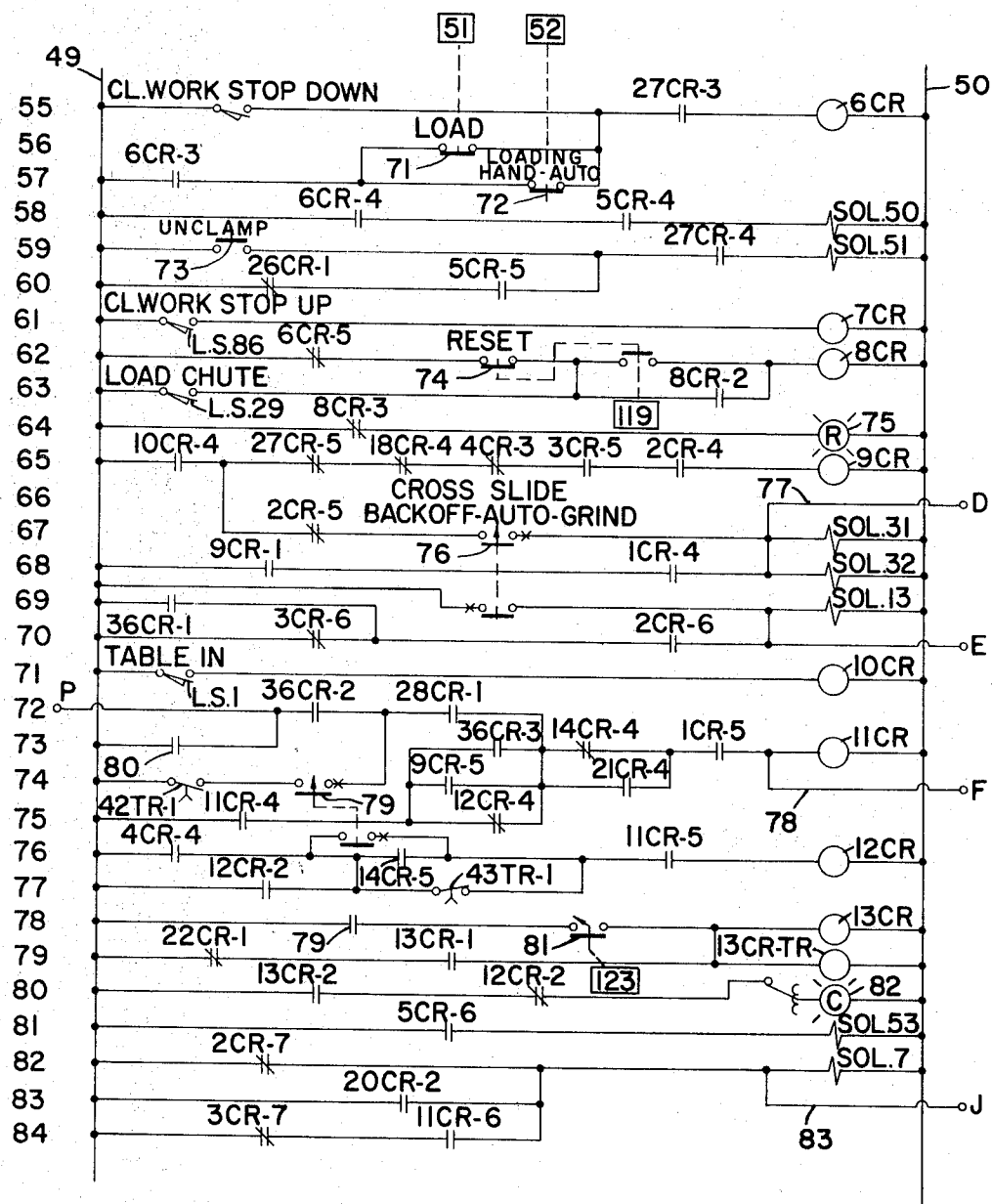


FIG.4

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GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 5

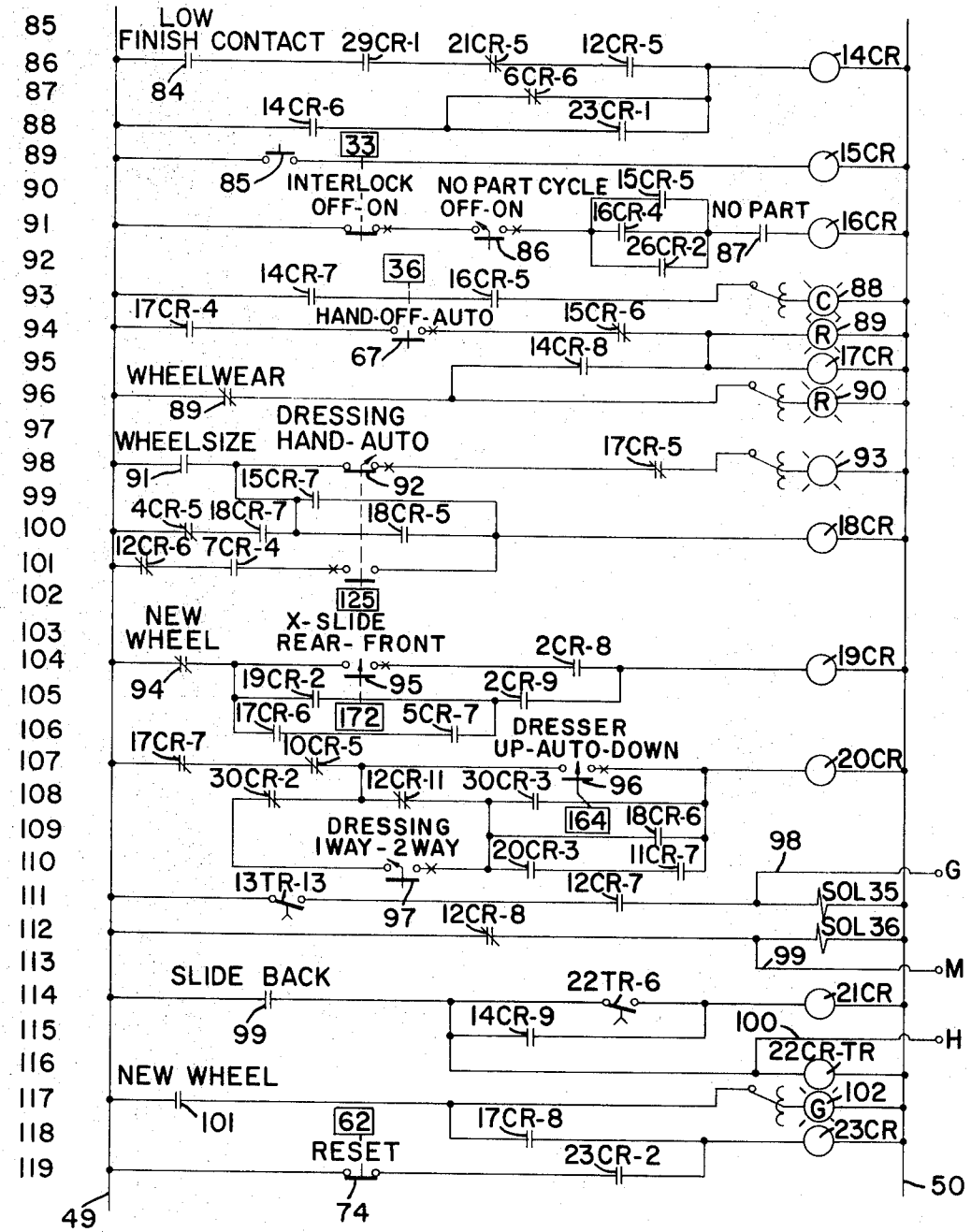


FIG.5

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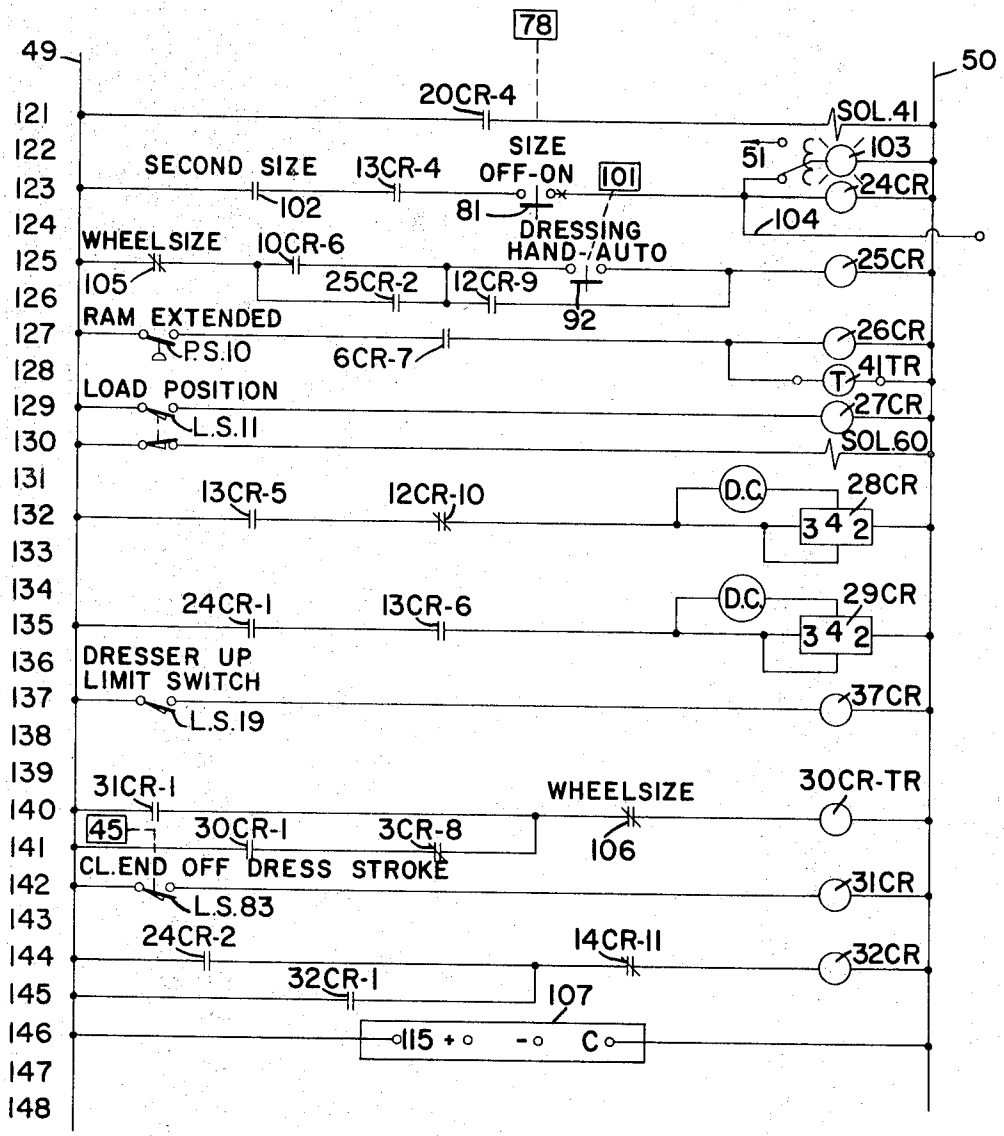


FIG.6

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GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 7

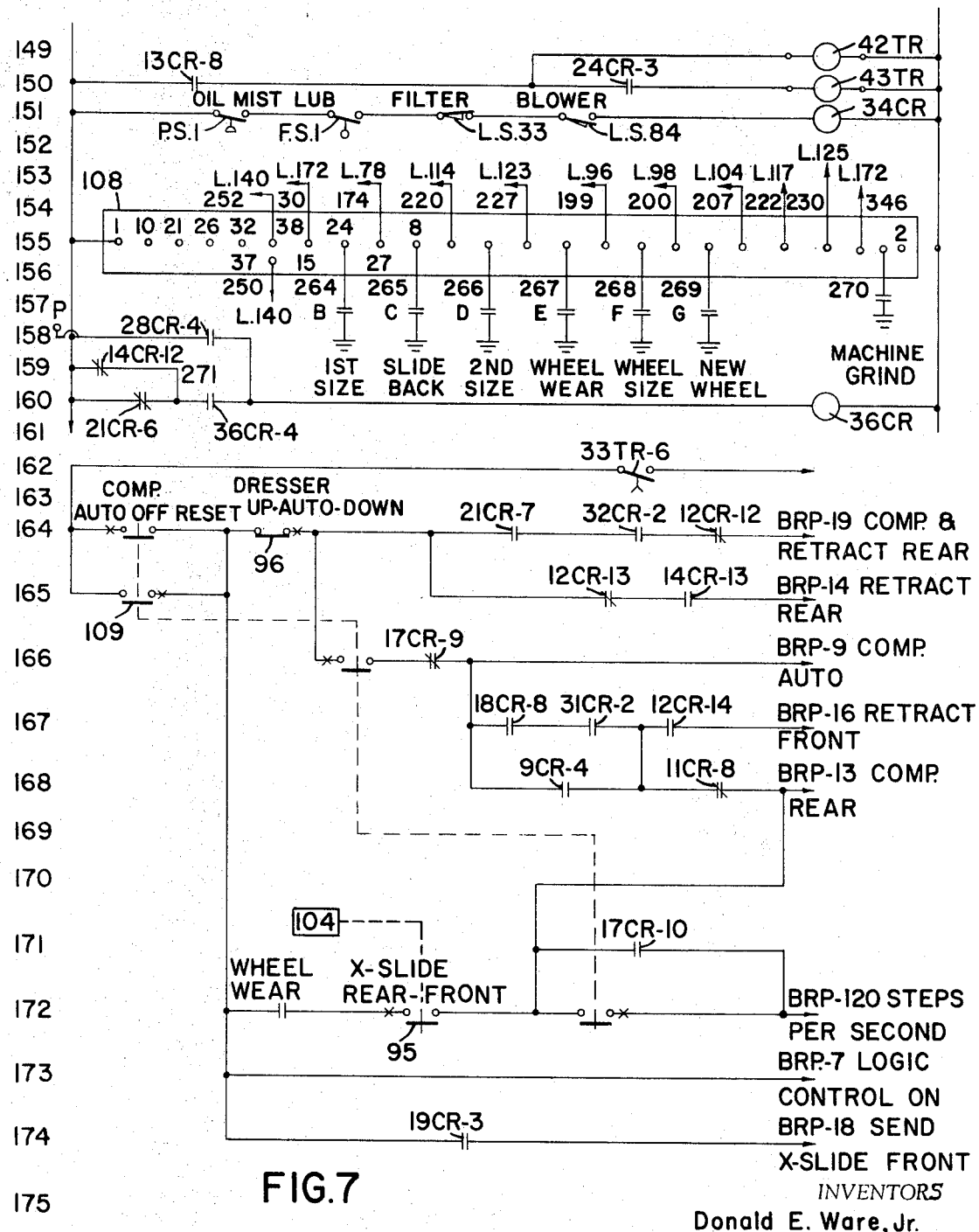


FIG.7

INVENTORS
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GRINDING MACHINE

Filed Sept. 11, 1967

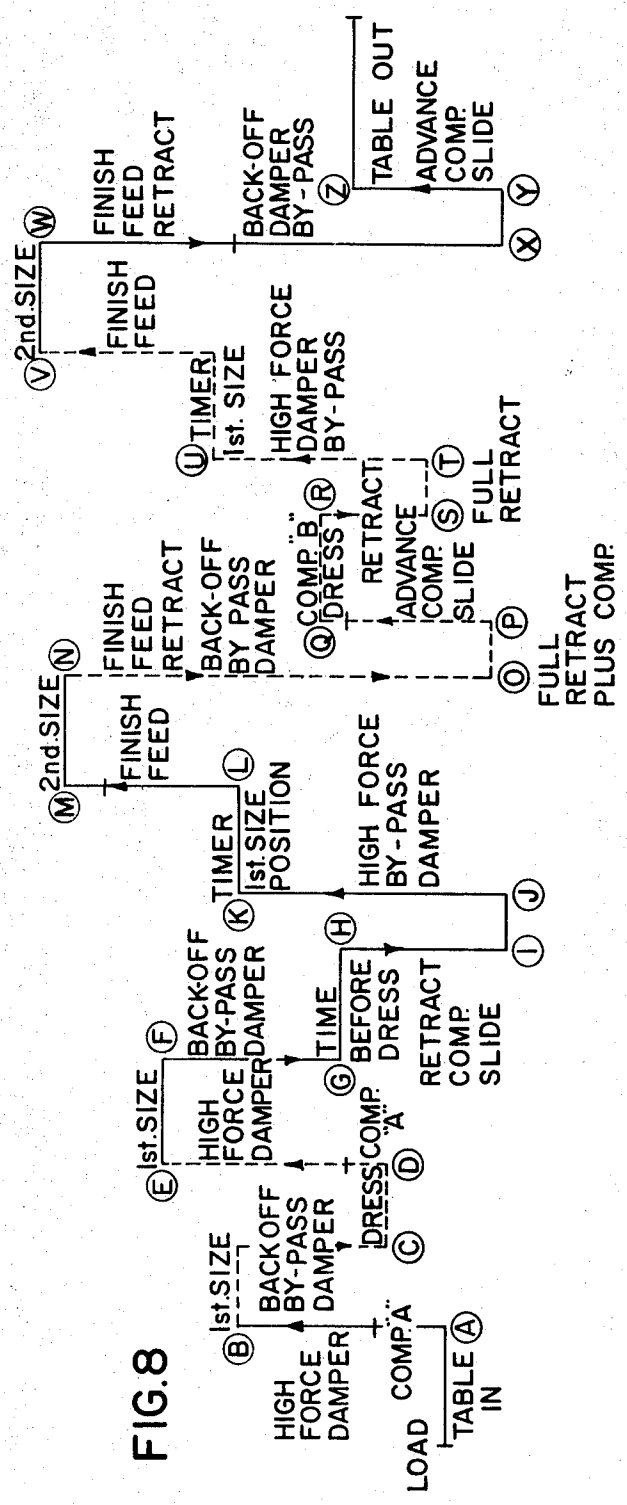


FIG. 8

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GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 9

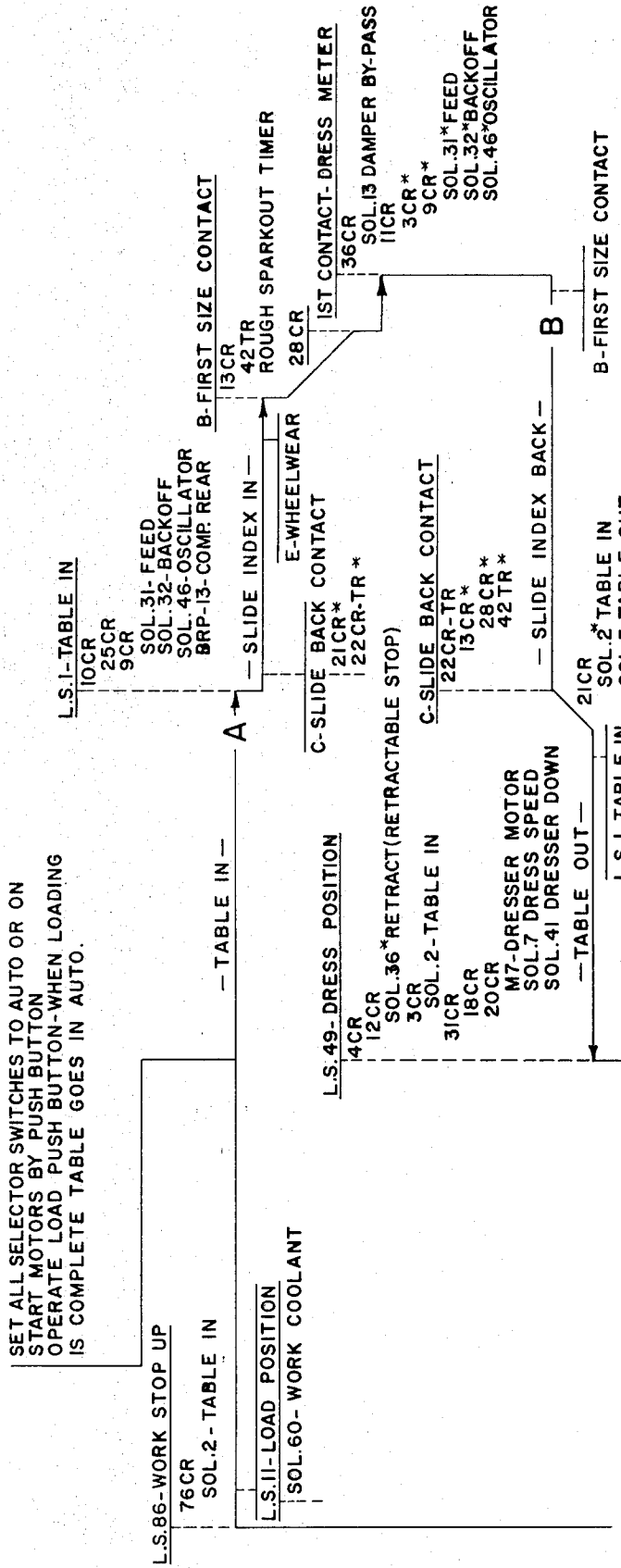


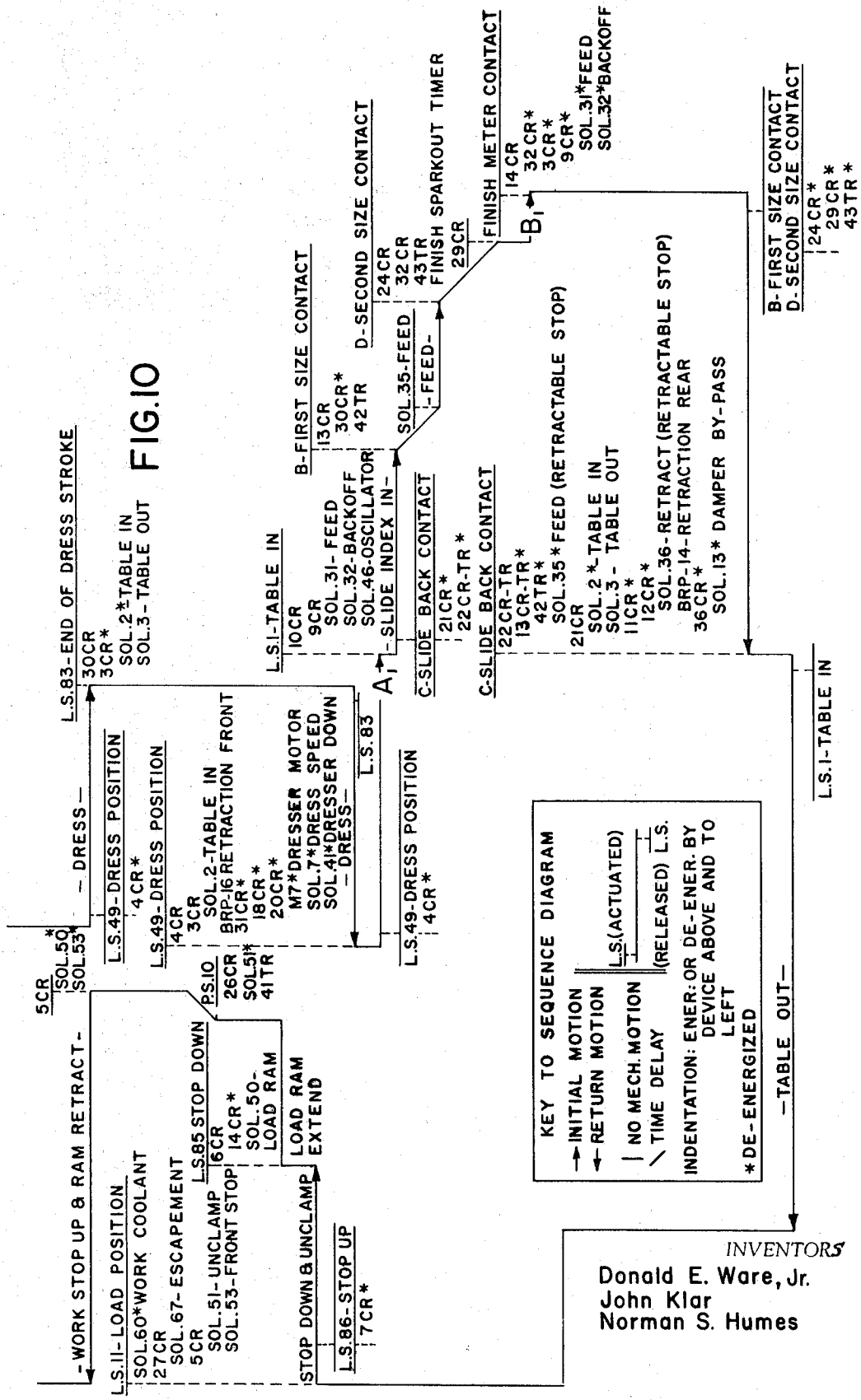
FIG.9

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Oct. 27, 1970 D. E. WARE, JR., ET AL 3,535,828

GRINDING MACHINE

Filed Sept. 11, 1967 10 Sheets-Sheet 10



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United States Patent Office 3,535,828 Patented Oct. 27, 1970

3,535,828

GRINDING MACHINE

Donald E. Ware, Jr., Westboro, John Klar, West Boylston, and Norman S. Humes, Worcester, Mass., assignors to The Heald Machine Company, Worcester, Mass., a corporation of Delaware

Filed Sept. 11, 1967, Ser. No. 666,677
Int. Cl. B24b 49/00
U.S. Cl. 51—165 8 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a grinding machine and, more particularly, to a grinding apparatus which makes use of measurements of load to bring about a dressing operation on the abrasive wheel if difficulty is experienced in a specific grinding cycle.

BACKGROUND OF THE INVENTION

There are many situations encountered in the abrasive machining of workpieces where the quality of the finished surface may vary due to variations in the grindability of the unfinished surfaces from one workpiece to another. An example of the field in which this problem is encountered is in the grinding of the internal bore of a hydraulic valve lifter of an internal combustion engine. To perform this operation, it is necessary to use a long wheel; this means that a considerable amount of spindle deflection takes place. It is possible by well-known means to compensate for this deflection to prevent the bore from being ground with an undesired taper, if the grindability of the bores were the same in all workpieces. However, in the case of the hydraulic valve lifter, the workpiece has to be heat-treated prior to the finish grinding operation. The heat treatment (or, in some cases, the basic material or previous operations) causes the grindability of the workpieces to vary from workpiece to workpiece. These differences in grindability from one workpiece to the next cause the spindle and the abrasive wheel to deflect by different amounts and to produce different amounts of taper in the internal bore of the valve lifter. Now, it so happens that taper in the internal bore of a hydraulic valve lifter is praticularly undesirable, because, if the taper exceds a small tolerance, noisy operation of the engine results. Attempts to overcome these deficiencies in the prior art apparatus have been without success. 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 grinding machine which will permit one to maintain the quality of finished surface within a narrow range of tolerance despite variations of grindability from workpiece to workpiece.

Another object of this invention is the provision of a grinding machine for grinding deep bores in workpieces while maintaining taper within a narrow range of tolerance despite substantial variation in hardness of the unfinished bore surface.

A further object of the present invention is the provision of a grinding machine wherein means is provided to renew the surface of the abrasive wheel when it is apparent that the surface of the workpiece to be finished has a grindability lying outside of a narrow range of tolerance.

It is another object of the instant invention to provide a grinding machine having an operating cycle which reduces the variation of taper in finished surfaces of revolution to within a narrow range of tolerance despite substantial variations in unfinished workpiece surface quality from workpiece to workpiece.

It is a further object of the invention to provide a grinding machine for grinding bores in workpieces where the wheel length is large as compared to the diameter without wide variation in taper.

A still further object of this invention is the provision of a grinding machine which will operate in such a manner that, when a given workpiece arrives in the machine and has a surface grindability outsides of a narrow range of tolarenace, the abrasive wheel surface will not be affected in such a way as to produce poor surface quality in subsequently ground workpiece surfaces.

It is a still further object of the present invention to provide a grinding machine which operates in such a way that when excessive loads are encountered (which would break down the wheel surface due to a variation in grindability of a particular workpiece), the apparatus automatically compensates for breakdown in abrasive wheel surface, so that not only is the quality of subsequent workpieces provided for, but the particular workpiece itself is furnished with a quality within tolerance.

Another object of the invention is the provision of a grinding machine which will operate to give a uniform dress to the abrasive wheel despite wide variations in grindability of the workpieces.

Another object of the invention is the provision of a grinding machine which grinds at a high force during a roughing grind followed by operation at a low force finish grind and in which the point at which the shift from rough to finish grind takes place is adjusted in the case of a workpiece whose grindability exceeds a pre-determined value.

Another object of the invention is the provision of a grinding machine having a rough grind at a constant high force value and a finish grind at a constant low force value, wherein a workpiece surface can be ground at the maximum rate of speed and, nevertheless, maintain a satisfactory finished workpiece surface in terms of size and surface finish.

Another object of the invention is the provision of a grinding machine in which the breakdown of abrasive wheel surface due to the unusual character of the particular workpiece will be compensated for during the grinding cycle involving that particular workpiece, because the breakdown is sensed early enough in the cycle for compensation to be made to the abrasive wheel so that the cycle can finish in the normal way.

Another object of the invention is the provision of a grinding machine having a grinding cycle with a first rough grind and a subsequent finish grind in which a breakdown of the abrasive wheel due to difficult grindability of a particular workpiece is compensated for during the rough grind so that the finish grind takes place in a normal manner.

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 ni the specification and covered by the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

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 somewhat schematic plan view of a machine tool embodying the principles of the present invention,

FIGS. 2 through 7 are electrical schematic diagrams of electrical equipment used in the machine tool,

FIG. 8 is a diagrammatic showing of the operation of the machine, and

FIGS. 9 and 10 constitute a further diagrammatic showing of the operation of the machine.

In general, the present invention has to do with a machine tool in which a feed means is provided which is

capable of presenting the tool to the workpiece with at least two different force levels and means is provided for measuring the load on the tool for changing from one force level to the other force level when a pre-determined load situation exists. More specifically, the invention has to do with a grinding machine in which a grinding operation is terminated for a dressing operation because the load on the wheelhead motor does not drop fast enough, thus indicating grinding difficulty.

Referring first to FIG. 1, which best shows the general features of the invention, the machine tool, indicated generally by the reference numeral **10**, as shown as an internal grinding machine having a base **11** on which are mounted a workpiece support **12** and a tool support **13**. The workhead **12** is provided with ways **14** and **15** for providing movement longitudinally of the axis of a workpiece **16** which is held on the workpiece support by fixture **20** and subjected to rotation about its axis. For the purpose of illustration, the workpiece **16** is shown as a hydraulic valve lifter for an internal combustion engine, the lifter having an internal bore **17** which is to be finished. A hydraulic cylinder **18** provides the longitudinal motion for the workpiece support **12**. The tool support **13** is provided with ways **19** and **21** and with a main hydraulic feed cylinder **22**. A dressing mechanism **23**, including a diamond, is mounted on the base **11** between the workpiece support **12** and the tool support **13**. Mounted on the tool support is a wheelhead **30** including a motor from which extends a spindle **24** carrying at its outer end an abrasive wheel **25**. The machine tool **10** thus described is of the general type using the controlled-force principle of grinding as shown and described in Pat. No. 3,197,921 which issued Aug. 3, 1965. Associated with wheelhead **30** is a power or dress meter **110** having three switch contacts engaged by the needle.

Extending downwardly from the lower surface of the tool support **13** is a horn **26** which lies in a recess **27** formed in a block **28** which rests on the upper surface of the base **11** and is movable independently of the base and of the tool support **13**. A fixed plug **29** is mounted at the front of the block **28** in position to be engaged by a retractable stop **31** which, on occasion, by contacting the plug, serves to bring about changes in the grinding cycle. The construction of the stop and its operation is similar to that shown in the patent application of Hatstat et al, Ser. No. 451,552, filed Apr. 28, 1965. The back end of the block **28** is provided with a threaded bore **32** and in this bore is carried a threaded feed shaft **33** whose rear end is mounted in a bearing **34** and which carries in its intermediate portion a gear **35**. This gear engages a gear **36** mounted on the end of the shaft **37** which extends transversely of the axis of the workpiece **16** and parallel to the feed shaft **33**. The other end of the shaft **37** is mounted on the shaft of a motor **38** carried on the base **11**, the other end of whose shaft extends from the front of the machine and is provided with a handwheel **39**. The motor **38** is of the type known as a stepping or slo-syn motor and has the ability to rotate in very small angular increments in response to electrical pulses. Extending from the right side of the tool support **13** is a finger **41** which engages switches **42** and **43** in a manner which will be described more fully hereinafter. The stepping motor **38** operates through the feed screw shaft **33** to provide for compensation, retraction, and the like, as these functions are known in the grinding machine industry in a manner shown and described in the application of Robillard, Ser. No. 482,846, filed Aug. 26, 1965, now pat. No. 3,403,480, dated Oct. 1, 1968.

Generally speaking, the stepping motor receives pulses from a pulse generator in certain pre-determined amounts. These amounts have been pre-set in a counting and computing apparatus to cause the machine tool to move through certain pre-determined cycles in the well-known manner. The transverse movement of the tool support **13** relative to the workpiece support **12** takes place in large amounts by means of the hydraulic cylinder **22** whose motion is controlled through the limit switches **31**, **42**, and **43** and in small amounts (for compensation, retraction, and the like) by the stepping motor **38** operating through the feed screw shaft **33** and the block **28**. A control is provided, including a device for measuring the load on the wheelhead motor **30**, which control is connected to the feed mechanism to bring about a shift from one portion of the grinding cycle to the other when a pre-determined load is exceeded. A size control including the switch **29** is used to terminate a feeding operation at a pre-determined size of the workpiece. The load control is capable of terminating the feeding operation before the said pre-determined size is reached, if the load on the said wheelhead motor **30** exceeds a predetermined value. In the discussion which follows, a distinction should be made between the force which exists between the wheel and the workpiece surface to be finished and the load or work being done by the wheel, which load is felt by the drive motor **30**.

FIGS. 2 through 7 show the electrical elements of the apparatus. The relationship of these electrical elements to the hydraulic valves and cylinders of the grinding machine are similar to those described in the application of Klar, Ser. No. 380,857, filed July 7, 1964, now pat. No. 3,341,980, dated Sept. 19, 1967. As indicated at the top of FIG. 2, the 3-phase alternating current supply enters the system and is connected through motor starters M1 to a main drive motor **44**, through starters M2 to the workhead motor **30**. It is also connected through starters M4 to a coolant pump motor **45**, through starters M5 to a coolant sump motor **46** and through starters M7 to a dresser motor **47** associated with the dressing mechanism **23**. Two of the lines are connected through a transformer **48** giving 110 volt A.C. output across power lines **49** and **50**. A great deal of the equipment is connected between these two power lines and for the purpose of ease of description, imaginary horizontal lines extending between the power line **49** and the power line **50** are given numbers and will be identified as cross-lines. Cross-line **1** includes, for instance, a surge protector **51**, while cross-line **2** includes a POWER ON light **52**; cross-line **4** includes a STOP pushbutton switch **53** and a START pushbutton switch **54** connected in series with the coil of the starter M1 for providing power to the main drive motor **44**. A contact M1–A is connected in parallel with the starting switch **54** to hold it in. Connected in parallel with the coil of the starter M1 is the coil of a table float timer 33CR–TR. Along cross-line **8** lie in series an EMERGENCY STOP switch **55**, a normally-open contact 34CR–1, a normally-closed contact 19CR–1, a STOP switch **56**, and a START switch **57**, as well as the coil of the motor starter M2. A three-way CYCLE switch **58** (giving HAND-OFF-AUTO selections) is connected in series with a normally-open contact M2–A of the motor starter M2 and the two of them are connected in parallel with the START switch **57**, these lying along cross-line **9**. The normally-open contact M4–A of the motor starter M4 is connected in parallel with the switch **58** and lies along cross-line **10**. On cross-line **11** it can be seen that a normally-open contact 20CR–1 is connected in series with the coil of the motor starter M7 and the two of them are connected from a point between the normally-open contact 34CR–1 and the normally-closed contact 19CR–1 to the power line **50**, these constituting a dresser motor operating circuit. Line **13** includes the elements controlling the oscillator of the grinding machine for producing oscillations of the wheel in the workpiece and include an OSCILLATOR OFF-AUTO switch **59**, a normally-open contact 9CR–3, and the coil of a solenoid SOL46, all connected at one end to the said common point between the contact 34CR–1 and the contact 19CR–1 and on the other end to the power line **50**. Connected around the contact

9CR–3 is a normally-closed contact 2CR–3 and a normally-open contact 10CR–3. The cross-line 15 contains coolant pump controls, including a COOLANT OFF-ON switch 61 and the coil of the starter M4, these being connected to a point between the contact 19CR–1 and the STOP switch 56 in cross-line 8. On cross-line 16 it can be seen that a normally-open contact of the motor starter M4 is connected around part of the COOLANT OFF-ON SWITCH 61. In cross-line 17 it can be seen that a COOLANT FLOAT switch FS2 and the coil of the motor starter M5 for the coolant sump pump motor are connected from the line 49 to the line 50. Line 19 includes equipment having to do with the high frequency wheelhead 30HF which may be used in place of the normal workhead motor 30. This consists of a STOP switch 62 and a START switch 63 connected in series with a high-frequency coolant pressure switch PS9 and a coil of the motor starter 46 for operating the high frequency wheelhead as well as a transducer blocking timer 35CR–TR. Connected across the START switch 63 is a normally-open contact M2–AUX associated with the motor starter M2 and a normally-open contact M6–A associated with the motor starter M6. Lying along cross-line 22 is an INTERLOCK OFF-ON switch 64; in parallel with that is part of the cycle switch 58, this latter lying along the cross-line 23.

Referring to FIG. 3, cross-line 31 contains connections for indicating the failure of lubrication to the wheelhead and a lamp 65 in series with a normally-closed contact 34CR–2 indicates blower failure. Cross-line 33 contains the cycle start equipment and includes a normally-open contact 33TR–5 in series with a normally-closed contact portion of the EMERGENCY STOP switch 55 (see cross-line 8), a TABLE OUT switch 66, a normally-open contact portion of the INTERLOCK OFF-ON switch 64 (see cross-line 22), a normally-open contact 15CR–1, a normally-open contact 27CR–1, and the coil of a relay 1CR. Associated with this equipment along cross-line 34 is a normally-closed contact 2CR–10, a normally-open contact 1CR–1, and a normally-open contact 7CR–1, while a normally-open contact of the motor starter M6 lies along cross-line 35. Along cross-line 36 is the automatic cycle equipment including the normally-open switch section of the cycle switch 58 (see cross-line 9), a COMPENSATION auto-off-reset switch 67 and the coil of a control relay 2CR. Associated with this equipment and lying along the cross-line 37 is a normally-closed relay contact 4CR–1, a normally-open contact 10CR–2, and a normally-closed contact 21CR–1. Cross-line 38 includes a TABLE hand-auto switch 68, a normally-closed contact 4CR–2, and a normally-open contact 3CR–1. Cross-line 39 includes a normally-open contact 15CR–2, a normally-open contact 14CR–1, and a normally-open contact 16CR–1. The common sides of the contacts 21CR–1 and 3CR–1 are connected through a normally-closed contact 31CR–3 (cross-line 39) and a normally-open contact 37CR–2 (cross-line 40), both of which are in parallel with one another and are connected through a normally-open contact 7CR–2 to the TABLE IN SOL2 to the line 50, and to a point C, which will be described more fully hereinafter. The cross-line 40 includes a normally-open contact 2CR–1, and a normally-open contact 11CR–1, while cross-line 41 includes a normally-open contact 18CR–1 and a normally-closed contact of a compensation control relay 69. Lying on cross-line 42 is a normally-closed contact 1CR–2, a normally-closed contact 3CR–2, a normally-closed contact 30CR–4, a normally-open contact 21CR–2, and the TABLE OUT solenoid SOL3. A mid-point between the contact 21CR–2 and the coil SOL3 are connected to a point K, as will be described hereinafter. In the cross-line 43 it can be seen that a contact 30TR–6 is connected around the contact 30CR–4 in cross-line 42.

The cross-line 44 contains the equipment for sending the table in (the word "table" indicating the workhead support 12 in all situations where used). The equipment lying along cross-line 44 includes a normally-open contact 15CR–3, a normally-closed contact 11CR–2, a normally-closed contact 14CR–2, a normally-open contact 1CR–3, a normally-closed contact 5CR–2, a normally-open contact 3CR–3, and the coil of a relay 3CR. Along cross-line 45 is an END DRESS switch LS83, a normally-closed contact 10CR–3, a normally-open contact 3CR–4, a normally-open contact 12CR–1. In the same line and extending around the contact 3CR–3 is a normally-open contact 21CR–3. In line 46 a normally-closed contact 18CR–2 extends from the line 49 to the mid-point between the contacts 10CR–3 and 3CR–4 in cross-line 45. A normally-closed contact 2CR–2 extends from a point between the contacts 15CR–3 and 11CR–2 (in cross-line 44) to a point between the contacts 14CR–2 and 1CR–3. Finally, in cross-line 47 lie a normally-open contact 4CR–10 and a normally-closed contact 17CR–1.

The cross-line 48 shows the equipment associated with the dress position and includes a DRESS POSITION switch LS49, a normally-open contact 18CR–3, and the coil of a relay 4CR. Connected along the contact 18CR–3 and lying in the cross-line 49 are a normally-open contact 11CR–3, a normally-closed contact 15CR–4, and a normally-closed contact 6CR–1. In cross-line 50 lies a normally-open contact 27CR–2 and a normally-closed contact 7CR–3.

Cross-line 51 has to do with loading of workpieces and includes a normally-closed contact 17CR–2, a LOAD switch 71, a LOADING hand-auto switch 72, a normally-open contact 37CR–1, and the coil of a relay 5CR. Lying in cross-line 52 are a normally-closed contact 6CR–2, a normally-open contact 14CR–3, a normally-open contact 8CR–1, a normally-open contact 17CR–3, and part of the LOADING hand-auto selector switch 72. In cross-line 52 it can be seen that a point between the contact 37CR–1 and the coil of the control relay 5CR is connected to a point R. In cross-line 53 it can be seen that a normally-closed contact 16CR–2 is connected around the contact 17CR–3. Finally, in cross-line 54 a normally-closed contact 41TR–1 is connected in series with a normally-open contact 5CR–3 to the point R.

Referring now to FIG. 4, the elements in cross-lines 55 through 84 have to do with the loading of workpieces by means of the apparatus shown and described in the patent application of Uhtenwoldt, Ser. No. 533,904, filed Mar. 14, 1966, now Pat. No. 3,420,008, dated Jan. 9, 1969; in this construction, a loading plug is automatically moved longitudinally and rotatably about a longitudinal axis from a low position in alignment with a machine chuck to an upper position in alignment with a workpiece chute pickup point. The loading apparatus is operated automatically by use of a sequential valve which shifts fluid from one operating cylinder to another of the mechanism. Cross-line 55 includes a WORK STOP DOWN limit switch LS85, a normally-open contact 27CR–3, and the coil of a control relay 6CR in series from the power line 49 to the power line 50. As is evident in cross-line 57, a normally-open contact 6CR–3 and a normally-closed contact of the LOADING hand-auto switch 72 (see cross-line 52) are connected in series with one another from the power line 49 to a point between the limit switch LS85 and the contact 27CR–3. Connected around the last-named normally-closed contact of the switch 72 is a normally-closed contact of the LOAD switch 71 (see cross-line 51). In line 58 is shown a normally-open contact 6CR–4, a normally-open contact 5CR–4, and the coil of a solenoid SOL50 connected in series from the power line 49 to the power line 50. Similarly, in cross-line 59 is shown an UNCLAMP switch 73, a normally-open contact 27CR–4, and the coil of an UNCLAMP solenoid SOL50 connected from the power line 49 to the power line 50. The cross-line 60 shows that a normally-closed contact 26CR–1, and a normally-open contact 5CR–5 are connected in series with one another from the

power line 49 to a point between the switch 73 and the contact 27CR–4. Cross-line 61 contains a WORK STOP UP limit switch LS86 and the coil of a WORK STOP UP relay 7CR connected in series with one another from the power line 40 to the power line 50. Cross-line 62 shows a normally-closed contact 6CR–5, a RESET switch 74, a normally-open contact of the RESET switch 74 and the coil of a LOAD CHUTE EMPTY relay 8CR connected in series with one another from the power line 49 to the power line 50. A LOAD CHUTE limit switch LS29 is connected from the power line 49 to a point between the two contacts of the RESET switch 74, as is evident in cross-line 63. It is also connected to one side of a normally-open contact 8CR–2, the other side of which is connected beside the coil of the relay 8CR.

In cross-line 64, a normally-closed contact 8CR–3 and a LOAD CHUTE EMPTY lamp 75 are connected from one power line to the other to show that the load chute needs to be filled.

In cross-line 65, which has to do with the machine feed, a normally-open contact 10CR–4, a normally-closed contact 27CR–5, a normally-closed contact 18CR–4, a normally-closed contact 27CR–5, a normally-closed contact 18CR–4, a normally-closed contact 4CR–3, a normally-open contact 3CR–5, a normally-open contact 2CR–4, and the coil of a control relay 9CR are connected in series from the power line 49 to the power line 50. As is evident in cross-line 67, a normally-closed contact 2CR–5, a CROSS SLIDE switch 76 (having backoff-auto-and grind positions) and the coil of a feed solenoid SOL31 are connected in series from a point in cross-line 65 between the contact 10CR–4 and 27CR–5 to the power line 50. The side of the solenoid SOL31 opposite its connection to the power line 50 is connected by a line 77 to a point D. In cross-line 68 (which concerns itself with machine backoff), a normally-open contact 9CR–1, a normally-open contact 1CR–4, and the coil of a backoff solenoid SOL32 are connected between the power line 49 and the power line 50. The side of the solenoid SOL32 which is not connected to the power line 50 is connected to the similar side of the solenoid SOL31 and to the point D. In cross-line 69 a portion of the CROSS SLIDE switch 76 is connected in series with coil of a damper bypass solenoid SOL13 between the two power lines. In cross-line 70 a normally-closed contact 3CR–6, and a normally-open contact 2CR–6 are connected in series with one another from the power line 49 to the side of the solenoid SOL13 which is not connected to the power line 50; this same point is connected to a point E. In addition, in the cross-line 69 a normally-open contact 36CR–1 is connected from the power line 49 to a point between the contacts 3CR–6 and 2CR–6 in cross-line 70. In cross-line 71 a TABLE IN limit switch LS1 is connected in series with the coil of a control relay 10CR between the two power lines.

Referring to cross-line 72, which has to do with sending the slide back at first size position, it can be seen that a HIGH-ROUGH CONTACT switch 80, a normally-open contact 36CR–2, a normally-open contact 28CR–1, a normally-closed contact 14CR–4, a normally-open contact 1CR–5, and the coil of a SLIDE BACK control relay 11CR are connected from one power line to the other. A point between the switch 80 and the contact 36CR–2 is connected to a line P (see cross-line 158). A point between the contact 1CR–5 and the coil of the relay 11CR is connected by a line 78 to a point F. A point between the contacts 36CR–2 and 28CR–1 is connected through a MULTI-DRESS switch 79 and a contact 42TR–1 to the power line 49. Referring to cross-line 75, a normally-open contact 11CR–4 is connected in series with a normally-closed contact 12CR–4 to a point between the contacts 28CR–1 and 14CR–4 in cross lines 72 and 73. In cross-line 73 a normally-open contact 36CR–3 is connected from the last-named point between the contacts 28CR–1 and 14CR–4 to a point in cross-line 75 between the contacts 11CR–4 and 12CR–4. Connecting the same two points in cross-line 74 is a normally-closed contact 9CR–5. Finally, that same point is connected by a normally-closed contact 21CR–4 to a point in cross-line 73 between the contacts 14CR–4 and 1CR–5.

In cross-line 76 (table in after dress), a normally-open contact 4CR–4, a normally-open contact 14CR–5, a normally-open contact 11CR–5, and the coil of a TABLE IN AFTER DRESS relay 12CR are connected in series from one power line to the other. A contact of the MULTI DRESS switch 79 is also connected around the control relay 14CR–5. As is evident in cross-line 77, a normally-open contact 12CR–2 connects the power line 49 to a point between the relays 4CR–4 and 14CR–5. In addition, a normally-closed contact 43TR–1 connects that same point to a point in cross-line 76 between the relay 14CR–5 and 11CR–5.

Along cross-line 78 a FIRST SIZE switch 79, a SIZE switch 81 (with off-on capabilities), and the coil of a first size contact control relay 13C are connected in series from one power line to the other. The switch 81 is also connected into a contact in cross-line 123. Similarly, in cross-line 79 a normally-closed contact 22CR–1, a normally-open contact 13 CR–1, and the coil of a control relay 13CR–TR are connected in series from one power line to the other. The sides of the relays 13CR and 13CR–TR that are not connected to the power line 50 are connected together. Along the cross-line 80 a normally-open contact 13CR–2, a normally-closed contact 12CR–3, and a FIRST SIZE lamp 82 are connected in series with each other and from one power line to the other. Along cross-line 81, which has to do with bringing the dresser down for dressing, a normally-open contact 5CR–6 and the coil of a FRONT STOP solenoid valve SOL53 are connected in series from one power line to the other. Along cross-line 82, a normally-closed contact 2CR–7 and the coil of a TABLE SPEED solenoid valve SOL7 are connected in series from one power line to the other; furthermore, the side of the coil of the solenoid SOL7, which is not attached to the power line 50, is connected by a line 83 to a point J. Along cross-line 83 a normally-open contact 20CR–2 is connected from the power line 49 to a point between the contact 2CR–7 and the solenoid SOL7. Similarly, along aross-line 84, a normally-closed contact 3CR–7 and a normally-open contact 11CR–6 are connected in series with each other and are also connected from the power line 49 to a mid-point between the contact 2CR–7 and the coil of the solenoid SOL7.

Referring next to FIG. 5, along cross-line 86, which has to do with sending the slide back at second size, a LOW FINISH contact 84, which is normally open, a normally-open contact 29CR–1, a normally-closed contact 21CR–5, a normally-open contact 12CR–5, and the coil of a SEND SLIDE BACK relay 14CR are connected in series with one another from one power line to the other. Along cross-line 88, a normally-open contact 14CR–6 and a normally-open contact 23CR–1 are connected in series with each other and connected from the power line 49 to a mid-point between the contact 12CR–5 and the coil of the control relay 14CR. On cross-line 87, it can be seen that a normally-closed contact 6CR–6 extends in parallel with and around the contact 23CR–1.

Referring to cross-line 89, a TABLE IN switch 85 is connected in series with the coil of a TABLE IN control relay 15CR and these two are connected from one power line to the other. Along cross-line 91, a part of the interlock switch 64 (see cross-line 22 and cross-line 33), a contact of the NO PART CYCLE switch 86, a normally-open contact 16CR–4, a NO PART switch 87, and the coil of a NO PART conrtol relay 16CR are connected in series from one power line to the other. Connected around the contact 16CR–4 is a normally-open contact 15CR–5 and a normally-open contact 26CR–2. Along the cross-line 93, a normally-open contact 14CR–7, a normally-open contact 16CR–5, and a NO PART lamp 88

are connected in series from one power line to the other. Along the cross-line **94**, a normally-open contact **17CR–4**, a contact of the compensation switch **67**, a normally-closed contact **15CR–6**, and a wheel wear lamp **89** are connected in series from one power line to the other. At the same time, along the cross-line **96**, a normally-closed wheel wear contact **89** and a wheel wear lamp **90** are connected in series with one another and across the power lines. The mid-point between the wheel wear switch **89** and the lamp **90** is connected through a normally-open contact **14CR–8** and the coil of a wheel wear conrtol relay **17CR** to the power line **50**. The sides of the lamp **89** and the coil of the relay **17CR**, which are not connected to the line **50**, are connected together.

Referring to cross-line **98**, a WHEEL SIZE switch **91** is connected through a DRESSING switch **92**, a normally-closed contact **17CR–5** and a WHEEL SIZE lamp **93** to the power line **50**. Similarly, along the cross-line **100**, a normally-closed contact **4CR–5**, a normally-open contact **18CR–7**, a normally-open contact **18CR–5**, and the coil of a WHEEL SIZE control relay **18CR** are connected in series with one another and from power line to power line. A normally-open contact **15CR–7** is connected on one side to a point between the WHEEL SIZE switch **91** and the DRESSING switch **92**, while on the other side, it is connected to a point between the contact **18CR–5** and the coil of the relay **18CR**.

Referring to cross-line **101**, it can be seen that a normally-closed contact **12CR–6**, a normally-open contact **7CR–4**, and a contact forming part of the DRESSING switch **92** are mounted in series and connected to the power line **49** on one end and on the other end to a point between the contact **18C8–5** and the coil of the control relay **18CR**. The elements along the cross-line **104** take care of the cross-slide reset. They include a normally-closed NEW WHEEL switch **94**, a contactor of a cross-slide switch **95**, a normally-closed contact **2CR–8**, and the coil of a CROSS-SLIDE RESET control relay **19CR** in series with one another from one power line to the other. In cross-line **105**, it can be seen that a normally-open contact **19CR–2** and a normally-open contact **2CR–9** are connected in series with one another from a point at one end between the NEW WHEEL switch **94** and the CROSS SLIDE switch **95** and, at the other end, to a point between the contact **2CR–8** and the coil of the control relay **19CR**. In cross-line **106**, it can be seen that a normally-open contact **17CR–6** and a normally-open contact **5CR–7** are connected in series with one another across the contact **19CR–2** in cross-line **105**.

The cross-line **107** takes care of the dresser operation on a new wheel and provides the energization for moving the dresser up and down to dressing position. Along cross-line **107** can be seen in series the following elements: a normally-closed contact **17CR–7**, a normally-closed contact **10 CR–5**, an element or contact associated with a DRESSER switch **96**, and the coil of a DRESSER relay **20CR**. Referring to cross-line **108**, a normally-closed contact **12CR–11** and a normally-open contact **30CR–3** are connected in series with one another and connected at one end to a point between the contact **10CR–5** and the DRESSER switch **96** and, at the other end, between the DRESSER switch **96** and the control relay **20CR**. In cross-line **109**, a normally-open contact **18CR–6** is connected in parallel with and around the contact **30CR–3**. Similarly, in cross-line **110**, a normally-open contact **20CR–3** and a normally-open contact **11CR–7** are connected in series with one another and in parallel and across the contact **30CR–3**. A DRESSING switch **97** and a normally-closed contact **30CR–2** are connected in series with one another and are connected at one end to the point in cross-line **107** between the contact **10CR–5** and the DRESSER switch **96** and, at the other end, to a common point shared by the contacts **30CR–3**, **18CR–6**, and **20CR–3**.

Cross-line **111** has to do with presentation of a retractable stop. A normally-open contact **13TR–13**, a normally-open contact **12CR–7**, and the coil of a feed solenoid **35** are connected in series from one power line to the other. The side of the solenoid **SOL35**, which is not connected to the power line **50**, is connected by a line **98** to a point G. The cross-line **112** has to do with the withdrawal of the retractable stop; a normally-closed contact **12CR–8** is connected in series with the coil of the RETRACT solenoid **SOL36** from one power line to the other and a line **99** extends from a point midway between these two elements to a point M. The cross-lines **114**, **115**, **116** contain elements having to do with a SLIDE BACK portion of the cycle; in the cross-line **114** a SLIDE BACK switch **99** is connected in series with a normally-open contact **22TR–6** and a coil of a control relay **21CR** from one power line to the other. A normally-open contact **14CR–9** extends parallel to and around the contact **22TR–6**. Similarly, a common point between the SLIDE BACK switch **99** and the contact **22TR–6** is connected to the line **50** through a coil of a control relay **22CR–TR**, the side of the relay **22CR–TR**, which is not connected to the power line, being connected through a line **100** to a point H.

Now, in cross-line **117** can be seen a NEW WHEEL switch **101** which is connected on one side to the power line **49** and on the other side through the NEW WHEEL lamp **102** to the power line **50**. A point between the NEW WHEEL switch **101** and the lamp **102** is connected through a normally-open contact **17CR–8** and a FIRST CYCLE SHUTDOWN control relay **23CR** to the power line **50**. A contactor of the RESET switch **74** and a normally-open contact **23CR–2** are connected in series with one another from the power line **49** to a point between the contact **17CR–8** and the control relay **23CR**.

Referring now to FIG. 6 and the cross-line **121**, this cross-line contains elements for carrying the dresser to down position, including a normally-open contact **20CR–4** and a solenoid **SOL41** which are in series with one another from one power line to the other. In cross-line **123** (which has to do with the second size position) is provided a SECOND SIZE switch **102**, a normally-open contact **13CR–4**, a contact of the SIZE switch **81** and a relay **24CR** in series with one another from one power line to the other for bringing about "second size" contact. The side of the relay **24CR**, which is not directly connected to the power line **50**, is connected indirectly through a SECOND SIZE lamp **103** to the power line **50** and that same side is connected by a line **104** to a point.

Cross-lines **125** and **126** have to do with wheel size and include a WHEEL SIZE switch **105**, a normally-open contact **10CR–6**, a contact of the DRESSING switch **92**, and the coil of a control relay **25CR** in series with one another from one power line to the other. Furthermore, a normally-open contact **25CR–2** and a normally-open contact **12CR–9** are connected in series with one another and on one end to a point between the WHEEL SIZE switch **105** and the contact **10CR–6** and on the other end to a point between the DRESSING switch **92** and the control relay **25CR**. Furthermore, the mid-point between these last two control relays is connected to a mid-point between the contact **10CR–6** and the DRESSING switch **92**. The cross-line **127** has to do with the longitudinal movement of the loading arm and includes a RAM-EXTENDED pressure switch **PS10** in series with a normally-open contact **6CR–7** and the coil of a control relay **26CR**, these three being connected in series from one power line to the other. Furthermore, the side of the relay **26CR** which is not attached to the power line **50** is connected through a control relay **41TR** to the line **50**. The cross-line **129** includes a LOAD POSITION switch **LS11** in series with the coil of a control relay **27CR** and connected between one power line and the other. Furthermore, the cross-line **130** contains another portion of the limit switch **LS11** which is connected through soleoid **SOL60** which provides work coolant to the power line **50**.

The cross-line **132** has to do with rough sparkout and includes a normally-open contact **13CR–5** which is connected on one side to the power line **49**; on the other side it is connected to one side of a normally-closed contact **12CR–10**. The other side of this last-named contact is connected through a TIMER circuitry **28CR**, the output of which extends to the power line **50**. In a similar way, the cross-line **135** includes a normally-open contact **24CR–1** and a normally-open contact **13CR–6** connected together in series and on one side to the power line **49**. At the other end the contact **13CR–6** is connected through a FINISH SPARKOUT timer circuitry **29CR** to the power line **50**. The cross-line **137** has to do with the dresser up position and shows a DRESSER UP limit switch **LS19** which is connected on one side to the line **49** and on the other side through the coil of a relay **37CR** to the power line **50**. The cross-line **140** has to do with end of the dress stroke and includes a normally-open contact **31CR–1**, a normally-closed WHEEL SIZE switch **106** and the coil of a control relay **30CR–TR**, which elements are connected in series with one another from one power line to another. In cross-line **141** a normally-open contact **30CR–1** and a normally-closed contact **3CR–8** are connected in series with one another and connected on one end to the power line **49** and the other end to a point between the contact **31CR–1** and the WHEEL SIZE switch **106**. The cross-line **142** has to do with the end of the dress stroke and includes an END OF DRESS STROKE limit switch **LS83** (which, it will be noted, has a corresponding element in cross-line **45**). One side of the switch **LS83** is connected to the power line **49** while the other end is connected through a control relay **31CR** to the power line **50**. Cross-lines **144**, **145**, and **146** have to do with a compensation B. In sross-line **144** a normally-open contact **24CR–2**, a normally-closed contact **14CR–11**, and a control relay **32CR** are connected in series with one another and from one power line to the other. In cross-line **145** a normally-open contact **32CR–1** is connected on one side to the power line **49** and on the other side to a point between the contact **24CR–2** and **14CR–11**. In cross-line **146** a control **107** is connected between the power lines.

Referring to FIG. 7, a cross-line **150** contains various elements having to do with a second dress signal. A normally-open contact **13CR–8**, a normally-open contact **24CR–3**, and the coil of a control relay **43TR** are connected in series with one another from one power line to the other. A point between the contact **13CR–8** and the contact **24CR–3** is connected through the coil of a control relay **42TR** to the power line **50** to take care of the high-low contact selection. The cross-line **151** contains a number of safety interlocks including an OIL MIST LUBRICATOR pressure switch **PS1**, a FLOAT switch **FS1**, a FILTER switch **LS33**, a BLOWER switch **LS84**, and the coil of a control relay **34CR** in series from one power line to the other. Extending along cross-line **155** is an alternating current slide contact unit **108**.

Along cross-line **160** it can be seen that a normally-closed contact **21CR–6**, a normally-open contact **36CR–4**, and the coil of a control relay **36CR** are arranged in series from one power line to another. In addition, in parallel with the contact **21CR–6**, is a normally-closed contact **14CR–12**. Finally, a point between the contact **36CR–4** and the coil of the control relay **36CR** is connected to one side of a normally-open contact **28CR–4**, the other side of which is connected to the point P, which appears in cross-line **72**.

Now, the material in line **162** to **174** is the apparatus associated with the counting and computing equipment necessary to operate the stepping motor **38**. It includes various connections associated with the equipment described in the application of Robillard Ser. No. 482,846, filed Aug. 26, 1965, now Patent No. 3,403,480 dated Oct. 1, 1968. In cross-line **162**, the switch **33TR–6** is connected on one side to a plus 24 volts D.C. point **BRP3** and, on the other side, to one side of the compensation auto-off-reset switch **109**. In cross-line **164**, the other side of the switch **109** is connected to one side of the dresser up-auto-down switch **96** (see line **107**), the other side of which is connected through a normally-open contact **21CR–7**, a normally-open contact **32CR–2**, and a normally-closed contact **12CR–12** to **BRP19** which is the "compensation and retract rear" section of the controls. The aforementioned other side of the switch **96** is also connected through a normally-closed control relay **12CR–13** and a normally-open control relay **14CR–13** to a point in the control apparatus point **BRP–14** which is a "retract rear" portion of the control apparatus. The said other side of the switch **96** is also connected through another contactor of the compensation switch **109** to one side of a normally-closed contact **17CR–9**, the other side of which is connected to a point **BRP–9**, which is the "automatic compensation" section of the controls.

The other side of the normally-closed contact **17CR–9** is also connected through a normally-open contact **18CR–8**, a normally-open contact **31CR–2**, and a normally-open contact **24CR–14** to a point **BRP16** which is a "retraction front" portion of the control apparatus. This same side of the normally-closed contact **17CR–9** is connected through a normally-open contact **9CR–4** and a normally-closed contact **11CR–8** to a point **BRP–13** which is a "compensation rear" portion of the control apparatus. A point between the contact **31CR–2** and contact **12CR–14** is connected to a point between the contact **9CR–4** and contact **11CR–8**. Now, a point between the compensation switch **109** and the dresser switch **96** is connected to one side of the wheel wear contact to one side of a "cross-slide rear-front" switch **95** (see cross-line **104**). The other side of this last switch is connected through a contact of the compensation switch **109** to a point **BRP–20** which is the control section for giving 120 steps per second. Connected around this last contact portion of the compensation switch **109** is a normally-open contact **17CR–10**. The common point in this line between the cross-slide switch **95** and the portion of the compensation switch **109** is connected by a line to the point **BRP–13** described above. The said other side of the compensation switch **109** is also connected directly to the point **BRP–7** which puts the logic control on in the controls. This same side of the switch **109** is connected through a normally-open contact **19CR–3** to a point **BRP–18** which is provided to send the cross-slide front.

The operation of the apparatus will now be readily understood in view of the above description and, particularly, in connection with FIG. 8 which shows a rough schematic diagram of the manner in which the machine tool operates. As is evident at the left side of FIG. 8, the cycle starts with the loading of a workpiece and the movement of the workpiece table **12** under the impetus of the cylinder **18** relative to the abrasive wheel **25**. With the abrasive wheel **25** lying within the bore **17** of the workpiece **16** at the point (A), oil is introduced into the feed cylinder **22** so that the tool support **13** moves rearwardly and carries the abrasive wheel **25** into contact with the surface of the bore **17** to bring about a grinding operation. A compensation "A" takes place first and the high force oil in the cylinder is damped in the known manner to assure that the wheel does not strike the workpiece too hard. Grinding takes place from the point (A) to the point (B) at high force to produce a roughing grind. As the rough grinding takes place and the slide is nearing the retractable stop, the load on the wheelhead motor **30** is building to a peak. Once it reaches the stop, the load begins to drop. If it has not reached too high a peak, and in a given time, it drops below a predetermined value, then the operation through the points (C) and (D) is omitted. If, however, the load on the wheelhead motor **30** exceeds a predetermined load at the end of a set time, then at the point (B) the wheel will be backed off to the point (C) and the wheel re-

moved from the bore 17 in order that a dress may take place by means of the dressing mechanism 23. Dress takes place from point (C) to point (D) and compensation by an amount "A" takes place. Then, the wheel is introduced into the bore for a grind at high force once more under the action of the feed cylinder 22. If, at any time, the load on the wheelhead motor exceeds the predetermined value at the end of the set time period, the wheel will be taken out and dressed again. Eventually, however, the load drops below the predetermined value before the time period has passed and the wheel is removed and backed off from the point (F) to the point (G) and the dressing device is activated. The wheel is withdrawn longitudinally from the point (G) to the point (H) and dressing takes place during this travel; the compensation slide is then retracted to the point (I). Then, the wheel 25 is re-introduced into the bore and is moved under high force to first size position, after which grinding takes place at a low constant force for finish grinding from the point (L) to the point (M). At the point (M) the retractable stop terminates the feed of the slide 13, but grinding continues with a sparkout due to spindle deflection until a predetermined load value is reached to bring the size and taper of the bore 17 up to finish size. When the slide reaches a point (M) and feed is terminated, a timer is started, if the load on the wheelhead motor has not dropped to the predetermined value during this time, the machine will enter the cycle indicated by the dotted lines extending from point (M) to point (V). For instance, from point (N) to the point (O) the machine goes through a finish feed retract and a backoff followed by advancing of the compensation slide from point (P) to point (Q) (compensation B) plus an advance equal to the amount of retraction that took place from (H) to (I). Dress now takes place from (Q) to (R). A retraction takes place from the point (R) to the point (S). Then, the wheel is introduced into the workpiece again and it advances under a high force condition to point (U). At point (U) feed takes place by low force grinding to point (V). At (V) the feed is again terminated and the sparkout timer is started. The portions of the cycle from the point (M) to the point (V) are repeated until during the sparkout the load drops to the predetermined value before the timer times out. When this finally happens and the final size is indicated, there is a retraction from the point (W) to the point (X), the compensation slide is advanced from point (Y) to the point (Z) and the table 12 is moved away from the abrasive wheel for removal of the workpiece and the loading of a new unfinished workpiece.

It will be understood that under ideal conditions (when the wheel is in good cutting condition and the stock is absolutely uniform in the hardness of the material and its size) the points in the cycle from point (B) to point (E) would automatically not occur as well as the parts in the section from point (M) to the point (V). It is, of course, the object of the present invention, however, to permit the grinding machine to operate on less than ideal conditions and still produce acceptable workpieces. It should be noted that it is possible to introduce a compensation A of a certain distance as well as later on a compensation B which is different in size, as is best described in the aforementioned application of Robillard, Ser. No. 582,846, filed Aug 26, 1965, now Pat. No. 3,403,480 dated Oct. 1, 1968.

Referring next to FIGS. 9 and 10, wherein are shown in a more sophisticated manner a typical cycle making use of the present invention, including a key to the sequence diagram. FIGS. 9 and 10 should be placed side-by-side and used as a single diagram. From this key chart, it can be seen that the horizontal lines with arrows indicate either initial motion or return motion longitudinally of the axis of the workpiece. The vertical lines indicate normal cross-feed motion and the slanted lines indicate a time delay. The asterisk indicates that the element is de-energized and the indentations of the elements indicate energization or de-energization by the device above and to the left of the element. At the start, the operator sets all the selector switches to "AUTO" or "ON" as is necessary. The motors are started by use of the pushbutton and the operator presses the "LOAD" pushbutton. When loading is complete, the table goes in automatically along the line A. Eventually, the limit switch LS1 is struck by the movement of the table longitudinally of the axis of the workpiece. The closing of the limit switch LS1 energizes the relay 10CR which, in turn, operates to energize the relay 25CR and the relay 9CR. The operation of the relay 9CR operates the feed solenoid SOL31, the backoff solenoid SOL32, the oscillator solenoid SOL46, and the compensation rear control BRP13. The operation of these elements brings about forward feed of the slide 13 transversely of the axis of the workpiece, at the same time bringing about oscillation of the wheel lengthwise in the usual manner and also adding to the feed a compensation A. Eventually, the wheel progresses to the point B or first size contact which brings about the energization of the relay 13CR. This, in turn, energizes the relay 42TR and starts the rough sparkout timer. In connection with the energization of the relay 42TR, if 42TR times out before the first contact in the dress meter operates, the relay 11CR is energized sending the table out for automatic wheel dressoff. The cycle A through A' will continue until the first contact in the load or dress meter 110 is made. The cycle then continues automatically. Eventually, the relay 28CR is energized, if the rough sparkout timer times out before the first contact is made in the dress meter. This independently energizes 11CR sending the machine through an automatic dress cycle as has been described above. If, on the other hand, the first contact of the dress meter 110 closes before the timing relay 42TR times out, then relay 36CR is energized, which serves to energize the damper bypass solenoid SOL13 as well as the relay 11CR. In either case, the energization of the relay 11CR de-energizes the relay 3CR which, by its energization, de-energizes the relay 9CR which, in turn, energizes three elements; i.e., the feed solenoid SOL31, the backoff solenoid SOL32, and the oscillator solenoid SOL46. Furthermore, the table runs out along the line B until the slide back contact is made and the relay 22CR–TR is energized, thus de-energizing the relay 13CR and, at the same time, de-energizing the relay 28CR and the relay 42TR. As the table passes the TABLE IN limit switch LS1, the relay 10CR is de-energized. At the same time, the relay 21CR is energized thus de-energizing the TABLE IN solenoid SOL2 and energizing the TABLE OUT solenoid SOL3. Eventually, the table reaches the DRESS POSITION limit switch LS49, energives the relay 4CR. This, in turn, energizes the relays 12CR and 31CR. The energization of the relay 12CR serves to de-energize the RETRACTABLE STOP solenoid SOL36 and, at the same time, energizing the relay 3CR to cause the TABLE IN solenoid SOL2 to be energized. The closing of the relay 4CR also energizes the relay 31CR which, in turn, energizes the relays 18CR and 20CR. The energization of the relay 20CR causes the dresser motor M7 contacts to close; it energizes the DRESS SPEED solenoid SOL7; and also the DRESSER DOWN solenoid SOL41. The table moves in and out to cause the dresser to pass over the wheel and at the end of the dress stroke a limit switch LS83 is actuated, thus energizing the relay 30CR and de-energizing the relay 3CR. The de-energization of the relay 3CR causes the TABLE IN solenoid SOL2 to be de-energized and causes the energization of the TABLE OUT solenoid SOL3. Incidentally, during dress motion, the limit switch LS49 was passed thus de-energizing the relay 4CR.

Now, with the solenoid SOL3 energized, the table moves out thus causing the diamond to produce another dressing pass on the wheel. Eventually, the table reaches the DRESS POSITION switch LS49 and energizes the relay

4CR again. This, in turn, energizes the relays 3CR, operates a RETRACTION FRONT counter BRP16 and also de-energizes the relay 31CR. Now, when the relay 3CR is energized, this also energizes the TABLE IN solenoid SOL2. When the relay 31CR is de-energized, this, in turn, de-energizes the relay 18CR. At the same time, it de-energizes the relay 20CR which, in turn, de-energizes the dresser motor starter M7, the DRESS SPEED solenoid SOL7, and the DRESSER DOWN solenoid SOL41. This, of course, causes the table to move in along the line A_1 and, as the table moves away from the dress position limit switch LS49, the relay 4CR is de-energized. Eventually, the table hits the TABLE IN limit switch LS1 and energizes the relay 10CR, thus energizing the relay 9CR and energizing the feed solenoid SOL31, the backoff solenoid SOL32, and the oscillator solenoid SOL46. The slide begins to index in until, eventually, the FIRST SIZE contact is made. The FIRST SIZE contact energizes the relay 13CR resulting in the de-energization of the solenoid 30CR and the energization of the timer relay 42TR. This assumes that at this time, when the wheel moves in, the load drops off fast enough so that the immediate contact of the meter 110 is closed before the timer times out, thus closing the feed solenoid SOL35 and causing feed to take place until the SECOND SIZE contact is made. Closing of the SECOND SIZE contact causes the relay 24CR to be energized and, in turn, results in the energization of the relay 32CR, the timer relay 43TR and the start of the finish sparkout primer. If 43TR times out before the "finish" meter contact operates, 12CR is de-energized sending the table out for an automatic wheel dressoff B through B'. This will continue until the finish contact of the meter 110 is made before the 43TR times out. The cycle then continues automatically. When the finish meter contact is made, this closes the relay 14CR, de-energizing the relay 32CR and the relay 3CR. The de-energization of the relay 3CR causes the relay 9CR to be de-energized and also results in a similar treatment of the feed solenoid SOL31 and the backoff solenoid SOL32. At that time the slide backs off until the SLIDE BACK contact is made energizing the relay 22CR–TR and the relay 21CR. The energization of the relay 22CR–TR causes a de-energization of the relay 13CR–TR, of the RETRACTABLE STOP solenoid SOL35. The energization of the relay 21CR causes the TABLE IN solenoid SOL2 to de-energize while, at the same time, energizing the TABLE OUT solenoid SOL3. The energization of the relay 21CR also de-energizes the relay 11CR, in turn, causing the relay 12CR to be de-energized which, in turn, operates on the RETRACTABLE STOP solenoid SOL36 to energize it and acts on the RETRACTION REAR counter BRP–14. In addition, the energization of relay 21CR brings about a deenergization of the relay 36CR and, in turn, de-energizes the damper bypass solenoid SOL13. This causes the table to move out longitudinally. Eventually, the table strikes the LOAD POSITION limit switch LS11 and operates to de-energize the WORK COOLANT solenoid SOL60. The closing of the limit switch LS11 also causes the relay 27CR to be energized. This, in turn, causes the escapement solenoid SOL63 to operate and energizes the relay 5CR which, in turn, operates the UNCLAMP solenoid SOL51 and the FRONT STOP solenoid SOL53. This causes the machine to send the loading arm down. The loading arm moving down releases the ARM UP limit switch LS86 and causes the relay 7CR to drop out. On the other hand, once the arm is down, it engages the limit switch LS85, thus energizing the relay 6CR, de-energizing the relay 14CR, and energizing the LOAD RAM solenoid SOL50. When the load ram is extended, eventually, a pressure switch PS10 is operated and acts to energize a relay 26CR to de-energize the solenoid SOL51 and energize the relay 41TR. Eventually, the relay 5CR is de-energized, thus de-energizing the solenoid SOL50 and the solenoid SOL53. The work arm goes to "up" position and the ram retracts so that, eventually, the limit switch LS86 is operated again to energize the relay 7CR which, in turn, operates to the TABLE IN solenoid SOL2. The table moves in and moves away from LOAD POSITION limit switch LS11 to again energize the WORK COOLANT solenoid SOL60 and the machine is ready to move in on another cycle.

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 secure by Letters Patent is:

1. A machine tool, comprising:
(a) a base,
(b) a workpiece support mounted on the base,
(c) a tool support mounted on the base,
(d) a tool and motor therefor mounted on the tool support,
(e) a feed mechanism for bringing about relative movement between the tool support and the work support to cause engagement of the tool with the workpiece selectively with one of two predetermined forces, and
(f) a control, including a device for measuring the load on the said motor, connected to the feed mechanism to bring about a shift from one of the forces to the other at a predetermined load.

2. A machine tool, comprising:
(a) a base,
(b) a workpiece support mounted on the base,
(c) a tool support mounted on the base,
(d) an abrasive wheel and a drive motor therefor mounted on the tool support,
(e) a feed mechanism for causing relative movement of the workpiece support and the tool support for bringing about engagement of the wheel and workpiece,
(f) a size control to terminate the said relative movement, and
(g) a control for terminating the grinding operation if the grindability of the workpiece exceeds a predetermined value.

3. A machine tool as recited in claim 2, wherein a workpiece to be finished has a deep bore to be finished within close limits on taper and the wheel has an axial dimension exceeding its diameter by a substantial amount.

4. A machine tool as recited in claim 2, wherein a dressing mechanism is mounted for access on occasion to the wheel and the feed mechanism is arranged to terminate a rough grind on demand by the size control to cause a dressing operation of the wheel, and then to bring about a finish grind, the said control acting to terminate the rough grind if the grindability of the workpiece exceeds the predetermined value.

5. A machine tool as recited in claim 2, wherein the feed mechanism brings about the said relative movement so as to provide a constant force between a tool and a workpiece held in the toop support and the workpiece support, respectively.

6. A machine tool, comprising a base, a workpiece support mounted on the base, a tool support mounted on the base, an abrasive wheel on a spindle and a drive motor therefor mounted on the tool support, a feed mechanism for causing relative movement of the workpiece support and the tool support for bringing about engagement of the wheel and a workpiece for a finish grinding operation, and means for stopping the feed mechanism to permit the grinding operation to be continued by a sparkout due to the spring in the spindle, characterized by the fact that means is provided to measure the load on the said drive motor, a timer operative during the

sparkout, and a control relating the load to the timer to cause a dressing of the wheel if the timer times out before a predetermined load level is reached.

7. A machine tool as recited in claim 6, characterized by the fact that the control causes the machine to repeat the sparkout and dressing until, during sparkout, the load level drops below the predetermined value before the timer times out.

8. An internal grinding machine having a workpiece support, a wheelhead support, a wheelhead having a motor and a cantilevered spindle with an abrasive wheel, and a feed mechanism for the supports, characterized by the fact that a stop is provided to terminate relative movement between the support to permit grinding to continue because of deflection of the spindle only, timing means which begins operation when the relative movement is terminated, means measuring load on the wheelhead motor, and means operative to dress the wheel if the load does not decrease to a predetermined level when a predetermined time has elapsed.

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